THE EFFECT OF MODERATE-INTENSITY RESISTANCE TRAINING ON HEALTH-RELATED OUTCOMES IN OLDER ADULTS

By

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DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the owner of the copyright therefore (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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SUMMARY

The inclusion of resistance training as part of an exercise program to improve and maintain health, and prevent disease in older adults, has been endorsed by the American Heart Association, American College of Sport Medicine, and the American Diabetes Association (Nelson *et al*., 2007; Braith & Stewart, 2006). However, relevant research is limited in healthy sedentary older adults. The literature also provides contradicting evidence regarding the effect of resistance training to improve health and functional status in older adults. The purpose of this study was to investigate the effect of moderate-intensity resistance training on health-related outcomes in healthy sedentary older adults.

Forty-one healthy sedentary individuals were randomly assigned to either an experimental (RESIS) or control group (CON). The RESIS (women: n = 15, 61.47 ± 4.98 yrs; men: n = 7, 64.29 ± 5.41 yrs) participated in a supervised 16-week moderate-intensity resistance training intervention. The intervention consisted of seven resistance exercises performed for three sets, of increasing resistance (50%, 75% and 100% of 10-RM), of 10 repetitions for each exercise, 3 sessions per week. The CON (men: n = 8, 63.00 ± 5.35 yrs; women: n = 11, 62.09 ± 6.20 yrs) did not participate in an intervention. Variables assessed pre-, and post-intervention included body composition, blood lipid profile, 10-RM bench press and incline leg press, functional capacity via the Timed-Up-and-Go (TUG) test and perceived health status via the SF-36 health survey.

The results showed that moderate-intensity resistance training significantly improve body composition and functional outcomes. However, no significant improvements were evident in blood lipid profile. Practically significant increases in percentage muscle mass (ES = 0.81), fat-free mass (ES = 0.62), and resting energy expenditure (ES = 0.64) were observed. Practically significant decreases in body fat percentage (ES = 0.78), total body (ES = 0.70) and abdominal fat mass as measured by waist circumference (ES =0.83) were also evident. Upper- and lower body strength increased significantly by 37% and 167%, respectively ($p < 0.0001$) and functional capacity was significantly improved ($p < 0.05$). The results also demonstrated significant improvements in the physical functioning domain of the SF-36 health survey ($P < 0.05$).

Sixteen weeks of moderate-intensity resistance training was shown to be an effective training method to improve health status and prevent obesity by improving body composition in healthy sedentary older adults. Moderate-intensity resistance training was also beneficial to improve physical performance and functional status in healthy sedentary older adults. However,

moderate-intensity resistance training was not a sufficient stimulus to improve blood lipid profile in this population group.

OPSOMMING

Die insluiting van weerstandsinoefening as deel van 'n oefenprogram om gesondheid te verbeter en te onderhou, en om siekte onder ouer volwassenes te voorkom, is deur die *American Heart Association*, *American College of Sport Medicine*, en die *American Diabetes Association* onderskryf (Nelson *et al*., 2007; Braith & Stewart, 2006). Relevante navorsing oor gesonde onaktiewe ouer volwassenes is egter beperk. Die literatuur bevat ook teenstrydige bevindinge met betrekking tot die effek van weerstandsinoefening op die verbetering van ouer volwassenes se gesondheid en funksionele status. Die doel van die studie was om die effek van weerstandsinoefening van matige intensiteit op die gesondheidsverwante uitkomste by gesonde onaktiewe ouer volwassenes te ondersoek.

Gesonde onaktiewe individue (n = 41) is ewekansig aan òf 'n eksperimentele (RESIS) òf 'n kontrole groep (CON) toegeken. Die RESIS (dames: n = 15, 61.47 ± 4.98 jr; mans: n = 7, 64.29 ± 5.41 jr), het onder toesig aan 'n 16-week weerstandsinoefening intervensie van matige intensiteit deelgeneem. Die intervensie het bestaan uit sewe weerstandsoefeninge wat in drie stelle elk, met toenemende weerstand (50%, 75% en 100% van 10-RM), van 10 repetisies vir elke oefening, 3 sessies per week, uitgevoer is. Die CON (mans: n = 8, 63.00 ± 5.35 jr; dames: n = 11, 62.09 ± 6.20 jr), het nie aan 'n intervensie deelgeneem nie. Die veranderlikes wat voor en na die intervensie geassesseer is, het liggaamsamestelling, bloed lipied profiel, 10-RM *bench press* en *incline leg press*, funksionele kapasiteit met behulp van die *Timed-Up-and-Go* (TUG) toets en waarneembare gesondheidstatus met behulp van die *SF-36* gesondheidsvraelys, ingesluit.

Die resultate toon dat weerstandsinoefening van 'n matige internsiteit die voordeel inhou dat dit liggaamsamestelling en funksionele uitkomste betekenisvol kan verbeter. Geen betekenisvolle verbeterings is egter in die bloed lipied profiel gevind nie. Prakties betekenisvolle toenames in persentasie spiermassa (ES = 0.81), vet-vrye massa (ES = 0.62) en rustende energie-verbruik (ES = 0.64) is waargeneem. Prakties betekenisvolle afnames in liggaamsvet persentasie (ES = 0.78), totale liggaam (ES = 0.70) en abdominale vet-massa soos gemeet deur middel-omtrek (ES =0.83) was ook duidelik. Liggaamskrag van die boonste en onderste ekstremiteite het betekenisvol ($p < 0.0001$) met 37% en 167% onderskeidelik toegeneem en funksionele kapasiteit het betekenisvol verbeter ($p < 0.05$). Die resultate het ook betekenisvolle verbeterings in die fisieke funksionering domein van die SF-36 gesondheidsvraelys getoon ($p < 0.05$).

Die resultate toon dat die 16-week weerstandsinoefening intervensie, van gematigde intensiteit, 'n effektiewe inoefeningsmetode is om die gesondheidstatus te verbeter en om

obesiteit te voorkom deur die liggaamsamestelling by gesonde onaktiewe ouer volwassenes te verbeter. Die intervensie van matige intensiteit was ook tot voordeel om fisieke prestasie and funksionele status by gesonde onaktiewe ouer volwassenes te verbeter. Weerstandsinoefening van matige intensiteit was nie 'n voldoende stimulus om die bloed lipied profiel in hierdie populasie groep te verbeter nie.

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"*I can do all things through Christ who strengthens me."* – Philippians 4:13

LIST OF ABBREVIATIONS AND ACRONYMS

°	:	Degree
%	:	Percentage
>	:	Greater than
≥	:	Greater or equal to
<	:	Less than
≤	:	Less or equal to
Δ	:	Change in
±	:	Plus-minus
ACSM	:	American College of Sports Medicine
ADA	:	American Diabetes Association
ADL	:	Activities of daily living
AHA	:	American Heart Association
ATP	:	Adenosine triphosphate
BIA	:	Bio-electrical impendance analysis
BMI	:	Body mass index
CON	:	Control group
cm	:	Centimetre
etc.	:	And so on
e.g.	:	For example
ECG	:	Electrocardiograph
EFI	:	Exercise-induced feeling inventory
FFA	:	Free fatty acid

GLUT4	:	Glucose transporter type 4
HbA1c	:	glycosylated haemoglobin
HDL	:	High-density lipoprotein
HOMA-IR	:	Homeostasis model assessment-estimated insulin resistance
i.e.	:	That is
IL-1	:	Interleukin-1
IL-6	:	Interleukin-6
Kcal	:	kilocalorie
Kcal/kg	:	Kilocalories per kilogram
kg	:	Kilogram(s)
$kg.m^{-2}$	:	Kilogram per square meter
kHz	:	Kilohertz
km/h	:	kilometre per hour
LDL	:	Low-density lipoprotein
LSD	:	Least significant difference
MCS	:	mental component summary
mg.dL-1	:	Milligrams per decilitre
mm	:	Millimetre
mmHg	:	Millimetre of mercury
mmol.L-1	:	Millimoles per litre
mU/L	:	Milliunits per litre
mIU/L	:	Milli-international units per litre
PCS	:	Physical component summary
QoL	:	Quality of life

RESIS	:	Experimental group
RM	:	Repetition maximum
RPE	:	Rating of Perceived Exertion
SD	:	Standard deviation
SF-36	:	10.36-item short-form Health Survey
TC	:	Total serum cholesterol
TNF- α	:	Tumor Necrosis Factor-Alpha
TUG	:	Timed-Up-and-Go
VO_2	:	Oxygen consumption
VO_{2max}	:	Maximum aerobic capacity
VO_2R	:	VO_2 reserve
WHR	:	Waist-to-hip ratio

LIST OF KEY TERMINOLOGY

Sacropenia:

A slow, progressive and inevitable process of loss of muscle mass and strength (Vilaça *et al.,* 2013).

Muscle strength:

The maximum force generation capacity of an individual (Macaluso & De Vito, 2004).

Muscle power:

The rate of performing mechanical work (Macaluso & De Vito, 2004).

Muscle quality:

Maximal force production per unit of muscle mass and is an indicator of the functional ability of muscle (Morley *et al*., 2001).

Perceived health status:

A multidimensional concept that represents an individual's satisfaction with life by measuring functional status in the domains of physical, cognitive, emotional and social health (McGraft *et al.,* 2010).

Physical activity:

Any bodily movement produced by the contraction of skeletal muscle that result in a substantial increase in resting energy expenditure (Thompson *et al*., 2010).

Exercise:

Exercise is a type of physical activity consisting of planned, structured, and repetitive bodily movement done to improve or maintain one or more physical fitness components (Thompson *et al*., 2010).

Resistance training:

Resistance training usually makes use of a form of weight lifting, but may include other exercise devices such as, free weights, machines with stacked weights or pneumatic resistance rubber to improve musculoskeletal fitness (strength, endurance and power) and muscle mass (Thompson *et al.,* 2010).

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CHAPTER ONE

1.1 INTRODUCTION

Aging results in physiological changes, such as the loss of muscle and bone mass, metabolic decline, reduced glucose tolerance, and increased total body and abdominal fat mass (Thompson *et al*., 2010). The loss of muscle mass (sarcopenia) contributes to strength declines of 20% to 40% in older adults which results in a substantial decrease in physical performance and health that can ultimately lead to a diminished functional status. Among the most important physical performance changes occurring with aging, and its associated sacropenia, are impairment in the performance of activities of daily living (ADL), and alterations in the motor control system. These effects lead to an impairment of mobility and eventually an increased risk of falling resulting in disability (Steib *et al.,* 2010).

Skeletal muscle, which represents up to 40% of total body mass, has a pronounced influence on metabolic physiology (Morley *et al.,* 2001). As such, age-related loss of muscle mass is related to metabolic decline, fat gain, metabolic syndrome and diabetes which are all well-known causes of decline in health and wellness (Westcott, 2012). Physiological problems associated with aging are very similar to those seen with physical inactivity and they are, in many cases, reversible with increased levels of physical activity (Bean *et al*., 2004).

Regular physical activity, including resistance and aerobic exercises, is essential for healthy aging as it reduces the risk of chronic disease, premature mortality, functional limitations and disability (William *et al.,* 2007). Adults and older adults should be encouraged to participate in the minimum recommended amounts of physical activity to improve physical fitness and achieve health benefits (Nelson *et al.,* 2007). Improved physical fitness will lead to an improved physiological state of well-being that allows adults and older adults to meet the demands of activities of daily living (Warburton *et al.,* 2006). However, with the focus strictly on attenuating the effect of sarcopenia and reducing health and functional risks, a growing body of evidence recommend resistance training compared to aerobic training (Hunter *et al.,* 2004). The basic physiological response to resistance training, even into old age, is increasing muscle mass and strength (Strasser & Schobersberger, 2010). Resistance training has also been shown to enhance resting energy expenditure and body composition, improve lipid profile, increase functional capacity, reduce the difficulty of performing daily tasks, and promote participation in spontaneous physical activity in older adults (Hunter *et al*., 2004; Poehlman *et al*., 2002; Broeder *et al*., 1992).

1.2 PROBLEM STATEMENT

Physiological changes occurring with ageing compromise older adult's ability to deal with internal and external challenges (Phillips, 2007). Age-related loss of muscle mass is considered the most debilitating and most predictable consequences (Flack *et al*., 2011), as it is strongly associated with a decrease in resting energy expenditure, and contributes to increases in total body fat mass and abdominal fat mass specially with aging (Campbell *et al.,* 1994). In addition, a strong relationship exists between the loss of lean muscle mass, decreases in strength, and decline in functional capacity in older adults, which in turn may lead to physical disability, functional limitations and decreased physical active status (Strasser *et al.,* 2009). Therefore, the loss of lean muscle mass may influence a variety of metabolic risk factors such as obesity, dyslipidaemia, type two diabetes, cardiovascular disease, as well as functional capacity and the ability to participate in physical activity (Henwood *et al.,* 2012). Considering that reduced health and functional status associated with aging contributes to physical inactivity in older adults, which leads to further decreases in lean muscle mass, the relationship of physical inactivity and muscle loss with aging is a good example of a positive feedback loop (Appendix A) (Flack *et al.,* 2011).

Although the ACSM has long regarded resistance training as part of a balanced approach to promote and maintain good health and physical independence, there are still insufficient numbers of older adults that engage in this type of exercise (Nelson *et al.,* 2007). This might be due to misconceptions about resistance training and its associated benefits. Traditionally, resistance training was limited to athletes to achieve hypertrophy and to improve muscle strength, power, and sport specific fitness. Although resistance training has been shown to have a profound effect on skill-related fitness components, resistance training has also been associated with health-related benefits (Kraemer *et al*., 2002). The importance of resistance training for disease prevention, wellbeing and functional independence for older adults is recognised worldwide, and it is a common inclusion into healthy ageing strategies (Henwood *et al*., 2012).

Resistance training, even later in life, was shown to be a safe and effective countermeasure to the age-related loss in muscle mass (Flack *et al.,* 2011). Specifically, resistance training has been shown to increase lean muscle mass, strength, muscle power and muscle quality (Westcott, 2012). Most importantly, these increases are associated with significant improvements in task replicating activities of daily living, which results in an improved physically active status (Henwood *et al*., 2012). Major barriers and motivators to exercise in older adults are their current physical injury and health status, availability of time, and the fear of falls (Henwood *et al*., 2012; Rubenstein, 2006). Older adults with functional limitations due to an injury and reduced health status choose not to participate in aerobic activity (e.g. walking) as it causes pain and discomfort (Henwood *et al.,* 2012). Therefore, resistance training might be more suitable for older adults with physical and health limitations. Resistance training has been shown to be a safe, suitable and effective training regimen for older adults that may reduce the loss of lean muscle mass and increase strength, consequently reducing the risk of falls and improvement of functional performance (Hurley & Roth, 2000). Resistance training has also been shown to improve metabolic health in older adults by increasing resting energy expenditure, decreasing total body and abdominal fat mass, insulin resistance, total cholesterol, LDL cholesterol, triglycerides and increase HDL cholesterol, which might be beneficial for the prevention of obesity, dyslipidaemia, type two diabetes and cardiovascular disease (Braith & Stewart, 2006).

However, there is still limited evidence available on the preventative role of resistance training on obesity, type two diabetes and dyslipidaemia in healthy sedentary older adults. Further research is needed to identify the effect of resistance training on body composition, insulin resistance, blood lipid profile, functional capacity, and perceived health status in older adults. Therefore, this study aimed to investigate the effect of moderate-intensity resistance training on health-related outcomes in older adults.

1.3 OBJECTIVES OF THE STUDY

The main objectives of the study were to investigate:

1. The relationship between moderate-intensity resistance training and body composition in older adults.
2. The relationship between moderate-intensity resistance training and blood lipid profile in older adults.
3. The effect of moderate-intensity resistance training on functional outcomes in older adults.

1.4 HYPOTHESES

This study was based on the following hypotheses:

1. Moderate-intensity resistance training will significantly improve body composition by decreasing weight, BMI, body fat percentage, total body and abdominal fat mass, and by increasing percentage muscle mass, fat-free mass and resting energy expenditure.
2. Moderate-intensity resistance training will significantly improve blood lipid profile by reducing insulin resistance, total cholesterol, triglycerides, LDL cholesterol and total cholesterol/HDL cholesterol ratio, and increasing β-cells function, insulin sensitivity and HDL cholesterol.
3. Moderate-intensity resistance training will significantly improve functional outcomes by increasing upper- and lower-body strength and perceived health status, and decrease Timed-Up-and-Go test time.

CHAPTER TWO

LITERATURE REVIEW
THE EFFECT OF RESISTANCE TRAINING ON HEALTH-RELATED OUTCOMES

2.1 INTRODUCTION

Loss of muscle mass (sarcopenia) effects all adults throughout their lifespan and has a substantial effect on health, functional and physical status (Steib *et al.,* 2010). Sarcopenia is associated with a decrease in strength, muscle quality and power, which in turn results in a reduced functional capacity and may lead to physical disability and functional limitations. Considering the interdependence between muscle mass and physical activity, individuals who do not participate in physical activity due to health limitations may be more prone to enter a positive feedback loop (Appendix A) where a reduction in physical activity due to poor functional health lead to diminishing health, strength and function.

The literature has revealed that resistance training might be the preferred training regimen to work against the effect of sarcopenia and the positive feedback loop, as resistance training is specifically designed to stimulate the growth of skeletal muscle, which eventually results in muscle hypertrophy (Burd *et al.,* 2010). However, contradicting evidence exist in the literature regarding the effect of resistance training on resting energy expenditure (REE), body composition, insulin resistance, lipid profile, functional capacity and perceived health status. At present it can only be stated that resistance training might enhance cardiovascular health, by decreasing, total cholesterol, LDL cholesterol and triglycerides and increasing HDL cholesterol (Westcott, 2012). Resistance training might be beneficial for the prevention of type 2 diabetes by increasing resting energy expenditure, and decreasing total body fat mass, abdominal fat mass and insulin resistance (Williams *et al.,* 2007). In terms of functional capacity resistance training might also have a beneficial effect, by increasing lean muscle mass and strength (Braith & Stewart, 2006). There is also limited evidence in the literature regarding the preventative role of resistance training in obesity, abdominal obesity, insulin resistance, dyslipidaemia, physical disability and functional limitations in healthy sedentary older adults.

In order to understand the effect of resistance training on health-related outcomes in older adults, there must be an understanding off the underlying mechanisms of sarcopenia and its effect on health-related outcomes. Therefore, the underlying mechanism of sarcopenia will be discussed first in the literature review, followed by the effect of sarcopenia on resting energy expenditure, body composition and health status, as well as strength, functional capacity and physical activity. Secondly, the importance of physical activity during aging will be discussed, followed by the reason why resistance training is the preferred training regimen to attenuate the effect of sarcopenia compared to aerobic training. This discussion will also include the ACSM recommendations for the prescription of resistance training for older adults. Lastly, the effect of resistance training on resting energy expenditure and body composition (lean muscle mass, total body fat mass, abdominal fat mass), blood profile (insulin resistance and blood lipids) and functional outcomes (strength, functional capacity and perceived heath status) will be discussed.

The purpose of chapter two is to understand the underlying mechanism of aging and how it affects health-related outcomes, as well as the role of resistance training in attenuating the effect of sarcopenia and improving health and functional status in older adults. Furthermore, the literature review will present the limitations and contradictions in the current research regarding the effect of resistance training on the selected outcome variables.

2.2 THE EFFECT OF AGING ON HEALTH-RELATED OUTCOMES

2.2.1 The underlying mechanism of sarcopenia

Age-related loss of muscle mass (sarcopenia, sarco = muscle, penia = lack of) and strength, involves progressive muscle wasting that effects all adults throughout their lifespan (Steib *et al.,* 2010). Loss of muscle mass occurs from 3% to 8% per decade, after the age of 30 years, to as much as 10% each decade after 50 years of age (Flack *et al*., 2011). This equates to muscle mass loss of about 0.2kg, and up to 0.4kg after the fifth decade of life in inactive adults (Westcott, 2012). Janssen *et al*. (2002) classified sarcopenia into moderate (class I) and severe (class II), based on the distribution of skeletal muscle (skeletal muscle index, SMI = skeletal muscle mass/body mass x 100). They defined sarcopenia as having an absolute skeletal muscle mass (appendicular) of at least two standard deviations below the mean of young adults. Using this approach, 45% and 59% of older (≥60 years) men and woman, respectively, were classified as having class I (moderate) sarcopenia and 7% and 10% of older men and woman, respectively, were classified as having class II (severe) sarcopenia (Janssen *et al.,* 2002).

The decrease in muscle mass involves both a decrease in muscle fibre size (atrophy) and their number (hypoplasia) (Narici & Maffulli, 2010). Sarcopenia, however, shows a fundamental difference from disuse atrophy in that it only involves a decrease in fibre size, but not in fibre number. With sarcopenia, type II fibres are more vulnerable to atrophy than type I fibres (Baumgartner *et al*., 1998). In addition, with aging, a loss of both types of fibres occurs with differing time courses (Narici & Maffulli, 2010). A greater loss of type II fibres may occur up to 70 years of age. Type I fibres are lost from 80 years and older and a new balance between the two fibres is reached (Narici & Maffulli, 2010). In addition to the change in the type of muscle fibre, there are also age-related changes that occur in the motor unit innervation of muscle (Morley *et al.,* 2001). Neuropathic processes during aging lead to α-motor neuron degeneration and muscle fibre denervation, resulting in a loss of motor units (Janssen *et al.,* 2002). Skeletal muscle undergoes a continuous cycle of denervation and reinnervation, but with ageing it seems that the process of reinnervation cannot keep pace with that of denervation, contributing to the loss of motor units (Narici & Maffulli, 2010). Narici and Muffulli (2010) reported that the number of motor units are constant up to 60 years of age, but then rapidly declines at a rate of 3% per year. Thus, at age 80 years, 60% of motor units will be lost.

Therefore aging, mediated by sarcopenia and disproportionate denervation/innervation rates, results in physical and biological changes in the structure and function of muscle (Hairi *et al.,* 2010). Since muscle accounts for approximately 40% of total body mass and 75% of the body's cell mass (Morley *et al.,* 2001), changes in its quantity has significant metabolic consequences.

2.2.2 The effect of sarcopenia on resting energy expenditure, body composition and health status

Energy produced by metabolic processes in humans consists of three main components: resting energy expenditure (REE), physical activity-induced energy expenditure and the thermic effect of food (Zurlo *et al*., 1990). Resting energy expenditure (REE) varies during the life span and it has been well-established to decline with advancing age (Bosy-West *et al*., 2003). Research has shown that a strong relationship exist between REE and fat-free mass (Hunter *et al.,* 2004). Fat-free mass is the main determinant of resting energy expenditure accounting for between 65% to 90% of its inter-individual variance (Bosy-Westphal *et al*., 2003).

Metabolically fat-free mass is a heterogeneous compartment, consisting of internal organs and skeletal muscle mass (Vaughan *et al.,* 1991). The sum of visceral organs and the brain comprise approximately 5% of body weight but accounts for 70% to 80% of REE because of the high metabolic rate of the brain. In contrast, muscle mass comprises approximately 40% of body weight but accounts for 20% of REE (Vaughan *et al.,* 1991). The heterogeneous composition of fat-free mass explains why REE per kilogram fat-free mass is not constant; REE per kilogram fat-free mass decreases with increasing body weight because of a disproportional increase in muscle mass (Hunter *et al*., 2004). According to Bosy-Westphal *et* *al.* (2003) it may be hypothesized that the age-related decrease in fat-free mass along with changes in the relative composition of fat-free mass may both add to the age-related decline in REE.

Consequently, Bosy-Westphal *et al.* (2003) found that REE was significantly lower in older adults when compared with young control participants, suggesting that there is a decrease in metabolic rate per fat-free mass with age. However, this does not necessarily mean a decrease in metabolic rate per kilogram organ mass with age. The underlying cause might be age-related changes in fat-free mass composition. Bosy-Westphal *et al.* (2003) concluded that the age-related decline in REE is not caused by a decreasing organ metabolism but fully accounted for by a reduction in lean muscle mass and proportional changes in its metabolically active components.

Hunter *et al.* (2001) reported that organ tissue is relatively resistant to age-related changes in body composition, whereas for lean muscle mass it has been well-established to decline with advancing age. The metabolic rate in the brain and kidneys is constantly sustained and varies very little during the course of the day, whereas skeletal muscle metabolism changes dramatically form resting to maximal physical activity (Zurlo *et al.*, 1990). However, because skeletal muscle comprises 40% of total body mass, it is therefore, quantitatively, the most important tissue mass of the body and can account for 20% to 30% of the total resting oxygen uptake (Vaughan *et al.,* 1991). According to Westcott (2012), muscle protein break-down and synthesis are largely responsible for energy expenditure in resting muscle, which is 11 to 12 $cal \cdot d^{-1} \cdot kg^{-1}$ of untrained muscle tissue. Consequently, skeletal muscle metabolism might represent an important variable component and determinant of whole-body REE (Westcott, 2012). Illner *et al.* (2000) found significant correlations between REE and lean muscle mass and concluded that lean muscle mass significantly contributes to REE. Therefore, the decrease in resting metabolic rate seen in older adults can be explained largely by decreases in lean muscle mass, as well as the physical and biological changes in the structure of muscle (Hunter *et al.,* 2004).

Phillips (2007) reported that the average age-related decline in REE, which is mainly due to the loss of lean muscle mass, is between 2% and 3% per decade in inactive adults. Resting metabolism accounts for approximately 65% to 70% of daily caloric use among sedentary adults (Westcott, 2012). Therefore, according to Westcott (2012), a reduction in muscle mass and resting metabolic rate may be a contributor to the increase in fat mass. For many older adults, decreased energy expenditure may not be matched by decreased energy intake, thereby contributing to an increase in body fat mass and the onset of obesity (Campbell *et al.*, 1994). Therefore, persons with lower resting muscle metabolism might in fact be at higher risk for sustaining a positive energy balance, thus resulting in increased fat mass and weight gain (Hunter *et al.,* 2001).

In addition, muscle tissue is the primary site for glucose and triglyceride disposal; therefore the loss of muscle mass also increases the risk of developing glucose intolerance (Flack *et al.,* 2011). According to Narici and Maffulli (2010), age-related loss of muscle mass is associated with reduced resting metabolic rate, reduced lipid oxidative capacity and increased adiposity. Therefore, skeletal muscle mass influences a variety of metabolic risk factors such as obesity, dyslipidaemia, type two diabetes and cardiovascular disease (Westcott, 2012). Considering this impact, the loss of muscle mass associated with aging may present a major health concern to the ageing population, as both the quality of life and the likelihood of age-associated declines in health status are influenced (Hunter *et al.,* 2004).

2.2.3 The effect of sarcopenia on strength, functional capacity, physical activity and health status

Sarcopenia, as previously discussed, has a substantial effect on the quantity of muscle mass, as well as the physical and biological changes in the structure of muscle. However, sarcopenia also has an effect on the quality of muscle mass which in turn influences strength and functional capacity in older adults (Strasser *et al*., 2009). Muscle quality can be defined as maximal force production per unit of muscle mass and is an indicator of the functional ability of muscle (Morley *et al.,* 2001). The decline in muscle quality may be related to a decrease in total muscle fitness with ageing with a disproportionate atrophy of type II muscle fibres, which is responsible for the power decline with ageing (Hunter *et al.,* 2001). According to Narici and Maffulli (2010), the loss of muscle strength and power exceeds that of muscle size and volume and, as a consequence, there is a decline in peak power and force per unit of cross-sectional area. Force depends on the muscle cross-sectional area, which is based on the number of force-generating sarcomeres arranged in-parallel (Howley, 2001). Power, on the other hand, is the product of force and velocity, and depends on the number of sarcomeres arranged in-series, which depends on the muscle volume (the product of cross-sectional area and muscle length) (Morley *et al.,* 2001). Consequently, the reduction in power and force with aging contributes to impaired muscle function in older adults (Morley *et al.,* 2001).

Functional impairment can be defined as having limitations in mobility performance (e.g. climbing stairs and walking). Physical disability can be defined as having difficulty performing activities of daily living (e.g. house chores) (Janssen *et al.,* 2002). Janssen *et al. (*2002) found that older adults who are classified as having severe (class II) sarcopenia have both functional impairment and physical disability, particularly older women. Sarcopenia is independently associated with physical disability and walking difficulty (Baumgartner *et al.*, 1998). Moderate (class I) sarcopenia is not clearly associated with an increased likelihood of functional impairment and physical disability (Janssen *et al.*, 2002). According to Hairi *et al.* (2010), the loss of lean muscle mass, muscle strength and muscle quality (specific force) are associated with impairment in physical function. Their finding supported the hypothesis that muscle quality is more strongly associated with functional limitations than muscle mass alone (Hairi *et al.*, 2010). Factors such as increased muscle fatigability and reduced endurance capacity also contribute to age-related physical disabilities (Morley *et al.*, 2001).

2.2.4 Physical inactivity and the positive feedback loop

There are multiple factors independent of age that influences sarcopenia and related strength and functional declines (Hunter *et al.,* 2004). Declines in physical activity is certainly one of these factors, and it is suggested that a substantial portion of the reductions in strength and function that occur with age are mediated by decreases in physical activity (Hunter *et al.*, 2001). The result is a positive feedback loop (Appendix A) as reduced activity further decreases strength, ease of physical activity and participation in physical activity (Hunter *et al.,* 2001). According to the 2002/2003 World Health Survey, the prevalence of physical inactivity was higher among women than men and higher among older adults (Guthold *et al.,* 2008). South Africa have a high prevalence of 43% and 49% of men and women respectively, who were insufficiently active to achieve health benefits (Joubert, *et al.*, 2007).

The high prevalence of physical inactivity seen in older adults also increases the risk of obesity (McGraft *et al.*, 2010). Puoane *et al.* (2002) reported that 29.2% and 56.6% of South African men and women, respectively, were overweight or obese (≥25 kg.m^2) according to the Demographic and Health Survey in 1998. In 2005, the number of South Africans diagnosed with being overweight increased to an estimated 40% for men and 60% for woman, resulting in a high burden of non-communicable diseases (Alwan *et al.*, 2010). Therefore, myosteatosis is of particular concern among inactive adults and older adults where sarcopenia is combined with obesity, known as sarcopenic obesity (Narici & Maffulli, 2010). Declines in resting metabolic rate seen in older adults is explained largely by decreases in lean muscle mass, as well as physical inactivity and results in a high risk of a positive energy balance and increases in fat mass (Hunter *et al.,* 2001). The loss of muscle tissue is accompanied by an infiltration of remaining muscle with fat and connective tissue (myosteatosis) and places a burden on locomotion due to the added mass that an individual must carry (Taaffe *et al.*, 2009). The accumulation of intramuscular fat and connective tissue is inversely related to an individual's level of physical activity. Thus, by doubling the level of physical activity, it halves the amount of intramuscular fat and connective tissue within muscle.

In addition, fat infiltration of skeletal muscle sustains sarcopenia through a macrophage infiltration mediated-release of pro-inflammatory cytokines (TNF- α, IL-6 and IL-1) and adipokines (leptin, adiponectin and resistin) from adipocites (Morley *et al.,* 2001). This chronic inflammation may be a mechanism for insulin resistance and the development of metabolic syndrome (Goodpaster *et al.*, 2000). Sarcopenic obesity is associated with an accelerated functional decline and high risk of cardiovascular disease and mortality (Narici & Maffulli, 2010). Insulin resistance is thus promoted by the loss of muscle mass and physical inactivity. The association between sarcopenia and sarcopenic obesity establishes a vicious cycle (e.g. positive feedback loop as previously mentioned) resulting in a further loss of muscle mass and mobility, leading to insulin resistance and increased risk of developing metabolic syndrome (Flack *et al.,* 2011). The prevalence of sarcopenic obesity in men and women increased from 13.5% to 17.5% in men and 5.3% to 8.4% in women, younger than 70 years and older than 80 years respectively (Morley *et al.*, 2001). The prevalence of type two diabetes also increases with sarcopenia (Morley *et al.,* 2001).

2.2.5 Conclusion

It can be concluded that sarcopenia does not only involve the reduction of lean muscle mass, but also include physical and biological changes in the structure and function of muscle, consequently reducing REE (Bosy-Westphal *et al.,* 2003). These metabolic changes are likely to be associated with increased adiposity in older adults, increasing the risk of developing dyslipidaemia, insulin resistance and cardiovascular disease. In addition to its role in disease progression, the strength loss and general neuromuscular deconditioning accompanying sarcopenia decrease the capacity to perform daily tasks and increase exercise difficulty. Reduced activity leads to further decreases in strength and function, ease of physical activity and participation in physical activity (Hunter *et al.,* 2001). Therefore, using resistance training as a means to interrupt the feedback loop (Hunter *et al.,* 2004) is a vital step toward maintaining the quality of life and health of an ageing population.

2.3 PHYSICAL ACTIVITY

At present only exercise has been shown to reverse sarcopenia (Morley *et al.* (2001). Exercise is the most universal and effective treatment for chronic disease and disability in later life (Bean *et al.*, 2004). Exercise can reverse physiological impairments, mitigate functional loss and disability, reduce morbidity, and is also important for preventing and treating chronic disease (Haskell *et al.,* 2007). Physical activity (resistance and/or aerobic training) during aging is needed to slow down or reverse the effect of sarcopenia by increasing lean muscle mass and strength (Hunter *et al*., 2004), which may result in an increased REE and reduced total body fat mass, as well as improved functional performance (Latham *et al.,* 2004). Therefore, by decreasing the exercise difficulty and improving the ability to carry out activities of daily living, may lead to the prevention of further decreases in strength and function, and promote the participation in physical activity (Macaluso & De Vito, 2004). Consequently, older adults may improve their health status, by decreasing the risk of developing dyslipidaemia, insulin resistance and cardiovascular disease (Strasser & Schobersberger, 2010).

2.3.1 Resistance and aerobic training during ageing

Resistance and aerobic training induce distinctly different adaptive responses when performed independently (Dudley & Djamil, 1985). The nature of adaptive responses to training is specific to the training stimulus. Aerobic training involves large muscle groups in dynamic activities that result in substantial increases in heart rate and energy expenditure (Hunter *et al.,* 2008). Regular participation in aerobic type exercise results in improvements in the function of the cardiovascular system and skeletal muscles, leading to an improved endurance capacity (Bean *et al.,* 2004). Resistance training, on the other hand, is specifically designed to increase muscular strength, endurance, and/or power. This is achieved by varying the resistance, the number of repetitions (the number of times the resistance is moved in a single group set of exercise), the number of sets done, and the rest period provided between sets (Phillips, 2007). The adaptive responses to resistance training and aerobic training play an important role in reducing the risk for cardiovascular disease, including diabetes mellitus, hypertension and dyslipidaemia (Braith & Stewart, 2006). However, each training mode has different effects on an individual's health and fitness status.

Strasser *et al.* (2009) found significant increases in lean body mass and strength following a 24-week resistance training intervention. Whereas, the aerobic training group did not show any significant improvements in muscle strength or lean muscle mass, a significant reduction in total body fat mass were evident. It is well established that aerobic training leads to substantial improvements in maximum aerobic power (VO_{2max}) in older adults, since an improved VO_{2max} is the fundamental specific physiological response to aerobic training

(Andersen *et al.,* 2003). Although aerobic training clearly improves the oxidative capacity of skeletal muscle, it has not been shown to be an effective training regimen to slow down or reverse sarcopenic processes (Hunter *et al.,* 2004). Strasser *et al.* (2009) found that aerobic training had little or no effect on muscle mass and strength in older adults. In addition, Poehlman *et al.* (2002) and Broeder *et al.* (1992) found that a 12- to 24-week aerobic training intervention was not effective in increasing lean muscle mass and strength. Therefore, aerobic training might not be the preferred training regimen to effectively attenuate the effect of sarcopenia, interrupt the positive feedback loop and decrease associated health and functional risks.

The primary focus of resistance training prescription among the elderly is the production of muscle growth (i.e. hypertrophy) in an effort to counteract sarcopenia to reduce health and functional risk (Hunter *et al.,* 2004). According to Poehlman *et al.* (2002) the basic physiologic response to resistance training, even into old age, is increasing the mass and strength of muscle. In addition to increasing strength, resistance training improves submaximal muscle performance (muscle endurance) in older adults. It has also been shown that resistance training can increase REE as a results of a greater muscle protein turnover and an increase in the rate of muscle protein synthesis has been observed following regular resistance training even in frail elderly individuals (>70 years) (Strasser & Schobersberger, 2010). Poehlman *et al*. (2002) found, after a 24-week resistance training intervention, significant increases in lean body mass, together with a moderate but not significant decrease in percentage body fat, so that body weight remained constant. Thus, according to Poehlman *et al*. (2002) the main effects of resistance training on body composition is a breakdown of body fat and simultaneous build-up of muscle mass. These results are more important to older adults, since the decrease in muscle mass and strength directly affect functional abilities and fall risk, as well as REE and health status. Hunter *et al.* (2004) stated that resistance training in older adults increases strength and power, reduces the difficulty of performing daily tasks, enhances energy expenditure and body composition, and promotes participation in spontaneous physical activity. Therefore, a growing body of evidence supports resistance training as the preferred training regimen to slow down or reverse the loss of muscle mass and interrupting the positive feedback loop in older adults (Hunter *et al.,* 2004).

2.3.2 Resistance training recommendations for adults and older adults

To promote and maintain good health and physical independence, the ASCM recommends adults (18 and 65 years) and older adults (≥ 65 years) to perform eight to ten resistance training exercises on two or more non-consecutive days per week using a total-body workout structure, which focusses on all major muscle groups (Haskell *et al.,* 2007; Nelson *et al.,* 2007). It is recommended that two to four sets of eight to 15 repetitions is performed at a moderate intensity (Haskell *et al.,* 2007; Nelson *et al.,* 2007). Resistance training intensities/loading can be described as a specific maximum repetition (RM) value or a percentage of 1-RM (Thompson *et al*., 2010). Moderate-intensity resistance training can be defined as 60% to 80% of 1-RM. Whereas, low-intensity resistance training as 50% of 1-RM and high-intensity resistance training as greater than 80% of 1-RM (Thompson *et al.,* 2010). If the intensity is expressed as a given RM, moderate loads are considered to be 8- to 15-RM (Bird *et al.,* 2005).

Low loads (> 20-RM) are used if local muscular endurance is the goal, moderate loads (8- to15-RM) are used if hypertrophy is the goal, and heavy loads are used if maximal strength (3- to 8-RM) or power (1- to 3-RM) are the goal (Bird *et al*., 2005). However, according to Kraemer & Ratamess (2004), 8- to 12-RM loading range is typically used if hypertrophy and strength is the goal. Although heavy loading (3- to 8-RM) is effective in achieving hypertrophy and maximal strength, it has been reported that the 8- to 12-RM loading range may provide the best combination of load and volume (Macaluso *&* De Vito, 2004). Lower loads than this (12- to 15-RM and lighter) rarely increase maximal strength, however, they are effective at increasing muscular endurance (Phillips, 2007). In addition, the ACSM recommends the use of a ten point scale (RPE scale, Appendix H) to identify the level of effort during training, especially in older adults (Nelson *et al.,* 2007). On a ten point scale, where no movement is equal to zero, and maximal effort is equal to ten, moderate intensity effort is a five or six and high intensity effort is a seven or eight (Nelson *et al.,* 2007).

2.4 EFFECT OF RESISTANCE TRAINING ON BODY COMPOSITION AND RESTING ENERGY EXPENDITURE

2.4.1 The effect of resistance training on fat-free mass

Resistance training is designed to stimulate the synthesis of skeletal muscle, which eventually results in muscle hypertrophy (Burd *et al.,* 2010). Muscle growth can only occur if there is a net anabolism within the muscle (Phillips *et al.,* 1999). This refers to a positive balance between muscle protein syntheses and muscle protein breakdown during the period in which hypertrophy occurs. Phillips *et al.* (1997) confirmed that an isolated bout of high-intensity (80% of 1-RM) resistance exercise stimulates muscle protein breakdown over the first four hours after the exercise session. The magnitude of increasing muscle protein synthesis due to moderate-intensity resistance exercise is similar in both older adults and young men and women (Yarasheski *et al*., 1993).

Based on the literature reviewed for this study, 6 to 26 weeks of moderate- to high-intensity resistance training is effective to increase fat-free mass in adults and older adults between the ages of 18 to 96 years (Appendix B). Research has also shown that low- and moderate-intensity resistance training is an effective training regimen to reduce or maintain fat-free mass during dieting in healthy sedentary and obese adults and older adults between the age of 19 and 70 years (Ishil *et al*., 1998; Geliebter *et al*., 1997; Donnelly *et al*., 1991). However, low-intensity resistance training has been shown not to be a sufficient stimulus to significantly increase fat-free mass in healthy sedentary older men without any dietary involvement (Kitamura *et al*., 2003). Moderate loads of 8 to 15-RM should be used if hypertrophy is the goal (Bird *et al*., 2005). However, research have shown that resistance training (12 to 20 weeks) might have to be performed at higher intensities to increase fat-free mass in obese adults, adults diagnosed with type two diabetes, or at high risk for cardiovascular disease (Misra *et al*., 2008; Fenkci *et al*., 2006; Smutok *et al*., 1993). It has been recommended that resistance training must be performed with high loads (i.e. ≥ 70% of 1RM) to provide an optimal stimulus for muscle growth (hypertrophy) (Burd *et al*., 2010). However, recent evidence established that myofibrillar protein synthesis is already maximally stimulated at 60% of 1-RM, with no further increase at higher load intensities (i.e. 75 to 90% 1-RM) (Burd *et al*., 2010). Muscle hypertrophy is due to the addition of new sarcomeres in a parallel force-producing arrangement (Phillips *et al.,* 1999). The training-induced addition of new sarcomeres requires the synthesis of new myofibrillar and non-myofibrillar proteins (Yarasheski *et al.,* 1993). Additionally, performance of low-load contractions of approximately 20% of 1-RM is sufficient to induce an increase in mixed muscle protein synthesis (Burd *et al*., 2010). Therefore, heavy (high-intensity) external loading might not be a prerequisite to elicit increases in muscle protein synthesis and ultimately hypertrophy in older adults (Yarasheski *et al*., 1993).

Therefore, there are contradictions in the literature, as research has also demonstrated that 10 to 24 weeks of moderate-intensity resistance training is beneficial to significantly increase fat-free mass in type two diabetic adults and older adults between the ages of 48 and 80 years (Bacchi *et al.,* 2012; Ho *et al*., 2007; Baldi & Snowling, 2003; Dunstan *et al*., 2002). Nevertheless, the majority of research indicate that moderate-intensity resistance training is beneficial to significantly increase fat-free mass in healthy sedentary adults and older adults. Older muscle adapt vigorously to resistance training with marked myofibre hypertrophy (Hunter *et al*., 2004). It has been shown that myofibre hypertrophy following a typical two to three days per week training programme can be substantial, ranging from 10% to 62% after 8 to 52 weeks of training; with similar gains in myofibre size in younger and older adults (18 to 96 years) following the same resistance training programme (Hunter *et al*., 2004).

2.4.2 The effect of resistance training on resting energy expenditure

It is well established that resistance training can significantly improve fat-free mass, which may lead to increases in resting energy expenditure (REE), since the reduction in REE in older adults is largely as a result of decreases in fat-free mass (Westcatt, 2012). According to Strasser and Schobersberger (2011) resistance training stimulates muscle protein turnover and has a dual impact on REE. First, as a chronic response, resistance training results in greater muscle mass that necessitates more energy at rest for ongoing tissue maintenance. Westcott (2012) reported that a gain of 1.0kg muscle mass should result in an increase in REE of approximately 21kcal/kg of new muscle. In other words, a difference of 5kg of lean muscle mass translates to a difference in energy expenditure of 100kcal per day, which is equivalent to 4.7kg of fat mass per year. Second, as an acute response, resistance training causes microtrauma that requires relatively large amounts of energy for muscle remodelling processes that may persist for 72 hours after the training session (Strasser & Schobersberger, 2011). Research has shown significant increases in resting metabolic rate (approximately 7%) after several weeks of resistance training (Westcott, 2012). However, Heden *et al.* (2011) have revealed a similar elevation in REE (5% to 9%) for three days following a single session of resistance training, as well as significant increases in REE expressed per lean muscle mass.

Twelve to 26 weeks of low- to moderate-intensity resistance training has been shown to significantly increase fat-free mass, REE, total energy expenditure and REE to fat-free mass ratio in healthy sedentary adults and older adults between the ages of 20 and 85 years (Lemmer *et al.*, 2001; Hunter *et al.*, 2000; Campbell *et al.*, 1994). However, significant improvements in REE as a result of resistance training might differ between men and women. Lemmer *et al.* (2001) found significant increases in REE only in men (20 to 70 years), when men and women were analysed individually, and increases in REE remained significantly correlated to changes in fat-free mass. However, it was expected that both men and women would have significant increases in REE, as both men and women had similar increases in fat-free mass (approximately 1.5kg and 1.4kg). Elevated sympathetic nerve activity and Na^+-K^+ ATPase activity in men compared to women are possible explanations for REE increasing in men, but not in women (Lemmer *et al.*, 2001). It was also concluded that the changes in REE in response to resistance training is affected by gender and not by age.

Van Etten *et al.* (1997) also found significant improvements in fat-free mass and resting energy expenditure in healthy sedentary men (23 to 41 years) as a result of 18 weeks of resistance training. However, this is in contrast with the findings of Broeder *et al.* (1992) who did not find significant improvements in REE in healthy sedentary men, even though fat-free mass significantly increased following 12 weeks of moderate-intensity resistance training. Furthermore, in contrast to the findings of Lemmer *et al.* (2001), Poehlman *et al*. (2002) found significant improvements in fat-free mass, as well as REE in healthy sedentary women between the ages of 18 and 35 years as a result of a 24-week moderate-intensity resistance training intervention. However, Poehlman *et al.* (2002) used a higher intensity of 60% to 80% of 1-RM, whereas Lemmer *et al.* (2001) used a lower intensity of 50% of 1-RM which may explain the differences in outcomes.

Although a strong body of evidence support resistance training as the preferred training regimen to increase REE in older adults (men and women) (Westcott, 2012), there are still conflicting evidence in the literature regarding the effect of resistance training on REE in healthy sedentary, young and older, men and women. In addition, it has been reported that age-related declines in lean muscle mass significantly contributes to the decline in REE during ageing (Illner *et al*., 2000), however there are conflicting evidence regarding the relationship between increases in REE following resistance training and the increase in fat-free mass. Therefore, it is unclear if the changes in fat-free mass with resistance training contribute to the changes in REE in older adults and whether this relationship differs between men and women.

Furthermore, it has been shown that resistance training can preserve fat-free mass during negative energy balance associated with dieting. However, Geliebter *et al.* (1997) found that the preservation in fat-free mass did not translate into a conservation of REE as a result of an 8-week high-intensity resistance training intervention in moderately obese adults (19 to 48 years). Whereas Donnelly *et al.* (1991) found a significant reduction in fat-free mass and REE following 12 weeks of moderate-intensity resistance training combined with a calorie restricted diet in obese women. However, evidence do exist that prolonged moderate-intensity resistance training (48 weeks and longer) can successfully conserve fat-free mass and REE during a diet induced weight loss program in overweight or obese women (Hunter *et al.,* 2008; Wadden *et al.,* 1997). It was reported that the preservation of REE was primarily mediated by the preservation of fat-free mass (Hunter *et al.,* 2008). Thus, these results suggest that chronic resistance training during weight loss may have a positive effect on subsequent weight maintenance by preserving muscle mass and REE.

2.4.3 The effect of resistance training on total body fat mass

In 1997, the World Health Organisation emphasised that obesity was becoming a major health problem in many developing countries, particularly in older adults (Thorogood *et al.,* 2011). Obesity is strongly associated with increased risk of developing hypertension, diabetes mellitus, cardiovascular disease, stroke and many forms of cancer, and therefore represents a significant threat to the raising global burden of chronic disease (Thompson *et al.,* 2010). In 2000, the World Health Assembly endorsed a global strategy for the prevention and control of non-communicable diseases, which included strategies on diet, physical activity and health to address two major risk factors, namely unhealthy diet and physical inactivity (Alwan *et al*., 2010). However, in 2008, 58% of total deaths in high-burden countries were mainly due to cardiovascular disease, diabetes mellitus and cancer and it was projected to increase by 0.7% per years (Alwan *et al*., 2010). Therefore, sarcopenic obesity is of great concern in older adults, as mortality rates increase by 50% and 100% when body mass index is equal to or greater than 30kg/m^2 (Kraemer *et al.,* 2002).

The development of obesity result from an energy imbalance over a prolonged time, which means that energy intake exceeds energy expenditure (Wolfe, 2006). Strategies for the prevention and treatment of obesity must focus on affecting the energy balance by altering either energy intake or energy expenditure, by means of diet or physical activity (Strasser & Schobersberger, 2011). It is well established that resistance training is effective in increasing muscle mass and strength in sedentary healthy older adults, and although conflicting evidence exist regarding the effect of resistance training on REE in healthy sedentary older adults, Wolfe (2006) suggested that muscle mass and strength play an important role in the prevention of obesity. Research has revealed that resistance training can increase fat free mass and strength by approximately 1.4kg and 60%, respectively, as well as decrease total body fat mass by 1.8kg (Westcott, 2012).

Twelve to 26 weeks of moderate-intensity resistance training has been shown to significantly decrease percentage body fat, as well as total body fat mass in healthy sedentary older adults between the ages of 56 and 80 years (Hunter *et al.,* 2000; Campbell *et al.,* 1994). In addition to the significant improvements in total body fat mass, both Hunter *et al.* (2000) and Campbell *et al.* (1994) also found significant increases in upper- and lower-body strength, fat-free mass, and REE in healthy sedentary older adults between the age of 56 and 80 years. In contrast, eight to 24 weeks of moderate-intensity resistance training has also resulted in no significant improvement in percentage body fat or total body fat mass in healthy sedentary older adults between the ages of 65 and 96 years; although significant increases in fat-free mass and upper- and lower-body strength were evident (Strasser *et al.*, 2009; Ryan *et al.* 2001; Fiatarone *et al.*, 1990).

When healthy sedentary men and women were investigated individually, percentage body fat significantly decreased in both men and women (> 2%) and similar significant reductions in fat mass for both the older men and women of 1.8kg and 1.7kg, respectively, were evident as a result of a 25-week moderate-intensity resistance training intervention (Hunter *et al.*, 2002). In contrast, Lemmer *et al.* (2001) did not find significant improvements in total body fat mass in women, but only in men between the ages of 20 and 70 years as a result of a 24-week resistance training intervention. Even though upper and lower body strength and lean muscle mass significantly improved in both men and women, REE was only significantly increased in men. However, a low-intensity resistance training programme was followed and might be a possible explanation for the lack of significant decreases in total body fat mass seen in women. It was also reported that changes in REE were only significantly correlated with the changes in fat mass and percentage body fat in men (Lemmer *et al.,* 2001). In addition, Hagerman *et al.* (2000) and Kitamura *et al.* (2003) also found that 16 weeks of high-intensity and 12 weeks of low- to moderate-intensity resistance training significantly reduce percentage body fat in older men between the age 60 and 75 years.

The literature provides conflicting evidence regarding the effect of resistance training on total body fat mass in healthy sedentary older adults. It is also unclear if fat-free mass, REE and strength, as a result of resistance training, play a significant role in the prevention of obesity in healthy sedentary older adults. In addition, there is also little research available on the preventative role of resistance training in age-associated fat gain in older adults, especially in older women. A substantial amount of research have been done on healthy sedentary men and women younger than 50 years, as well as on the effect of resistance training in the treatment of obesity in adults.

Resistance training has been shown to be effective in preventing age-associated fat gains in adults younger than 50 years (Schmitz *et al.*, 2003). Eight to 18 weeks of low- and moderate-intensity resistance training has been shown to significantly reduce percentage body fat and total body fat mass, as well as significantly increase upper and lower body strength and fat-free mass in healthy sedentary men between the ages of 18 and 41 years (Shaw *et al.,* 2009; Shaw & Shaw, 2006; Broeder *et al.*, 1992; van Etten *et al.,* 1992). Whereas, 6 to 24 weeks of low-, moderate- and high-intensity resistance training has been shown to significantly decrease percentage body fat and total body fat mass and, increase upper- and lower-body strength and fat-free mass in healthy sedentary women between the ages of 23 and 50 years

(Fenicchia *et al*., 2004; Schmitz *et al*., 2003; Marx *et al.,* 2000; Prabhakaran *et al.,* 1999). Only Poehlman *et al.* (2002) did not find significant reductions in total body fat mass following 24 weeks of resistance training in healthy sedentary women between the ages of 18 and 35 years. However, significant increases in fat-free mass, REE and strength were evident, which reiterates the question whether improvements in fat-free mass, REE and strength significantly contribute to improvements in total body fat mass.

Furthermore, for the treatment of obesity, Wooten *et al.* (2011) did not find significant improvements in percentage body fat after 12 weeks of low-intensity resistance training in obese women between the ages of 60 and 70 years. However, when moderate-intensity resistance training were combined with a calorie restricted diet, significant improvements in percentage body fat and total body fat mass were evident in both obese men and women (Hunter *et al*., 2008; Ahmadizad *et al*., 2007; Rice *et al*., 1999; Donnelly *et al.,* 1991). However, these findings are in contrast with the findings of Wadden *et al*. (1997) as they found no significant decrease in total body fat mass after 48 weeks of resistance training in obese women who were also on a calorie restricted diet. For the assessment of type two diabetic adults and older adults, 8 to 24 weeks of low- and moderate-intensity resistance training has been shown to significantly decrease percentage body fat and total body fat mass in older adults between the ages of 40 and 70 years (Bacchi *et al.,* 2012; Cauza *et al*., 2005; Dunstan *et al*., 2008; Ng *et al*., 2011). On the other hand, 12 to 16 weeks of moderate- and high-intensity resistance training had no significant effect on percentage body fat or total body fat mass in adults and older adults between the age of 39 and 70 years (Misra *et al.,* 2008; Brooks *et al*., 2007; Sigal *et al*., 2007). Therefore, conflicting evidence also exists regarding the effect of resistance training on obesity in obese and/or type two diabetic adults and older adults.

2.4.4 The effect of resistance training on abdominal fat

Excessive central obesity, in particular, abdominal subcutaneous and visceral fat, are known to be independent predictors of metabolic risk factors, that are antecedents for the development of dyslipidaemia, hypertension, insulin resistance, type two diabetes and cardiovascular disease (Strasser & Schobersberger, 2010). Older adults demonstrate changes in body fat distribution, with increasing levels of upper body fat percentage and especially abdominal visceral fat (Flack *et al*., 2011). Adipose tissue is a major endocrine organ, secreting substances such as resistin, interleukin 6, leptin, tumor necrosis factor α and adiponectin, which play a critical role in the pathogenesis of metabolic syndrome (Björntorp, 1990). The adipose tissue depot in the abdominal area in the obese state may lead to increased circulating free fatty acids (FFA) as a result of its sensitivity to lipolytic stimuli (Strasser & Schobersberger, 2010). It has been reported that visceral fat lipolysis may be responsible for 5% to 10% of circulating FFAs in lean individuals, however, this value may increase to 20% to 25% in obese individuals (Flack *et al*., 2011). Increased FFA concentrations have been associated with the development of insulin resistance and metabolic syndrome (Björntorp, 1990).

Abdominal distribution of fat is usually measured as the ratio of the circumferences of the waist and hip, the waist-to-hip ratio (WHR) (Thompson *et al.,* 2010). Health risk increases with increases in WHR and the standards for risk vary with age and sex (de Almeida Paula *et al.,* 2012). According to the ACSM guidelines, for adults between the age of 60 and 69 years, the health risk is very high if the WHR values are greater than 1.03 for men and 0.90 for woman (Thompson *et al.,* 2010). Men (normal weight or obese) have at least twice the proportion of total fat localised in the intra-abdominal depots compared to woman.

Sagittal abdominal diameter is also used as a reliable measurement of abdominal fat distribution (Ehrlich & Smith, 2011). According to Gustat *et al*. (2000), sagittal abdominal diameter is more strongly correlated to cardiovascular disease risk factors compared to WHR and can therefore be used as a risk parameter. In addition it may help to assess a component of visceral fat deposition, which WHR misses *(*Gustat *et al*., 2000). It has also been reported that sagittal abdominal diameter contributes most to the prediction of fasting triglyceride and insulin levels, and blood pressure compared to WHR (Gustat *et al*., 2000).

The literature has shown that resistance training might reduce intra-abdominal fat in both men and women without any dietary involvement (Westcott, 2012). Hunter *et al.* (2002) investigated the effect of a 25-week moderate-intensity resistance training intervention without any dietary involvement on intra-abdominal adipose tissue (via computerized tomography) in healthy sedentary older men and women between the ages of 61 and 77 years. The results demonstrated that women lost a significant amount of intra-abdominal adipose tissue, as well as abdominal subcutaneous adipose tissue, whereas the men did not. In contrast young healthy sedentary men (20 to 35 years) and women (30 to 50 years), no significant decreases in abdominal fat (as measured by waist circumference and WHR) were evident following 8 to 16 weeks of moderate-intensity resistance training without any dietary involvement (Shaw *et al*., 2009; Shaw and Shaw, 2006; Schmitz *et al*., 2003). However, Broeder *et al.* (1992) reported significant improvements in WHR in healthy sedentary men (18 to 35 years) as a result of 12 weeks of moderate-intensity resistance training without any dietary involvement.

In addition, 8 to 12 weeks of moderate-intensity resistance training without any dietary involvement (calorie intake was only monitored) has been shown to significantly reduce subcutaneous abdominal fat and decrease waist circumference in adults and older adults between the ages of 18 and 70 years who were classified as overweight or obese and/or with moderate dyslipidaemia (Ho *et al*., 2012; Slentz *et al.,* 2011). When obese men and women were investigated individually, 12 weeks of progressive (low- to high-intensity) resistance training without any dietary involvement resulted in significant reduction in waist circumference in women (Fenkci *et al*., 2006). Whereas, 16 weeks of resistance training (intensity not specified) combined with a specific diet resulted in significant reductions in waist circumference, WHR and subcutaneous abdominal fat in men (Rice *et al*., 1999).

In contrast, the literature also reveal contradicting evidence, which indicate that 10 to 12 weeks of low- to moderate-intensity resistance training without any dietary involvement had no significant effect on waist circumference or WHR in obese men and women with high or low metabolic risk factors (20 to 69 years) (Ahmadizad *et al*., 2007; Levinger *et al.,* 2007; Sarsan *et al*., 2006). It might be suggested that resistance training should be combined with a calorie restricted diet to achieve significant reductions in abdominal fat.

In adults and older adults (24 to 70 years) with or at high risk of developing type two diabetes, 8 to 24 weeks of moderate-intensity resistance training without any dietary involvement has shown to significantly decrease waist circumference (Bacchi *et al*., 2012; Minges *et al*., 2011; Misra *et al*., 2008). However, contradicting evidence exist indicating that 6 to 16 weeks of moderate-intensity resistance without any dietary involvement had no significant effect on abdominal fat as measured by waist circumference (Ng *et al*., 2011; Brooks *et al*., 2007; Fenicchia *et al*., 2004). Fenicchia *et al*. (2004) performed one of the few studies that measured sagittal abdominal diameter and they also found no significant improvements. Levinger *et al.* (2007) suggested that there are at least two factors that may limit fat loss in overweight individuals and those with metabolic risk factors, including insulin resistance after resistance training. First, overweight individuals and those at risk of developing type two diabetes have higher fasting insulin levels compared to healthy individuals with no excessive fat mass. An increase in insulin levels may reduce lipolysis and promote fat storage by inhibiting lipase activity (Fenicchia *et al*., 2004). Secondly, although obesity and hyperinsulinemia may lead to chronic activation of the sympathetic nervous system, the responsiveness of adipose tissue to sympathetic stimulation is reduced, resulting in an inhibition of fat loss in these individuals (Levinger *et al.,* 2007).

However, it can be concluded that conflicting evidence exist regarding the effect of resistance training on abdominal fat and it is still unclear if resistance training without any dietary involvement can significantly reduce abdominal fat in young and older men and women from different populations groups. There are limited evidence regarding the effect of moderate-intensity resistance training on abdominal fat as measured by waist circumference, WHR and sagittal abdominal diameter in healthy sedentary older adults. Further research is needed to assess if resistance training can significantly reduce abdominal fat in healthy sedentary older adults, as well as men and women individually, and indicate what role resistance training plays in the prevention of abdominal obesity with ageing.

2.5 EFFECT OF RESISTANCE TRAINING ON AND BLOOD LIPID PROFILE

2.5.1 The effect of resistance training on insulin resistance

The global estimated prevalence of diabetes among adults (aged between 20 and 79 years) was 6.4% in 2010, rising to 7.7% in 2030 (Shaw *et al.,* 2010). Shaw *et al.* (2010) predicted that there would be a 69% increase in the number of adults with diabetes in developing countries and a 20% increase in developed countries, between 2010 and 2030. This indicates a growing burden of diabetes, particularly in developing countries and it correlates with the rising burden of obesity globally (Alwan *et al*., 2010). Diabetes is a group of metabolic diseases characterised by an elevated fasting glucose level as a result of either defects in insulin secretion or an inability to use insulin (Strasser & Schobersberger, 2010). Type one diabetes is characterised by absolute insulin deficiency, caused by autoimmune destruction of the insulin producing β-cells of the pancreas. Type two diabetes is caused by insulin resistance with an insulin secretory effect. Type two diabetes is associated with an unhealthy lifestyle, physical inactivity and an unhealthy diet, resulting in excess body fat especially in the abdominal area (Thompson *et al.,* 2010). In contrast to type one diabetes, type two diabetes is often associated with elevated insulin concentrations (Strasser & Schroberberger, 2010), referred to as insulin resistance.

Type two diabetes, insulin resistance and glucose intolerance are strongly related to dyslipidemia, hypertension, proinflammatory markers, thrombogenic factors and endothelial dysfunction and is therefore a central marker of cardiovascular disease risk (Braith & Stewart, 2006). These abnormalities increase with age and represent an early stage of cardiovascular disease that precedes the manifestation of cardiovascular disease over time (Thompson *et al*., 2010). Maintaining good glycaemic control is dependent on enhancing insulin secretion or availability and overcoming insulin resistance (Thompson *et al.,* 2010). Insulin is an important contributor to the maintenance of glycaemic control due to its responsibility for complex signalling pathways within peripheral tissue such as skeletal muscle and adipose tissue. Insulin signalling within skeletal muscle is responsible for the translocation of the glucose transporter type 4 (GLUT4) protein to the cell surface, which is in turn responsible for the transport of glucose across the membrane into the target cell (Flack *et al*., 2011). Alterations in any of the related pathways reduce insulin's effectiveness, resulting in insulin resistance and glucose intolerance associated with aging (Strasser & Schroberberger, 2010). Both age related declines in glucose tolerance and diabetes are distinguished by a decreased uptake of glucose in peripheral tissues, primarily skeletal muscle.

Unfortunately, physical inactivity, obesity and abdominal obesity seen with ageing hinder the chances for adults and older adults to maintain good glycaemic control (Braith & Stewart, 2006). However, according to Flack *et al.* (2011), age appears to be an independent determinant of impaired glucose tolerance, even though there is a strong correlation between reduced physical activity, reduced lean muscle mass (including associated strength declines), changes in fat distribution, obesity, abdominal obesity, and glucose intolerance.

It is recommended by the American Heart Association (AHA), American College of Sport Medicine (ACSM) and American Diabetes Association (ADA) to include resistance training as part of a lifestyle intervention programme to prevent and treat type two diabetes (Braith & Stewart, 2006). The basis for this recommendation is that muscle contraction increases glucose uptake and improves insulin sensitivity in skeletal muscle (Williams *et al.,* 2007). The ACSM and AHA recommend progressive resistance training in the absence of contraindications for individuals with type two diabetes. According to these guidelines individuals with diabetes should have two to three training sessions per week with at least 48 hours between sessions. A total-body workout or split workout must be performed consisting of 8 to 10 multi-joint exercises, and each exercise must consist of two to three sets of 8 to 10 repetitions, performed at a moderate- to high-intensity (Bacchi *et al*., 2012; Thompson *et al*., 2010).

The literature suggest that 12 to 24 weeks of resistance training tends to improve insulin sensitivity in both healthy sedentary men and women (65 to 74 years), however, these results of both Kitamura *et al.* (2003) and Ryan *et al.* (2001) were not statistically significant. However, the training interventions of Kitamura *et al.* (2003) and Ryan *et al*. (2001) were performed at a low- and moderate intensity and on healthy sedentary older adults. Both the low to moderate-intensity nature of the programmes, as well as the fact that the participants were not insulin resistant may explain their results. Williams *et al*. (2007) stated that resistance training does not appear to alter glucose tolerance or glycaemic control unless baseline glucose tolerance is abnormal. The literature suggests that resistance training is not beneficial to improve glycaemic control in non-insulin resistant individuals. However, there is limited research done on the preventative role of resistance training of type two diabetes in healthy sedentary older adults. The majority of research is done on overweight or obese adults and older adults, as well as on the treatment of type two diabetes.

In overweight or obese adults and older adults (18 to 70 years), 8 to 12 weeks of moderate-intensity resistance training had no significant effect on blood glucose, insulin levels or insulin resistance as measured by HOMA-IR (Ho *et al.*, 2011; Slentz *et al.,* 2011). When men and women were investigated individually, no significant improvement in blood glucose or insulin levels or insulin resistance as measured by HOMA-IR were found as a result of a 12-week low- to moderate-intensity resistance training or a 48-week resistance training intervention combined with an energy restricted diet in obese women (Fenkci *et al.*, 2006; Weinstock *et al.*, 1998). In contrast, 16 weeks of resistance training combined with a weight loss programme, significantly reduced blood insulin levels in obese men (Rice *et al.*, 1999).

Furthermore, 12 to 16 weeks of moderate-intensity resistance training has shown to significantly reduce TNF-α, IL-6, blood glucose as measured by HbA_{1c}, insulin resistance as measured by HOMA-IR and improved glycaemic control in type two diabetic adults older than 55 years (El-Kader, 2010; Brooks *et al.*, 2007; Cauza *et al.*, 2005; Castaneda *et al.*, 2002). According to Hurley *et al.* (2011), HbA_{1c} is a well-accepted measure of glycaemic control for the determination of insulin sensitivity and is strongly associated with risk of diabetes, cardiovascular disease and death. In addition, the combination of resistance training and a calorie restricted diet has also shown to successfully improve glycaemic control in type two diabetic adults and older adults between the age of 39 and 80 years (Sigal *et al.*, 2007; Dunstan *et al.,* 2002). Only Levinger *et al.* (2007) and Fenicchia *et al.* (2004) reported that 6 to 10 weeks of low- to moderate-intensity resistance training did not significantly improve fasting glucose or insulin levels in adults with a high or low number of metabolic risk factors or diagnosed with type two diabetes. A possible explanation for the lack of improvements might be the low-intensity resistance used, as well as the short duration intervention.

Therefore, the literature indicates that resistance training is an effective training regimen to improve glycaemic control and insulin resistance in type two diabetic adults and older adults and, therefore, may play an important role in the treatment of type two diabetes (Cauza *et al.*, 2005). However, the role of resistance training in the prevention of type two diabetes in healthy, overweight or obese sedentary older adults is still unclear.

a. HOMA-IR

The homeostatic model assessment of estimated insulin resistance (HOMA-IR) is a method used to quantify insulin resistance and β-cell function and was first developed in 1985 by Matthews *et al.* (1985). It estimates steady state β-cell function (%B) and insulin sensitivity (%S) as percentages of a normal reference population. The HOMA-IR model is a reliable method that has been widely used since it was first published, and has been shown to be a more convenient method to quantify insulin resistance compared to the 'gold' standard, euglycaemic clamp method (Qu *et al.,* 2011). The insulin resistance score (HOMA-IR) is calculated by multiplying fasting plasma insulin (mU/L) and fasting plasma glucose (mmol/L) divided by a constant of 22.5 (Bonora *et al.,* 2002). A low HOMA-IR value indicates high insulin sensitivity, whereas a high HOMA-IR value indicates low insulin sensitivity (Hosker *et al.,* 1985). The computed model has been improved to a HOMA2-IR model, which is calibrated to modern insulin assays and reflects human physiology better. In the updated HOMA2-IR model, it is possible to determine β-cell function and insulin sensitivity from paired fasting plasma glucose, as well as specific insulin, radioimmunoassay insulin, or C-peptide concentrations (Reaven, 2013).

2.5.2 The effect of resistance training on blood lipids

Dyslipidaemia is a condition where an individual experiences abnormal blood lipid and lipoprotein levels, caused by genetic, environmental or pathological conditions (Thompson *et al.,* 2010). Severe forms of dyslipidaemia are linked to genetic defects in cholesterol metabolism. However, less severe cases of dyslipidaemia may be a result of a response to other diseases, such as diabetes mellitus, or as a result of combining a specific genetic pattern with various environmental exposures, such as diet, smoking and physical inactivity (Nelson *et al*., 2007). Dyslipidaemia is considered to be a major modifiable cause of cardiovascular disease. According to the ACSM guidelines for risk stratification, dyslipidaemia can be considered a risk factor for cardiovascular disease when LDL cholesterol is ≥ 130 $mg.dL^{-1}$ (3.37 $mmol.L^{-1}$), or HDL cholesterol is < 40 $mg.dL^{-1}$ (1.04 $mmol.L^{-1}$), or if only total serum cholesterol is ≥ 200 $mg.dL^{-1}$ (5.18 $mmol.L^{-1}$) (Thompson *et al.,* 2010).

For the treatment of dyslipidsemia, a healthy lifestyle focusing on increasing physical activity and weight reduction is important (Williams *et al*., 2007). According to Thompson *et al.* (2010), physical activity has been shown to improve blood lipid profiles in adults and older adults, but these changes are not universal, especially among individuals with dyslipidemia. Nevertheless, physical activity is highly important for controlling other cardiovascular disease risk factors, which include reducing body fat, increasing resting energy expenditure, reducing abdominal fat, improving glucose tolerance and insulin resistance. Physical activity should be the primary component of a healthy lifestyle (Kraemer *et al*., 2002).

Westcott (2012) reported, based on the ACSM position stand on exercise and physical activity for older adults, that there is evidence to suggest that resistance training may reduce LDL cholesterol between 13% and 23%, decrease triglycerides between 11% and 18% and increase HDL cholesterol between 8% and 12%. Kelley and Kelley (2009) demonstrated the effect of progressive resistance training on lipids and lipoproteins. Their results indicated a significant reduction in total serum cholesterol, HDL/total cholesterol ratio, non-LDL cholesterol, LDL cholesterol and triglycerides, with no significant improvement in HDL cholesterol. A variety of evidence indicate that elevated LDL cholesterol is a powerful risk factor for cardiovascular disease and that lowering of LDL cholesterol results in striking reduction in the incidence of cardiovascular disease (Thompson *et al.,* 2010), whereas a low HDL cholesterol level is strongly and inversely associated with the risk of cardiovascular disease. Strong evidence exists indicating that rising HDL cholesterol levels reduce the risk of cardiovascular disease (Williams *et al*., 2007).

Sixteen weeks of resistance training has shown to significantly decrease total cholesterol, triglycerides, LDL cholesterol, and HDL cholesterol in healthy sedentary older adults older than 65 year (Boardley *et al*., 2007). The decline in HDL cholesterol might be of concern, however, total cholesterol/HDL cholesterol risk ratio also significantly decreased. Other studies in sedentary healthy women (mean age 27 years) and elderly women (70 to 78 years) suggested that 10 to 14 weeks of high-intensity resistance training significantly reduces total cholesterol, LDL cholesterol and total cholesterol/HDL cholesterol ratio (Fahlman *et al*., 2002; Prabhakaran *et al*., 1999). In contrast, healthy active men with no weight training experience between the ages of 60 and 75 years did not show significant improvements for any of the blood lipid-related tests after a 16-week high-intensity resistance training intervention (Hagerman *et al.,* 2000). However, it was reported that each of the lipid markers showed appreciable improvement following training. Hagerman *et al*. (2000) stated that the reduction of total cholesterol and HDL/total cholesterol ratio indicates a possible physiological effect of resistance training on elderly men. HDL/total cholesterol ratio lowered from a high risk value (> 5.2) for developing coronary artery disease to a moderate risk value (< 4.5). It was concluded that resistance training provides a sufficient stimulus to cause improvement in serum lipids, and this response may have a greater impact on elderly men who are completely sedentary.

Furthermore, in contrast with Boardley *et al.* (2007), Ho *et al.* (2011) found significant increases in HDL cholesterol as a result of a 16-week moderate-intensity resistance training intervention, with no other improvements in blood lipid profile. However, the population consisted of overweight and obese sedentary adults between the ages of 40 and 66 years compared to healthy sedentary older adults in the study of Boardley *et al.* (2007). Obese postmenopausal women (60 to 70 years) showed significant decreases in total cholesterol, LDL cholesterol and non-HDL cholesterol as a result of a 12-week low-intensity resistance training intervention (Wooten *et al.,* 2011). However, Fenkci *et al.* (2006) only found significant decreases in total cholesterol and triglycerides as a result of a 12-week low- to moderate-intensity resistance training intervention in obese women (mean age 43 years). In the investigation of men (mean age 50 years) at high risk for cardiovascular disease, Smutok *et al.* (1993) reported no significant improvements of any of the blood lipids following 20 weeks of moderate-intensity resistance training. The literature suggests that resistance training might have a greater impact on blood lipid profile in obese women compared to obese men. However, there is limited research done on the effect of resistance training on blood lipid profile in obese men and further research is needed in this field.

When type two diabetic adults and older adults were investigated, 16 weeks of moderate-intensity resistance training has been found to significantly reduce total cholesterol, triglycerides and LDL cholesterol and significantly increase HDL cholesterol in adults and older adults between the ages of 40 and 70 years (Bacchi *et al.*, 2012 ; Cauza *et al.*, 2005). Whereas, adults between the ages of 24 to 50 years only showed significant decreases in total cholesterol and triglycerides following 12 weeks of resistance training (Misra *et al.*, 2008). In contrast, 16 to 24 weeks moderate- to high-intensity resistance training alone or combined with a calorie restricted diet, resulted in no significant improvements in blood lipid profile in adults and older adults between the ages of 39 and 80 years (Sigal *et al.*, 2007; Castaneda *et al.*, 2002; Dunstan *et al.*, 2002). According to Smutok *et al.* (1993) most common reasons for the lack of change in lipid profile is an insufficient training intensity or duration, the initial VO_{2max} being too high, HDL cholesterol being too low, no weight loss or the absence of a decrease in body fat.

There is contradicting evidence in the literature regarding the effect of resistance training on blood lipid profile and lipoproteins (total serum cholesterol, LDL cholesterol, HDL cholesterol, and total cholesterol/HDL cholesterol ratio). Several studies have shown beneficial effects on blood lipid profile and lipoproteins, whereas other studies have reported no changes in blood lipid profile and lipoproteins after resistance training. Inconsistencies in the literature may be due to differences in resistance training interventions, type of resistance exercises used (i.e.

circuit machines, free weight or elastic bands), duration of training, total resistance exercise volume and intensity of work performed, as well as participant characteristics (genotype) (Wooten *et al*., 2011). It is suggested that lipoprotein-lipid responses to resistance training likely are to be genotype dependent, indicating that genetic factors may determine the degree to which resistance training influences blood lipid profiles (Hurley *et al*., 2011).

2.6 EFFECT OF RESISTANCE TRAINING ON FUNCTIONAL OUTCOMES

2.6.1 The effect of resistance training on strength

It has been well establish that resistance training is an effective training regimen to increase strength, power and the quality of muscle mass in older adults (Westcott, 2012). Thirty three studies in the literature reported significant increases in strength as a result of 6 to 26 weeks of low-, moderate-, and high-intensity resistance training in adults and older adults between the ages of 18 and 96 years (Appendix B). This significant increase in strength were evident in the following population groups; healthy sedentary men and women, frail elderly, obese sedentary men and women, men and women diagnosed with type two diabetes, men at high risk for cardiovascular disease, and men and women with high and low numbers of metabolic risk factors. Macaluso and De Vito (2004) reported that resistance programmes based on the application of the overload principle, which state that muscles should work close to their force-generating capacity, will increase in strength.

According to Hurley and Roth (2000) resistance training is the most suitable and effective training regimen to reverse age associated strength declines. Hurley and Roth (2000) reported that strength losses assessed from isokinetic peak torque values occur at the rate of about 12% to 15% per decade after the age of 50 years, and strength gains, assessed from 1-RM values, of greater than 30% occur within the first couple of months of heavy resistance training in 65 to 75 year old men and women. Thus, about two months of resistance training essentially reverses at least two decades of strength loss with advancing age.

There are various factors that contribute to strength gains following resistance training in both young and older adults (Macaluso & De Vito, 2004). In the first phase of training (about one to two weeks), a rapid improvement in the ability to perform a specific exercise is evident, such as lifting weights, and this is mainly a result of a learning effect (Ivey *et al*., 2000). The learning effect is mediated by changes in motor skill coordination and level of motivation, and can be substantial especially when the test used to evaluate strength requires a high level of skill (Macaluso & De Vito, 2004). In the second phase (three to four weeks), muscle strength gains are obtained without a matching increase in size of the trained muscles. The improvement in this phase is mainly attributed to neural adaptations (Brooks *et al.,* 2007). Neural adaptations refer to an increased activation of muscle (which is a result of an increased number of recruited motor units or firing rate and synchronization of the individual motor units), an increased neural drive from the highest levels of the central nervous system and a better coordination of synergistic and antagonist muscle (Macaluso & De Vito, 2004). The third phase of adaptation to resistance training (more than six weeks) is characterised by an increase in both the size and strength of the exercised muscle (Ivey *et al*., 2000).

Hagerman *et al.* (2000) found significant increases in cross-sectional areas in muscle fibre types I and II as a result of a 16-week high-intensity resistance training intervention in older men between the ages of 65 and 75 years. These intramuscular responses were consistent with significant increases in strength and it was reported that similar findings have been found in younger individuals. However, it is important to note that strength gains were specifically accompanied by transitions in the fast fibre population (type II muscle fibre). According to Murlasits *et al*. (2012) hypertrophy contributes significantly to strength improvement in older adults just as it does in younger adults. It is therefore possible that resistance training may prevent atrophy and loss of muscle fibre and motor units that is associated with aging and inactivity. Thus, according to Hagerman *et al.* (2000) resistance training can maintain muscle mass of older adults which may, in turn, also prove valuable in maintaining the functional capacity of muscle.

In addition, Macaluso and De Vito (2004) stated that factors unrelated to muscle mass account for a significant portion of the strength gains with resistance training regardless of age and gender. These factors refer to the alterations in the neuromuscular, mechanical, contractile, and architectural components, which affect the quality of muscle. According to Brooks *et al.* (2007), muscle quality is a better indicator of muscle function than strength alone. Muscle quality, as well as lean muscle mass, more specifically type I and II cross-sectional area, and strength has been found to significantly increase as a result of 9 to 16 weeks of moderate-intensity resistance training in adults and older adults between the ages of 20 to 75 years (Brooks *et al.*, 2007; Ivey *et al*. 2000). Significant improvements in muscle quality were also found to be associated with improved functional capacity in type two diabetic patients (Brooks *et al*. 2007). According to Hurley and Roth (2000) increases seen in muscle quality following resistance training is potentially as a result of neural adaptations that enhances contractile properties (e.g. increased number of recruited motor units or firing rate). Ivey *et al.* (2000) found that muscle quality remained significantly elevated above baseline levels for at least 31 weeks after detraining in younger men and women, and in older men, which illustrates that non-muscle mass adaptations are retained long after cessation of the resistance training stimulus. Ivey *et al*. (2000) also reported that these adaptations are instrumental in preserving strength, despite declining muscle mass during the same time period.

In addition, increases in type II muscle fibre and motor units, as well as neural adaptations as a result of resistance training does not only lead to strength gains, but also improvements in power (Hurley & Roth, 2000). According to Marx *et al.* (2000) the preservation of muscle power into late life can greatly decrease the risk of disability and enhance functional independence. Macaluso and De Vito (2004) reported that moderate-intensity resistance training leads to small but significant increases in power, despite much larger increases in strength. It was reported that a 10-week progressive resistance training intervention produced 113% and 28% increases in muscle strength and power, respectively. A strong correlation exists between strength, power, and the ability to perform functional tasks, therefore increases in strength and power during ageing is important to maintain and improve functional ability (Carmeli *et al.,* 2000).

2.6.2 The effect of resistance training on functional capacity

A great deal of evidence indicates that resistance training is a safe and effective training regimen to increase lean muscle mass and strength in older adults from several population groups (Appendix B). According to Kraemer *et al.* (2002), several benefits are associated with increased lean muscle mass and strength, such as enhanced physical performance, e.g., the ability to climb stairs, sit and stand from a chair, walking speed, movement control, functional independence and self-esteem, which ultimately lead to an improved functional status in older adults. Some evidence also reveal that resistance training can increase type II muscle fibre, muscle quality and power, which has a strong positive effect on muscle performance and functional ability in older adults (Ivey *et al.,* 2000). Therefore, increases in lean muscle mass, muscle quality, strength and power as a result of resistance training would suggest improvements in functional capacity and the ability to perform daily tasks with ageing (Ivey *et al.,* 2000). However, according to Macaluso and De Vito (2004), this is an area of research that remains unclear, with only a few studies supporting this statement.

Functional capacity as measured by the Timed-Up-and-Go test (TUG) has been shown to significantly improve as a result of 8 to 24 weeks of low- to moderate-intensity resistance training in adults and older adults between the ages of 40 to 93 years with high and low numbers of metabolic risk factors or those diagnosed with type two diabetes (Minges *et al*., 2011; Levinger *et al*., 2007). Significant improvements in TUG test performance were accompanied by significant increases in lean muscle mass and strength and it was reported that significant improvements in strength were correlated with improvements in the capacity to perform activities of daily living (Minges *et al.*, 2011; Levinger *et al.*, 2007). However, TUG test performance remained unchanged in healthy sedentary older adults over the age of 60 years after eight weeks of moderate-intensity resistance training, although significant improvements in lean muscle mass, strength and force producing capabilities were evident (Murlasits *et al.*, 2012). According to Murlasits *et al.* (2012), strength improvements in well-functioning, active older adults with normal baseline levels, does not directly translate to functional improvements and therefore need specific functional training (i.e. including balance training).

In addition, Carmeli *et al*. (2000) also did not find significant improvements in TUG test performance after 12 weeks of low-intensity resistance training in older adults between the ages of 79 and 83 years who did not suffer from acute disease or uncontrolled chronic conditions. However, significant improvements in TUG test performance and three metre distance walk time were reported in older adults between the ages of 84 and 87 years, although significant strength improvements were more pronounced in the relatively younger group (79 to 83 years) (Carmeli *et al*., 2000). Westcott (2012) also reported that older adults (mean age 89 years) in their study increased their overall strength by 60%, added 1.7kg of lean muscle mass, and improved functional independence by 14% following a 14-week resistance training intervention. It was concluded by Carmeli *et al.* (2000) that resistance training can improve strength and functional abilities in older adults, however, improvement in functional abilities do not necessarily correlate with strength improvements.

A review done by Latham *et al.* (2004) were consistent with either no effect or a small, non-significant effect in TUG test performance in older adults between the ages of 75 and 82 years. Latham *et al.* (2004) reported that strength gains as a result of resistance training have a positive effect on several important functional limitations in older adults, such as gait speed. However, there is no evidence that resistance training alone has an effect on physical disability. It is possible that, to impact at this higher level of functioning, resistance training needs to be combined with other forms of exercise (e.g. balance training) and that more consideration needs to be given to other factors that contribute to disability such as self-efficacy, motivation, or barriers to participate (Latham *et al.,* 2004). However, resistance training has been shown to have a modest significant beneficial effect on gait speed as measured by three metre distance walk time, a moderate to large beneficial effect on sit-to-stand test performance, as well as a significant improvement in total distance walked in six minutes in adults and older adults (Sarsan *et al*., 2006; Latham *et al*., 2004; Carmeli *et al*., 2000; Fiatarone *et al*., 1990).

Therefore, the literature has shown that resistance training has a beneficial effect on some aspects of function, such as gait speed or chair rise (Steib *et al.*, 2010). However, TUG test performance were only significantly improved in individuals older than 83 years and in diseased populations. According to Macaluso and De Vito (2004) training adaptations are more substantial the older the person or with increased fat mass, especially for those in poor physical condition, which could potentially explain why significant results were only found in these population groups. However, there is limited research done on functional capacity as measured by TUG test in healthy sedentary older adults younger than 75 years. Further research is needed in this population to identify what the effect of resistance training is on TUG performance.

2.6.3 The effect of resistance training on perceived health status

The self-administered SF-36 survey is a 36 item scale that measures eight aspects of functional health due to physical or emotional problems. The eight subscales are summarised into the physical component summary score and mental component summary score. According to Brazier *et al.* (1992), the SF-36 is a promising instrument for measuring perceived health status in a general population. It is also acceptable for patients and fulfils strict criteria of reliability and validity.

Levinger *et al.* (2007) examined the effect of 10 weeks of resistance training on the ability to perform activities of daily living and health status in adults (40 to 69 years) with a high number of metabolic risk factors, compared to individuals with a low number of metabolic risk factors. The results indicated that resistance training improved muscle strength and the capacity to perform activities of daily living in adults with a low and high number of metabolic risk factors. Resistance training also improved the health status of adults with a high number of metabolic risk factors; this result was independent of changes in body fat content or aerobic power. There was a significant improvement in the physical functioning, general health and social functioning domain. It was stated that a longer training regimen may be needed to improve health status in adults with a low number of metabolic risk factors.

Ng *et al.* (2011) aimed to determine the effect of eight weeks of resistance training on health status, measured by the short-form 36 (SF-36) health survey in type two diabetic adults (mean age 58 years). Their results revealed that resistance training significantly improved physical functioning, general health, vitality and mental health. Benjamini *et al.* (1997) assessed a variety of health status parameters in 38 cardiac patients who had completed either 12 weeks of high-intensity resistance training or flexibility training added to their outpatient cardiac rehabilitation aerobic exercise programme. The resistance training group increased their selfefficiency scores for lifting, climbing, jogging and push-ups compared to the flexibility group. The resistance training group's score was also significantly improved for the role-emotional health domain of the SF-36 questionnaire when compared to the flexibility group, and role-functional scores improved for both groups. Increased strength seen with the resistance training group was associated with enhanced self-efficacy and an improved mood and well-being score. It was concluded that high-intensity resistance training combined with a cardiac rehabilitation programme leads to improvements in health status.

It can therefore be concluded that resistance training may be effective in improving perceived health status as measured by the SF-36 health survey in different population groups. However, there is a lack of evidence regarding the effect of resistance training on perceived health status in healthy sedentary older adults. Thus, further research is needed in this field.

CHAPTER THREE

METHODS AND PROCEDURES

3.1 INTRODUCTION

The application of resistance training has been shown to be beneficial for the prevention of obesity, dyslipidaemia, type two diabetes and cardiovascular disease by increasing resting energy expenditure, and improving body composition and blood lipid profile in older adults (Westcott, 2012). Resistance training has also been shown to improve functional capacity by increasing fat-free mass and strength (Ivey *et al.,* 2000). However, there are contradicting and limited evidence in the literature regarding the effect of resistance training to improve health and functional status in older adults. Therefore, the main objectives were to investigate the effect of moderate-intensity resistance training on body composition, blood lipid profile and functional capacity in older adults.

3.2 STUDY DESIGN

This study used a parallel group, quasi-experimental study design. The participants were randomly allocated to two groups; a control group (CON) who received no intervention and an experimental group (RESIS) who took part in an exercise intervention of three resistance training sessions per week for a period of 16 weeks. Pre- and post-intervention testing were done, as well as every four weeks.

3.3 PARTICIPANTS

Recruitment of the potential participants took place by means of an advertisement of the study via the Boschtelegram (newsletter of Stellenbosch University) and through word of mouth. Participants volunteered to participate in the study, but only the participants who met the following inclusion criteria were invited to participate in the study:

- between the ages of 50 and 75 years
- passed the preliminary screening procedure for co-morbidities based on ASCM risk stratification guidelines (atherosclerotic cardiovascular disease risk factor threshold)
    a. non-fasting total cholesterol and glucose test
    b. hemodynamic measures (resting blood pressure and heart rate)
    c. 12-lead resting electrocardiograph (ECG)
    d. Health screening form (Appendix C) – participants with more than two risk factors were asked to obtain medical clearance from their physician before being allowed to participate in the study (Appendix D)

- BMI ≤ 30kg.m-2
- medical clearance from their physician (if required after screening)
- occasionally participated in recreational physical activities such as walking, biking, hiking and swimming prior to the intervention.

Participants were excluded from the study if:

- they did not comply with the regulations preceding the tests
- they were diagnosed with cardiovascular, pulmonary and/or metabolic diseases
- they had any organ damage
- they had orthopaedic or musculoskeletal problems that can affect their exercise ability or increase their risk of injury
- they had a BMI of less than 18.5kg.m^{-2}
- they had three or more risk factors according to ACSM guideline for exercise testing (Appendix D)
- they had been participating in at least 30 minutes of moderate intensity physical activity (64%-76% of maximal heart rate) on at least three days of the week for at least three months prior to the intervention.

The health questionnaire (Appendix C) and screening procedure covered all the aspects mentioned above. This ensured that the necessary precautions were taken in order to exclude a participant from the study if the risk of participation was deemed to high.

3.4 MEASUREMENTS AND INSTRUMENTATION

3.4.1 Anthropometric measurements

The body composition evaluation consisted of the following anthropometric measurements; weight and height for the calculation of BMI, hip and waist circumference, Bio-electrical Impedance Analysis (BIA), and sagittal abdominal diameter with a Holtain-Kahn Calliper. Anthropometric measurements were conducted according to the International Standards for Anthropometric Assessment (ISAK) guidelines (Marfell-Jones *et al.*, 2001). Repeated measurements were taken as near as possible to the same time of day as the original measurement.

Weight was measured with a calibrated electronic scale (UWE BW – 150, 1997 model, Brisbane Australia) while participants were barefoot and dressed in shorts and shirts. Participants' body mass were recorded to the nearest 0.1 kilogram (kg).

Height was measured with a stadiometer. Measurements were recorded to the nearest 0.1 centimetre (cm).

Body mass index (BMI) was calculated as weight (kg) / (height (m))^2

Circumferences were measured with a spring loaded, non-extensible anthropometric tape (Rosscraft, Canada), with participants standing in the anatomical position. All measurements were recorded to the nearest millimetre (mm).

Waist circumference was measured at the narrowest point between the lower costal (10th rib) border and the top of the iliac crest, perpendicular to the long axis of the trunk. If there was no obvious narrowing, the measurement was taken at the mid-point between the lower costal (10th rib) border and the iliac crest (Marfell-Jones *et al.,* 2001).

Hip circumference measurements were taken at the level of the participants' greatest posterior protuberance, perpendicular to the long axis of the trunk (Marfell-Jones *et al.,* 2001).

Sagittal abdominal diameter, defined as the thickness of the abdomen at waist level was measured with the Holtain-Kahn calliper (Holtain Limited, United Kingdom) recorded in centimetres. The measurement was taken in a supine position as in this position the body's visceral fat projects the abdomen in a sagittal direction, and the gravity moves the subcutaneous fat to the side.

Bioelectrical Impedance Analysis (BIA): Percentage body fat was measured with a portable Bodystat unit (Quadscan 400, Isle of Man, United Kingdom) using bio-electrical impedance analysis (BIA). Participants were asked to empty their bladders and remove any jewellery, as well as their shoes and socks prior to the measurement. Participants were then instructed to lie supine on a plinth with their arms and legs spread apart, so that their arms did not touch the centre of their body and their legs did not make contact with each other. Four electrodes were placed at standard anatomical points on the right side of the body after the area was cleaned with alcohol swaps. One of the electrodes was placed on the dorsal side of the right hand, one centimetre proximal to the knuckle of the middle finger, while the other electrode was placed on the dorsal side of the wrist between the heads of the radius and ulna. The other two electrodes were placed on the dorsal foot, one between the hallux and third phalanges, and the other between the medial and lateral malleoli.

After correct placement of the electrodes, the Bodystat unit was connected to the electrodes and a low electrical current (800uA at 50 kHz) was sent through the participants' body. The Bodystat software used the measurement of resistance and reactance along with anthropometrical data (weight and height) to calculate each participant's fat-free mass, percentage body fat, total body fat mass and resting energy expenditure. This was possible due to the difference in resistance of adipose and non-adipose tissue.

3.4.2 Blood pressure and heart rate readings

Blood pressure readings were taken according to ACSM guidelines (Thompson *et al.,* 2010) and were only used to monitor each participant during the testing and intervention period. Participants were seated for at least five minutes in a chair with back support, with feet on the floor and arms supported at heart level before taking the measurement. A second blood pressure reading was taken at least one minute after the first reading following the same procedure as previously explained. If the two measures for either the systolic or diastolic blood pressure differed by more than five mmHg, a third measurement was taken to determine the average of the three measurements. If the difference between the first two readings was not more than five mmHg, the average of the first two readings was recorded as the blood pressure reading.

Heart rate readings were taken manually and the readings were only used to monitor each participant during the testing and intervention period. The radial pulse was measured by placing the tips of the index and second fingers just below the base of the thumb over the radial artery at the wrist. The number of heart beats was recorded within 60 seconds and was recorded as the participant's resting heart rate (Thompson *et al.,* 2010).

3.4.3 12-lead resting Electrocardiograph

A 12-lead resting electrocardiograph (ECG) (ELI 250, Milwaukee, U.S.A.) was conducted during the screening procedure to identify any participants with underlying cardiovascular disease. The participants' were instructed to lie comfortably in a supine position. A total of 10 electrodes were placed on the participants' body after the skin was prepared. Preparation of the skin included the removal of any excessive hair and wiping of the skin with alcohol swaps and dry gauze pads. Six electrodes (V1-V6) were placed on the chest area and four on the limbs (RA, LA, RL and LL); one for each limb. The placement of the electrodes was as follow:

V1 – In the fourth intercostal space (between the 4^{th} and 5^{th} rib) at the right sternal border
V2 – In the fourth intercostal space (between the 4^{th} and 5^{th} rib) at the left sternal border
V3 – Midway between leads V2 and V4

V4 – In fifth intercostal space (between 5th and 6th rib) on the midclavicular line
V5 – On the same horizontal level as lead V4 on the anterior axillary line
V6 – On the same horizontal level as leads V4 and V5 on the mid-axillary line
RA – On the right wrist or deltoid
LA – On the left wrist or deltoid
RL – On the right ankle medially
LL – On the left ankle medially

A South African Sport Medicine Association (SASMA) accredited sport physician examined the participant's ECG results and determined if the participant can be cleared for participation in the study.

3.4.4 Lipogram and HOMA-IR

Before initiation and after the completion of the exercise intervention, participants were asked to visit PathCare Centre (Stellenbosch) for a full lipogram and HOMA-IR. Participants were instructed to fast for eight hours prior to the blood tests.

The lipogram evaluated the participant's total serum cholesterol, HDL-cholesterol, LDL-cholesterol, triglyceride, HDL; cholesterol ratio and free fatty acid levels. The HOMA-IR used measurements of fasting plasma glucose and fasting plasma insulin (also measured by PathCare) for the in vivo determination of insulin sensitivity. HOMA-IR was calculated using the following formula: fasting plasma glucose (mmol/L) x fasting plasma insulin (mU/L) / 22.5 (Bonora *et al.,* 2002). HOMA2 %B and HOMA2 %S was also calculated by means of the HOMA2 calculator by using fasting plasma glucose and insulin as measured by PathCare.

3.4.5 Muscle strength tests

A ten-repetition maximum (10-RM) test was used to determine each participant's maximal muscle strength during two exercises, namely the incline leg press and bench press. The incline leg press was used to determine lower-body strength, whereas the bench press was used to determine upper-body strength. A one repetition maximum test was not used because it is not advised for untrained, elderly individuals. Prior to each test, the participants were asked to complete a warm-up, which consisted of five repetitions with the leg press machine and bench press bar with no added weights. A one minute rest was allowed after the warm-up.

The 10-RM for each exercise was determined within four to five trials with rest periods of three to five minutes between trials. The initial weight was selected within the participant's perceived capacity (~ 50% - 70% of capacity). The resistance increased progressively by 2.5 to 20 kilogram until the participant could not complete ten repetitions. All repetitions were performed at the same speed of movement and range of motion to instil consistency between trials. The final weight lifted successfully for ten repetitions was recorded as the absolute 10-RM.

The RESIS also performed the 10-RM test for the seated latissimus dorsi pull downs, seated shoulder press with dumbbells, seated rows, seated hamstring curls and squats on a Smith machine. This information, along with the incline leg press and bench press results was used to determine the intensity of the resistance exercises performed during the exercise program. More importantly, the information was also used to record strength changes during the intervention.

3.4.6 Rating of perceived exertion (RPE)

The Borg CR10 Scale (Appendix H) was used during the resistance training intervention to determine each participant's perceived intensity of each set during all seven exercises (Egan *et al.,* 2006). The readings taken during the intervention was only used to keep the participants working at their true 10-RM and progressively increasing the weight as the participants strength increased. The rating on the RPE scale should have been 5 (hard) or more for the first set (50% of 10-RM), 7 (very hard) or more for the second set (75% of 10-RM) and 9 or 10 (very, very hard, maximum) for the third set (100% of 10-RM). If the participant reported a lower RPE score, the weight/ resistance of the specific exercise was increased.

3.4.7 Timed-up-and-Go test

The Timed-up-and-Go test was used to determine each participant's functional ability. The participant was asked to sit on a chair approximately 46 cm high. A distance of three metres was measured from the front of the chair and was indicated by a marker. The participants were instructed to stand up on the command "Go", walk as fast as possible for three metres, turn at the marker, and walk back to the chair and sit again. The time in seconds was recorded from the command "Go" until the participant has returned seated in the chair (Steib *et al.*, 2010).

3.4.8 36-item short-form Health Survey (SF-36)

The participants were asked to complete a SF-36 Health Survey, which was used to measure functional health and well-being from the participants' point of view. The SF-36 includes one multi-item scale that assesses eight health concepts: (1) physical functioning; (2) social functioning; (3) role-physical (limitations in physical activities because of physical problems); (4) role-emotional (limitations in social activities because emotional problems); (5) general mental health (psychological distress and well-being); (6) vitality (energy and fatigue); (7) bodily pain; and (8) general health perception. An aggregate percentage score was calculated for each of the eight domains, psychometrically-based physical component summary (PCS) and mental component summary (MCS), in the SF-36. The percentage scores range from 0% (lowest level of functioning) to 100% (highest or best level of functioning) (Brazier *et al*., 1992).

The SF-36 is an easy to use instrument and includes information regarding the participants' perceived physical, mental, and health status. The reliability statistics for the SF-36 health survey have exceeded the minimum standard of 0.70 recommended for measures used in group comparisons in more than 25 studies (Tsai *et al.,* 1997). The median reliability coefficient for each of the eight domains was equal or greater than 0.80, except for social functioning, which had a median reliability of 0.76 (Tsai *et al.,* 1997). In addition, the SF-36 domains correlate substantially ($r = 0.40$ or greater) with most of the general health concepts and with the frequency and severity of many specific symptoms and problems. SF-36 domains have been shown to reach about 80% to 90% of their empirical validity in studies involving physical and mental health "criteria" (McHorney *et al*., 1993).

3.5 EXERCISE INTERVENTION

The participants were randomly allocated into two groups by means of a randomized block design, namely a CON that did not receive an intervention and an RESIS that took part in a resistance exercise intervention over a period of 16 weeks. The participants in the RESIS were asked to train at Stellenbosch Biokinetics Centre three times per week (preferably Mondays, Wednesdays and Fridays). The CON was asked to continue their daily activities and refrain from starting an exercise program or changing their diet during the study period. The participants in the CON underwent all testing as expected from the RESIS.

The duration of each session was 50 minutes. Each exercise session consisted of a warm-up, seven resistance exercises and a cool-down, which included flexibility exercises. The warm-up consisted of five minutes on a cross trainer at low intensity (50% to 63% of age-predicted maximum heart rate calculated as 220 – age). The setting on the cross trainer was set at level one or two based on the participant's age and fitness level (Thompson *et al*., 2010) The RESIS completed three sets of ten repetitions per set. For the first set the participants' trained at 50% of their 10-RM, the second set at 75% of their 10-RM and the third set at 100% of their 10-RM. Forty seconds of rest was given between sets and one and a half to two minutes of rest were given between exercises (Pollock *et al*., 2000).

The resistance exercise programme included the following exercises; incline leg press, bench press, seated latissimusdorsi pulldown, seated shoulder press with dumbbells, squats at the Smith machine, hamstring curl and seated rows. The exercises were chosen based on ACSM guidelines for exercise prescription for older adults, which recommends a total-body workout stressing all major muscle groups (Nelson *et al.,* 2007). This programme allows activation and strengthening of all major muscle groups in a safe and feasible manner for this population group (Paoli *et al*., 2012). The exercises were executed in the following order:

1. Incline leg press
2. Bench press
3. Squats using the Smith machine
4. Seated rows
5. Seated latissimusdorsi pulldown
6. Hamstring curls
7. Seated shoulder press with dumbbells

This order was chosen based on the guidelines for designing a resistance training programme to enhance muscular fitness (Bird *et al.,* 2005).

The cool down comprised flexibility exercises, which consisted of stretching of the hamstrings-, quadriceps-, gluteus-, latissimus dorsi-, quadratus lamborum- and pectorals muscle groups. Each static stretch was held for 30 seconds for only one repetition (Nelson *et al*., 2007). The flexibility exercises were chosen based on ACSM recommendations for exercise prescription for older adults (Nelson *et al*., 2007).

Participants' blood pressures and heart rates were monitored before and after each exercise session. The rating of perceived exertion (RPE) scale was used to monitor each participant's perception regarding the intensity of each exercise (Appendix H). A feeling scale (Exercise-Induced Feeling Inventory) was also completed before and after each exercise session to evaluate fluctuations in participants' mood caused by the exercise session (Appendix I).

3.6 EXPERIMENTAL PROCEDURE

3.6.1 Laboratory visits

The participants were asked to visit the Department of Sport Science on various occasions (depending on the specific group they were allocated to) for a screening procedure, baseline testing, exercise- and testing sessions during the intervention and post-intervention testing. The following activities were conducted on separate visits:

Visit 1:

The details and aims of the study were explained to the volunteers, as well as what was expected of each participant during testing procedures and the intervention. Each volunteer was asked to complete a health screening form (Appendix C), consent form (Appendix F) and undergo standardized screening tests (Appendix E). The standardized screening consisted of testing the following markers; non-fasting glucose, non-fasting total cholesterol, resting blood pressure, resting heart rate, hip- and waist circumference, stature and body mass for the calculation of body mass index (BMI), and resting ECG. Baseline blood pressure was determined from the average of three measurements taken in a seated position. After the completion of the screening, risk stratification was conducted according to the ACSM risk stratification guidelines (Appendix D). Participants who had no signs/symptoms of, or diagnosed cardiovascular, pulmonary and/or metabolic diseases, and who complied with the inclusion criteria, were approved to participate in this study. After approval, participants were allocated randomly into the two groups.

Visit 2:

Baseline testing was conducted during the second visit and consisted of the following tests in the specific order (Appendix G):

1. The SF-36 health survey was completed for the measurement of perceived physical and mental health status.
2. Bioelectrical impedance analysis (BIA) was conducted for the evaluation of the participant's body composition; this procedure also included the measurement of height and weight.
3. The Holtain-Kahn abdominal calliper was used to measure participants' sagittal abdominal diameter.
4. Participants' functional capacity was tested via the Timed-Up-and-Go (TUG) test.
5. Muscle strength testing was conducted using the 10-RM maximum incline leg press and bench press tests for the determination of lower- and upper-body strength.
6. The RESIS also conducted 10-RM maximum strength test for the following exercises, seated latissimus dorsi pull downs, seated shoulder press with dumbbells, seated

rows, seated hamstring curls and squats on a Smith machine. Information obtained during the first visit (screening) regarding waist- and hip circumferences were also used as baseline values. This session also served as familiarisation with all the equipment which were used during the intervention.

It took approximately one hour and 30 minutes to complete the baseline testing. The different procedures followed directly after on another. However, three to five minutes of rest were given between 10-RM strength tests.

<u>Visit 3</u>: On a separate occasion, before the start of the intervention, participants were asked to visit the PathCare Centre (Stellenbosch) for a full lipogram and HOMA-IR. The lipogram evaluated the participant's total serum cholesterol, HDL, LDL, triglyceride and free fatty acid levels. The HOMA2-IR, HOMA2 %B and HOMA2 %S used measurements of fasting plasma glucose and fasting plasma insulin, measured by ParthCare, for the in vivo determination of insulin resistance, β-cell function and insulin sensitivity.

<u>Visit 4 – 51</u>: The exercise sessions commenced from the fourth visit. The RESIS completed three sets of ten repetitions per set. For the first set, the participants' trained at 50% of their 10-RM, the second set at 75% of their 10-RM and the third set at 100% of their 10-RM. The initial resistance/weight for each exercise was determined by calculating the percentage of the 10-RM maximum strength tests obtained for each exercise during the second visit. The RESIS trained three days per week (preferably Mondays, Wednesdays and Fridays). The duration of each session was 50 minutes and the intervention was administered over a period of 16 weeks. The warm-up consisted of five minutes on a cross trainer at low-intensity (50% to 63% of age-predicted maximum heart rate). Each exercise session consisted of a warm-up, seven resistance exercises namely, incline leg press, bench press, seated latissimus dorsi pull downs, seated shoulder press with dumbbells, seated rows, seated hamstring curls and squats on a Smith machine. The training session was ended with a cool down that consisted of static flexibility exercises focussing on major muscle groups. Before and after each exercise session, participants' blood pressures were taken and they completed an exercise-induced feeling (EFI) questionnaire (Appendix I). The structure of the exercise sessions was consistent throughout the 16-week intervention period.

<u>Visit 52 – 54</u>: Every four weeks during the intervention period, participants completed assessments consisting of measures of functional capacity, non-fasting glucose and total cholesterol, resting blood pressure and heart rate, stature and body mass, waist- and hip circumference, sagittal abdominal diameter and BIA. The 10-RM strength tests (incline leg

press and bench press) were also conducted every four weeks. The four weekly 10-RM strength test results were used to progress the participants' resistance training programs.

Visit 55: After completion of the intervention the participants' total serum cholesterol, HDL cholesterol, LDL cholesterol, triglycerides and free fatty acid levels were tested again via a full lipogram at the PathCare Centre (Stellenbosch). Also the HOMA2-IR, HOMA2 %B and HOMA2 %S was calculated using post-intervention fasting plasma glucose and fasting plasma insulin values, which were also measured by PathCare.

Visit 56: For the participants' final visit, the full baseline testing procedure was repeated. The following was tested again; resting blood pressure and heart rate, BIA including stature and body mass, sagittal abdominal diameter, waist- and hip circumference, non-fasting glucose and total cholesterol, and upper body- and lower body strength. The participants were also asked to complete the SF-36 health survey, as well as indicate if they adapted their diet and life style during the intervention (Appendix J).

Table 3.1. Summary of assessments done during each laboratory visit.

Visit	**Time elapsed since last visit**	**Duration of visit**	**Procedures**
Visit 1	None	One hour	Personal information Health screening form Non-fasting glucose Non-fasting total cholesterol Resting blood pressure Resting heart rate Hip- and waist circumference Height and weight Resting ECG
Visit 2	At least one day	One hour and 30min	SF-36 health survey Height and weight BIA Sagittal abdominal diameter via Holtain-Kahn Calliper Timed-Up-and-Go test 10-RM muscle strength test
Visit 3	At least two days	30 minutes	Blood test at PathCare Centre

Visit 4 - 51	At least one day	50 minutes	Exercise sessions (3 sessions per week)
Visit 52 – 54	At least one day	45 minutes to one hour and 30 minutes	Every four weeks: Non-fasting glucose Non-fasting total cholesterol Height and weight BIA Hip- & waist circumferences Sagittal abdominal diameter Timed-Up-and-Go 10 RM muscle strength test
Visit 55	EXP: At least two days since the last training session	30 minutes	Blood test at PathCare Centre
Visit 56	EXP: At least two days since the last training session	Two hours	SF-36 health survey Non-fasting glucose Non-fasting total cholesterol Height and weight BIA Hip- & waist circumferences Sagittal Abdominal diameter Timed-Up-and-Go test 10 RM muscle strength tests

3.7 STATISTICAL ANALYSIS

The statistical analysis was performed with Microsoft Office Excel (2013) and STATISTICA 12. Descriptive statistics were calculated as means and standard deviations (SD). Percentage mean difference between pre- and post-testing was calculated for all variables to indicate the percentage change over time. Mixed model repeated measures ANOVA was done to test the effects of the intervention on the various outcome measurements. In the analysis, time and group were treated as fixed effects with the participants as random effects. Fisher least significant difference (LSD) was used for post hoc testing. The level of significance for all variables was set at $p \leq 0.05$. Cohen's effect sizes were calculated for the determination of practically significant differences between groups. The effect size results were interpreted based on the following criteria (Cohen, 1992):

ES < 0.15:	Negligible
ES ≥ 0.15 and ES < 0.40:	Small
ES ≥ 0.40 and ES < 0.75:	Medium
ES ≥ 0.75 and ES < 1.1:	Large
ES ≥ 1.1 and < 1.45:	Very large
ES ≥ 1.45:	Huge

3.8 ETHICAL CONSIDERATIONS

The study protocol was approved by the Ethics Committee of Human Research (Humanities) at Stellenbosch University (HS891/2013). The investigator took precautions for participants at risk for cardiovascular disease. Each participant was screened for co-morbidities before participation in the study. Participants were informed that their participation was completely voluntary and that they could withdraw from the study at any point during the intervention. Participants completed an informed consent before participation commenced and all procedures, tests and exercises were clearly explained. All participants in the RESIS had a thorough introductory session of the different resistance training exercises before initiation of the resistance training intervention. Participants in the CON were also introduced to the leg press and bench press exercises before pre-testing. Participants might still have been uncomfortable with the load of the different exercises, however, the first set of each exercise was performed at a low load of 50% of 10-RM. All exercise sessions were supervised by a student or intern biokineticist. Participants might also have experienced some discomfort or delayed onset of muscle soreness after the exercise session, due to the fact that the participants were untrained.

CHAPTER FOUR

RESULTS

4.1 DESCRIPTIVE CHARACTERISTICS

The physical and physiological characteristics of the participants are summarized in *Table 4.1*. Forty one healthy, sedentary individuals (men = 15, women = 26) between the ages of 55 and 73 years were included in this study. The participants had less than three risk factors according to ACSM guidelines for exercise testing (Appendix D) and did not participate in a structured exercise program for at least three months prior to the commencement of the study intervention. The participants also did not have any orthopaedic or musculoskeletal problems that affected their exercise ability or increased their risk of injury. The experimental group (RESIS) consisted of 22 participants (men = 7, woman = 15) and the control group (CON) of 19 participants (men = 8, woman = 11). There were no significant differences in any of the descriptive characteristics between the two groups ($p > 0.05$).

Table 4.1. Physical and physiological characteristics of participants.

	RESIS (n = 22) **Mean (SD)**	**CON (n = 19)** **Mean (SD)**
Men (n)	7	8
Women (n)	15	11
Age (years)	60.61 (9.82)	62.47 (5.72)
Weight (kg)	73.26 (15.84)	76.81 (14.07)
Height (m)	167.73 (7.99)	168.63 (8.19)
BMI ($kg.m^{-2}$)	25.81 (4.10)	26.89 (3.79)
Fat mass (kg)	25.55 (8.10)	25.79 (6.78)
Fat-free mass (kg)	47.72 (11.33)	47.72 (11.33)
Bench press (kg)	22.68 (14.69)	22.53 (11.38)
Leg press (kg)	70.45 (40.29)	81.32 (42.97)

RESIS, experimental (resistance) group; CON, control group; $kg.m^{-2}$, kilogram per square metre.

4.2 OUTCOME VARIABLES

4.2.1 Body composition

a. Within-group changes

The within-group comparisons for anthropometric and metabolic variables are presented in *Table 4.2.* There were statistically significant reductions in weight and BMI for both the RESIS ($p < 0.05$) and CON ($p < 0.05$) after the intervention period compared to baseline data. The RESIS showed significant reductions in waist ($p < 0.001$) and hip circumference ($p < 0.0001$), total body fat mass ($p < 0.001$) and body fat percentage ($p < 0.05$) after the resistance training intervention. A significant increase in percentage muscle mass ($p < 0.05$) was also evident in the RESIS after the resistance training intervention. The CON showed a significant decrease in hip circumference ($p < 0.05$), but significant increases in waist-to-hip ratio and sagittal abdominal diameter ($p < 0.05$).

Table 4.2. Pre- and post-differences in body composition for the RESIS and CON.

Variables	RESIS		CON	
	Pre-testing Mean (SD)	**Post-testing Mean (SD)**	**Pre-testing Mean (SD)**	**Post-testing Mean (SD)**
Weight (kg)	73.26 (15.84)	71.84 (14.92)*	76.81 (14.07)	75.70 (14.28)§
BMI (kg.m^{-2})	25.81 (4.10)	25.33 (3.86)*	26.89 (3.79)	26.44 (3.64)§
Waist (cm)	85.46 (11.94)	83.54 (12.19)**	87.89 (11.13)	87.84 (12.23)
Hip (cm)	104.69 (7.94)	101.60 (8.11)***	104.23 (10.65)	103.55 (8.46)§
WHR	0.81 (0.09)	0.82 (0.09)	0.84 (0.10)	0.85 (0.10)§
SAD (cm)	20.93 (3.66)	21.33 (2.94)	21.83 (2.53)	22.62 (2.60)§
FFM (kg)	47.72 (11.33)	48.05 (11.86)	51.02 (12.18)	50.31 (12.74)
% Muscle mass	65.23 (6.53)	66.80 (7.23)*	66.09 (7.31)	66.03 (7.69)
Fat mass (kg)	25.55 (8.10)	23.74 (7.46)**	25.79 (6.78)	25.39 (6.75)
Body fat %	34.78 (6.53)	33.16 (7.26)*	33.91 (7.31)	33.97 (7.69)
REE (kcal)	1486.86 (258.64)	1496.32 (274.38)	1565.05 (279.81)	1549.68 (292.92)

*RESIS, experimental (resistance) group; CON, control group; kg.m^{-2}, kilogram per square metre; kcal, kilocalorie; * statistically significant change from pre- to post-testing in RESIS, $p < 0.05$; § statistically significant change from pre- to post-testing in CON, $p < 0.05$; ** statistically significant change from pre- to post-testing in RESIS, $p < 0.001$; *** statistically significant change from pre- to post-testing in RESIS, $p < 0.0001$.*

b. Between-group comparison

Table 4.3 compares the change (%) in anthropometric and metabolic variables from pre- to post-testing, as well as the effect size of the differences between the groups. With the exception of weight and BMI, the RESIS had statistically significantly greater improvements in body composition than the CON. Strong practically significant differences were detected between the two groups for waist (ES = 0.83; $p < 0.05$) and hip circumference (ES = 0.77; $p < 0.05$), percentage muscle mass (ES = 0.81; $p < 0.05$) and body fat percentage (ES = 0.78; $p < 0.05$) (Fig 4.1 – 4.3). Moderate practically significant differences were observed between the two groups for fat-free mass (ES = 0.62), total body fat mass (ES = 0.70; $p < 0.05$) and resting energy expenditure (ES = 0.64). A small effect size was evident for sagittal abdominal diameter.

Table 4.3. The comparison of percentage change between the RESIS and CON in body composition variables.

Variables	**RESIS** **% Δ pre-post** **Mean (SD)**	**CON** **% Δ pre-post** **Mean (SD)**	**P-value**	**Effect size**
Weight	-1.76 (2.35)	-1.49 (2.82)	0.64	0.01
BMI	-1.78 (2.35)	-1.60 (3.03)	0.89	0.07
Waist	-2.30 (2.29)	-0.17 (3.01)$^{\#}$	0.01	0.83^{L}
Hip	-2.96 (1.95)	-0.34 (5.29)$^{\#}$	0.03	0.77^{L}
Waist/hip ratio	0.53 (3.00)	0.91 (6.03)	0.11	0.48^{M}
SAD	2.64 (6.19)	3.82 (5.53)	0.31	0.20^{S}
FFM	0.55 (2.84)	-1.59 (4.17)	0.05	0.62^{M}
% Muscle mass	2.40 (3.52)	-0.11 (2.74)$^{\#}$	0.02	0.81^{L}
Fat mass	-6.64 (8.62)	-1.50 (5.93)$^{\#}$	0.03	0.70^{M}
Body fat %	-5.06 (7.38)	0.02 (5.72)$^{\#}$	0.01	0.78^{L}
REE	0.51 (2.02)	-1.09 (3.08)	0.06	0.64^{M}

% Δ pre-post, percentage change between pre- and post-testing; RESIS, experimental (resistance) group; CON, control group; $^{\#}$ statistically significant difference between RESIS and CON in the change from pre- to post-testing, $p < 0.05$; ^{S} small effect size; ^{M} medium effect size; ^{L} large effect size

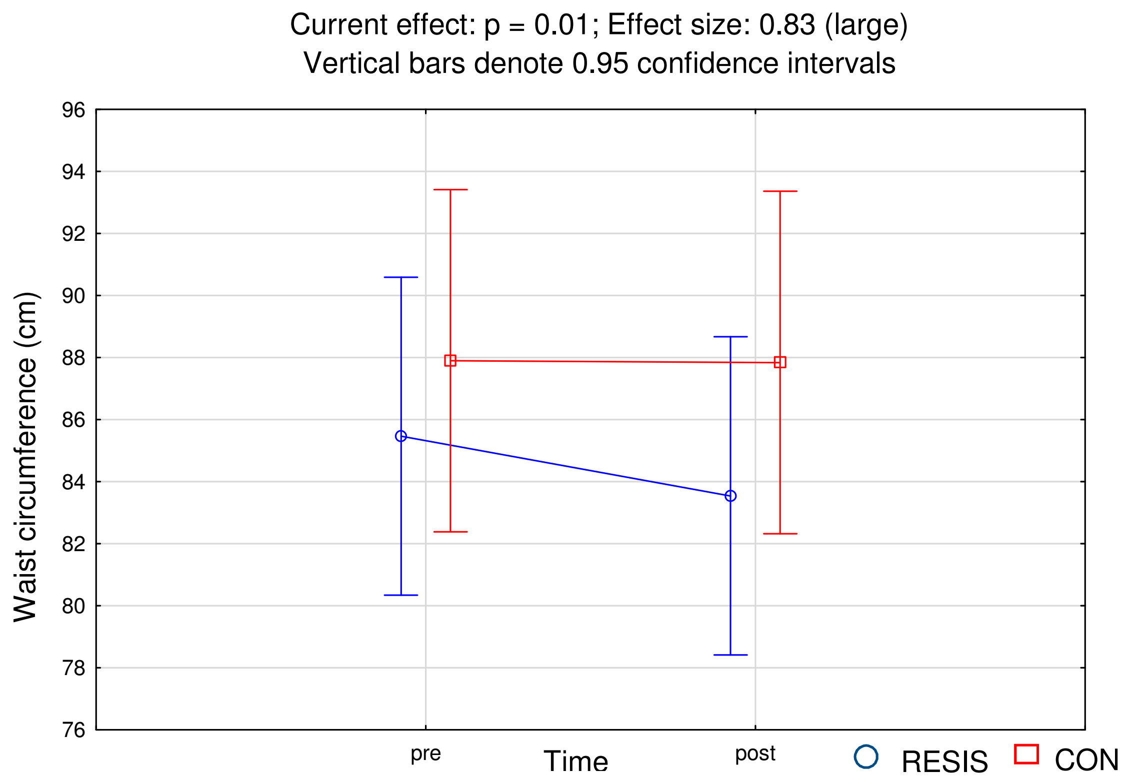

Figure 4.1: Absolute change in waist circumference between the RESIS and CON over the intervention period.

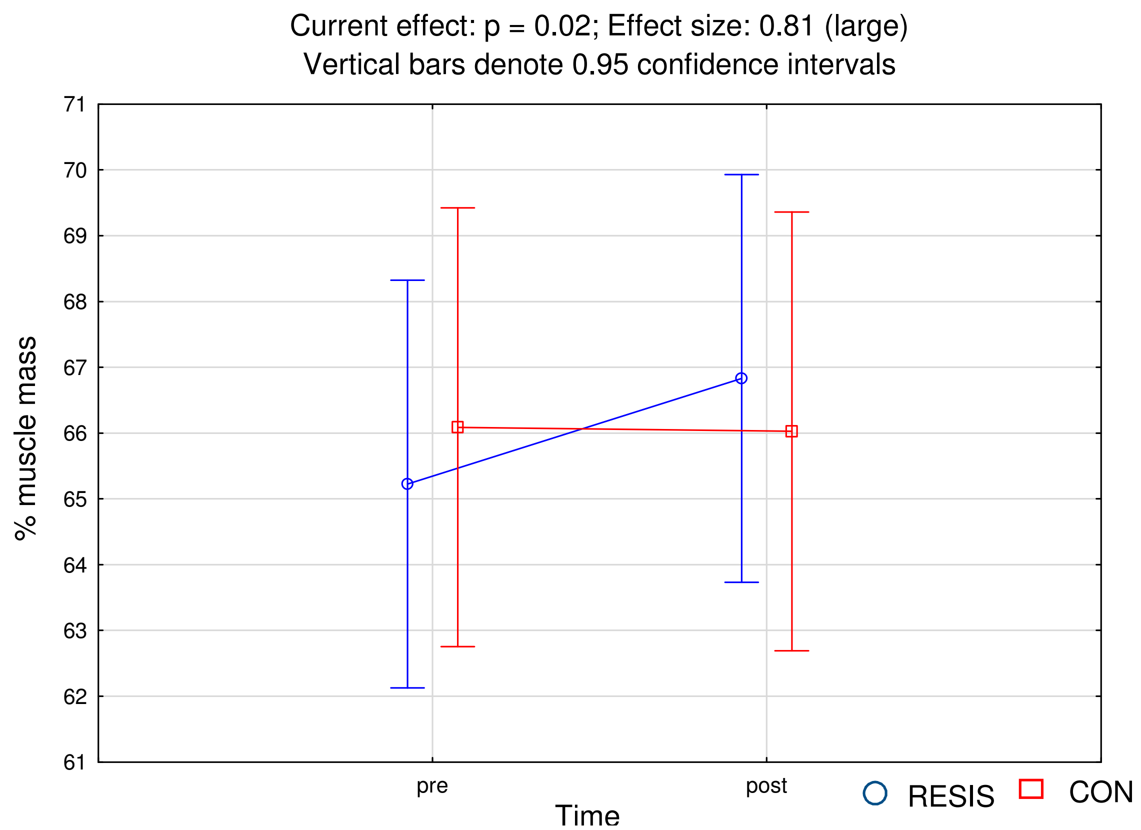

Figure 4.2: Absolute change in muscle mass percentage between the RESIS and CON over the intervention period.

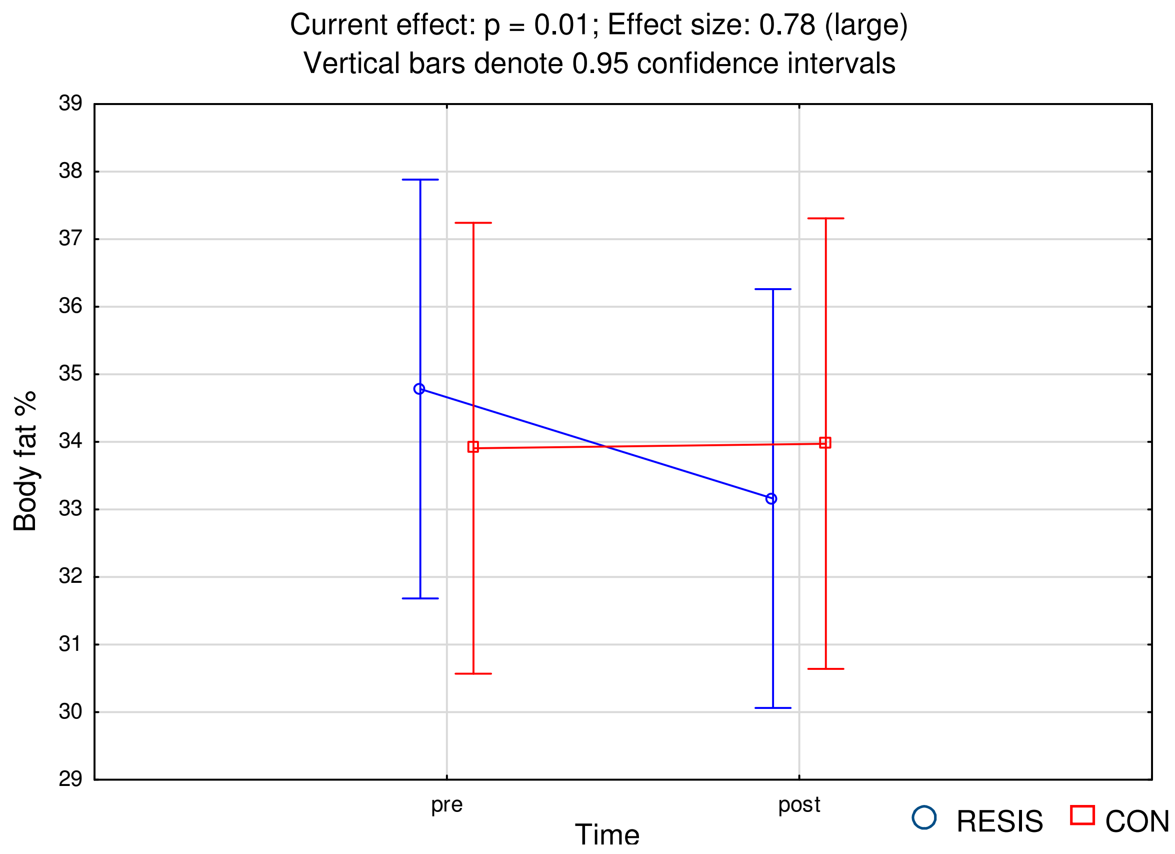

Figure 4.3: Absolute change in body fat percentage between the RESIS and CON over the intervention period.

4.2.2 Blood lipid profile

a. Within-group changes

Table 4.4 portrays the within-group changes in blood lipid profile of the RESIS and CON. One participant did not complete the pre-intervention blood lipid profile, leaving 21 participants for analysis. Nineteen participants in the CON completed pre-testing and only 16 participants completed the post- testing.

The RESIS and CON independently demonstrated significant decreases in total cholesterol ($p < 0.001$), LDL cholesterol ($p < 0.001$) and total cholesterol/HDL cholesterol ratio ($p < 0.05$) after the 16 weeks. Both groups showed a decline in HDL cholesterol, but only the results of the RESIS was statistically significant ($p < 0.05$). The CON showed a statistically significant decrease in fasting plasma glucose ($p < 0.001$) and increase in HOMA2 %B ($p < 0.05$) after the 16 weeks, while the results for the RESIS was not statistically significant. There were no significant changes in triglycerides, fasting plasma insulin, HOMA2-IR and HOMA2 %S after the intervention period in either groups.

Table 4.4. Pre- and post-differences in blood lipid profile for the RESIS and CON.

Variables	RESIS		CON	
	Pre-testing Mean (SD)	Post-testing Mean (SD)	Pre-testing Mean (SD)	Post-testing Mean (SD)
TC (mmol/L)	5.48 (1.00)	4.98 (0.81)**	5.94 (0.76)	5.19 (0.89)§§
Triglycerides (mmol/L)	1.10 (0.44)	1.10 (0.45)	1.17 (0.58)	1.18 (0.59)
LDL-C (mmol/L)	3.36 (0.95)	2.92 (0.78)**	4.00 (0.71)	3.27 (0.77)§§
HDL-C (mmol/L)	1.68 (0.40)	1.55 (0.33)*	1.41 (0.43)	1.38 (0.34)
TC/HDL-C ratio	3.48 (1.26)	3.34 (0.93)*	4.48 (1.15)	3.94 (1.02)§
Glucose (mmol/L)	5.19 (0.72)	5.10 (0.63)	5.11 (0.61)	4.64 (0.52)§§
Insulin (mIU/L)	5.93 (3.01)	6.10 (2.49)	6.61 (4.41)	6.16 (3.63)
HOMA2-IR	0.68 (0.35)	0.69 (0.28)	0.75 (0.52)	0.68 (0.42)
HOMA2 %B	66.13 (17.26)	70.38 (18.16)	70.35 (17.04)	85.18 (30.97)§
HOMA2 %S	180.87 (81.57)	174.23 (94.26)	179.54 (100.61)	177.81 (65.58)

*RESIS, experimental (resistance) group; CON, control group; TC, total cholesterol; LDL-C, low density lipoprotein cholesterol; HDL-C, high density lipoprotein cholesterol; TC/HDL-C, total serum cholesterol/high density lipoprotein cholesterol ratio; HOMA2-IR, homeostatic model assessment-estimated insulin resistance; HOMA2 %B, homeostatic model assessment-percentage β-cell function; HOMA2 %S, homeostatic model assessment-percentage insulin sensitivity; mIU/L, milli-international units per litre; mmol/L, millimol per litre; * statistically significant change from pre- to post-testing in RESIS, $p < 0.05$; § statistically significant change from pre- to post-testing in CON, $p < 0.05$; ** statistically significant change from pre- to post-testing in RESIS, $p < 0.001$; §§ statistically significant change from pre- to post-testing in CON, $p < 0.001$.*

b. Between-group comparison

Table 4.5 presents the percentage change in blood lipid profile between the groups, as well as the effect sizes of the differences. There was a significant difference in the change in fasting glucose levels ($p < 0.05$) between the RESIS and CON after the intervention period and this differences was of moderate practically significance (ES = 0.72). Although not statistically significant, the differences in changes in total cholesterol/HDL cholesterol ratio and HOMA2 %B was of moderate practically significance. Small practically significant differences were evident between the two groups for triglycerides, LDL cholesterol, HDL cholesterol, and HOMA2 %S.

Table 4.5. The comparison of percentage changes between the RESIS and CON in blood lipid profile variables.

Variables	RESIS % Δ pre-post Mean (SD)	CON % Δ pre-post Mean (SD)	P-value	Effect size
TC	-9.62 (10.89)	-10.87 (12.25)	0.59	0.11
Triglycerides	6.41 (40.25)	19.36 (49.40)	0.66	0.3^{S}
LDL-C	-11.93 (12.27)	-16.16 (12.77)	0.20	0.35^{S}
HDL-C	-5.65 (12.76)	-2.75 (15.50)	0.47	0.21^{S}
TC/HDL-C ratio	-3.40 (11.24)	-7.68 (8.59)	0.26	0.43^{M}
Glucose	-1.50 (8.91)	-7.67 $(8.63)^{\#}$	0.04	0.72^{M}
Insulin	8.49 30.58)	-11.65 (58.91)	0.67	0.07
HOMA2-IR	7.87 (30.95)	9.67 (59.45)	0.41	0.04
HOMA2 %B	9.59 (24.13)	23.37 (36.64)	0.12	0.47^{M}
HOMA2 %S	-0.41 (27.34)	9.08 (39.11)	0.97	0.3^{S}

% Δ pre-post, percentage change between pre- and post-testing; RESIS, experimental (resistance) group; CON, control group; TC, total cholesterol; LDL-C, low density lipoprotein cholesterol; HDL-C, high density lipoprotein cholesterol; TC/HDL, total serum cholesterol/high density lipoprotein cholesterol ratio; HOMA2-IR, homeostatic model assessment-estimated insulin resistance; HOMA2 %B, homeostatic model assessment-percentage β-cell function; HOMA2 %S, homeostatic model assessment-percentage insulin sensitivity; $^{\#}$ statistically significant difference between EXP and CON in the change from pre- to post-testing, $p < 0.05$; ^{S} small effect size; ^{M} medium effect size; ^{L} large effect size.

4.2.3 Strength and functional capacity

a. Within-group changes

The within-group changes in strength and functional capacity of the two groups are presented in *Table 4.6*. Upper- and lower-body strength significantly increased ($p < 0.0001$) in the RESIS after the resistance training intervention compared to baseline data. There were no statistically significant changes in Timed-Up-and-Go test time in the two groups after the 16 weeks.

Table 4.6. Pre- and post-differences in strength and functional capacity for the RESIS and CON.

Variables	RESIS		CON	
	Pre-testing Mean (SD)	**Post-testing Mean (SD)**	**Pre-testing Mean (SD)**	**Post-testing Mean (SD)**
Bench press (kg)	22.68 (14.69)	29.64 (16.75)***	22.53 (11.38)	20.21 (8.82)
Leg press (kg)	70.45 (40.29)	157.05 (70.70)***	81.32 (42.97)	71.58 (37.16)
TUG test (sec)	5.36 (0.94)	5.15 (0.78)	5.53 (1.15)	5.67 (0.83)

*RESIS, experimental (resistance) group; CON, control group; TUG, Timed-Up-and-GO; *** statistically significant change from pre- to post-testing in RESIS, p < 0.0001.*

b. Between-group comparison

Table 4.7 compares the percentage change in strength and functional capacity between the groups, as well as effect sizes. The changes in upper-body and lower-body strength were statistically significantly different between the groups ($p < 0.0001$) and the differences were also of huge practical significance (Fig 4.4 and 4.5). The RESIS performed statistically significant better than the CON in the TUG test ($p < 0.05$) and this difference was of large practical significance (Fig 4.6).

Table 4.7. The comparison of percentage changes between the RESIS and CON in strength and functional capacity.

Variables	RESIS	CON	P-value	Effect size
	% Δ pre-post Mean (SD)	**% Δ pre-post Mean (SD)**		
Bench press	37.48 (29.20)	-6.30 (17.45)$^{\#\#\#}$	< 0.0001	1.83^{H}
Leg press	166.72 (127.81)	-9.31 (21.67)$^{\#\#\#}$	< 0.0001	1.90^{H}
TUG test	-2.90 (10.95)	5.84 (10.84)$^{\#}$	0.02	0.82^{L}

% Δ pre-post, percentage change between pre- and post-testing; RESIS, experimental (resistance) group; CON, control group; TUG, Timed-Up-and-Go; $^{\#}$ *statistically significant difference between RESIS and CON in the change from pre- to post-testing, p < 0.05;* $^{\#\#\#}$ *Statistically significant difference between RESIS and CON in the change from pre- to post-testing, p < 0.0001;* ^{H} *Huge effect size;* ^{L} *Large effect size.*

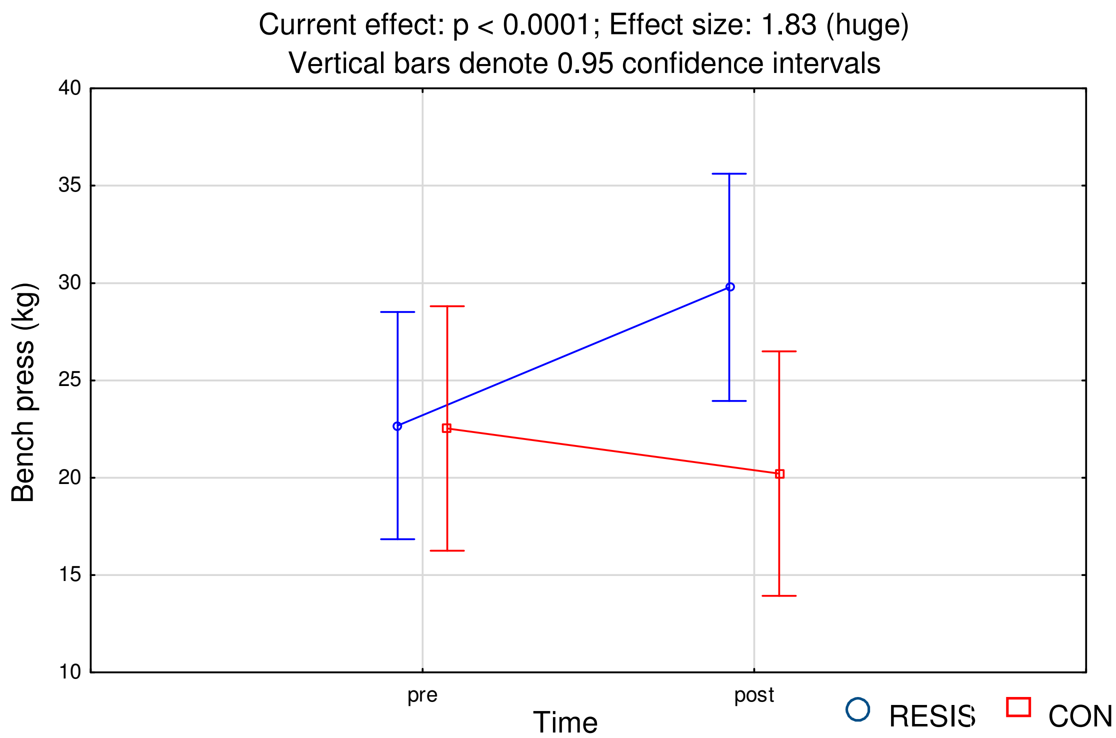

Figure 4.4: Absolute change in upper-body strength between the RESIS and CON over the intervention period.

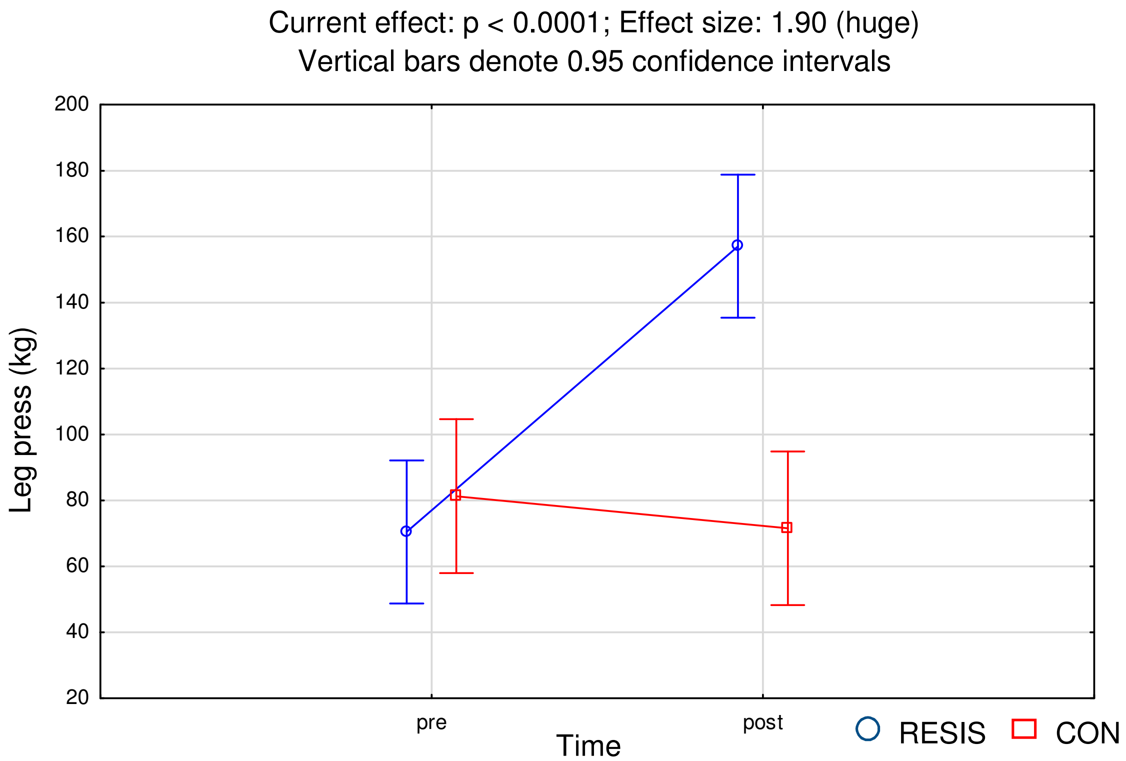

Figure 4.5: Absolute change in lower-body strength between the RESIS and CON over the intervention period.

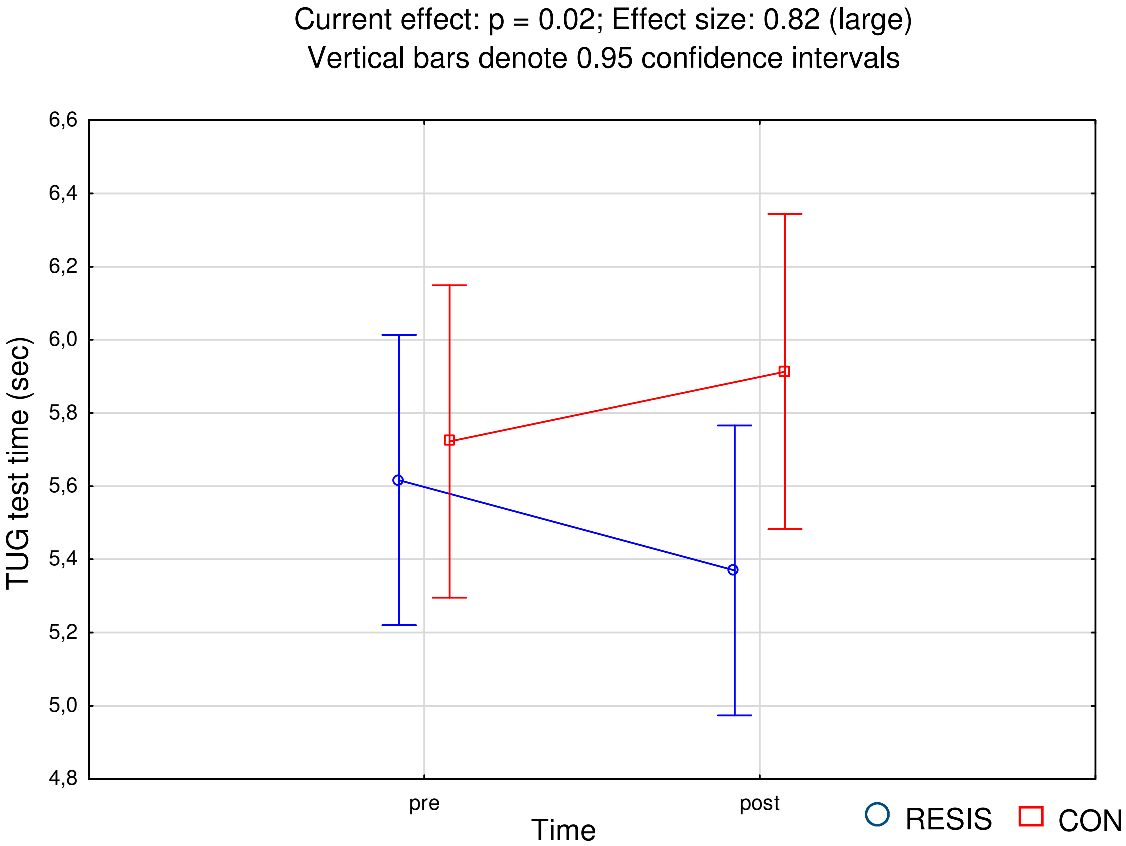

Figure 4.6: Absolute change in functional capacity between the RESIS and CON over the intervention period.

4.2.4 Perceived health status

a. Within-group changes

The within-group changes for perceived health status from baseline are demonstrated in *Table 4.8.* The RESIS mean score was significantly increased for the physical functioning domain ($p < 0.001$), role-emotional domain ($p < 0.001$) and mental health domain ($p < 0.05$), indicating a significant improvement in these domains. A statistical significant increase in the bodily pain domain ($p < 0.05$) was also evident in the RESIS. The CON only scores for the general health domain ($p < 0.05$) and role-emotional ($p < 0.05$) were significantly improved after the 16 weeks.

Table 4.8. Pre- and post-differences in the perceived health status for the RESIS and CON.

Variables	RESIS		CON	
	Pre-testing Mean (SD)	Post-testing Mean (SD)	Pre-testing Mean (SD)	Post-testing Mean (SD)
Physical health status				
Physical functioning	82.73 (12.51)	90.45 (10.79)**	79.21 (14.17)	78.16 (17.34)
Role-physical	88.92 (12.19)	80.26 (18.07)	90.63 (12.16)	83.55 (14.76)
Bodily pain	73.73 (18.05)	80.45 (13.21)*	70.00 (12.88)	72.68 (14.55)
General health	78.68 (12.25)	84.18 (12.01)	67.58 (16.01)	74.84 (18.63)§
Mental health status				
Vitality	74.15 (13.40)	73.01 (10.81)	66.12 (15.91)	66.12 (12.90)
Social functioning	81.82 (23.06)	87.50 (17.68)	85.53 (15.74)	84.50 (13.82)
Role-emotional	81.82 (17.37)	92.80 (10.06)**	80.26 (16.72)	88.60 (16.72)§
Mental health	75.00 (16.62)	80.00 (14.06)*	76.32 (13.52)	78.42 (16.75)

*RESIS, experimental (resistance) group; CON, control group; * statistically significant change from pre- to post-testing in RESIS, p < 0.05; § statistically significant change from pre- to post-testing in CON, p < 0.05; ** statistically significant change from pre- to post-testing in RESIS, p < 0.001.*

b. Between-group comparison

Between-group comparison for perceived health status, expressed as the percentage change between pre- and post-testing, as well as the effect sizes indicating the practical significance of the differences between groups are presented in *Table 4.9.* The change in physical functioning in the RESIS was statistically significantly better than the CON (ES = 0.85; $p < 0.05$) and this difference was of large practical significance (Fig 4.7). Although the RESIS experienced greater changes in three of the four mental health scores, these improved scores were not statistically significantly better than those of the CON. Medium practical significance were evident between the two groups for the mental health domain (ES = 0.43). Small practical significance were evident between the two groups for the role-physical domain, bodily pain domain, role-emotional domain, vitality domain, social functioning domain and role-emotional domain.

Table 4.9. The comparison of percentage changes between the RESIS and CON in perceived health status.

Variables	RESIS % Δ pre-post Mean (SD)	CON % Δ pre-post Mean (SD)	P-value	Effect size
<u>Physical health status</u>				
Physical functioning	10.41 (11.58)	-0.98 (15.90)[#]	0.01	0.85[L]
Role-physical	3.90 (21.97)	7.84 (25.33)	0.74	0.17[S]
Bodily pain	14.43 (31.52)	5.91 (23.87)	0.40	0.31[S]
General health	8.13 (13.73)	15.21 (38.63)	0.68	0.26[S]
<u>Mental health status</u>				
Vitality	-0.26 (13.78)	4.46 (30.69)	0.74	0.21[S]
Social functioning	18.27 (49.29)	4.39 (20.81)	0.55	0.37[S]
Role-emotional	16.87 (19.71)	12.48 (20.54)	0.53	0.22[S]
Mental health	9.29 (17.67)	2.53 (14.36)	0.35	0.43[M]

% Δ pre-post, percentage change between pre- and post-testing; RESIS, experimental (resistance) group; CON, control group; [#] statistically significant difference between RESIS and CON in the change from pre- to post-testing, $p < 0.05$; [S] small effect size; [M] medium effect size; [L] large effect size

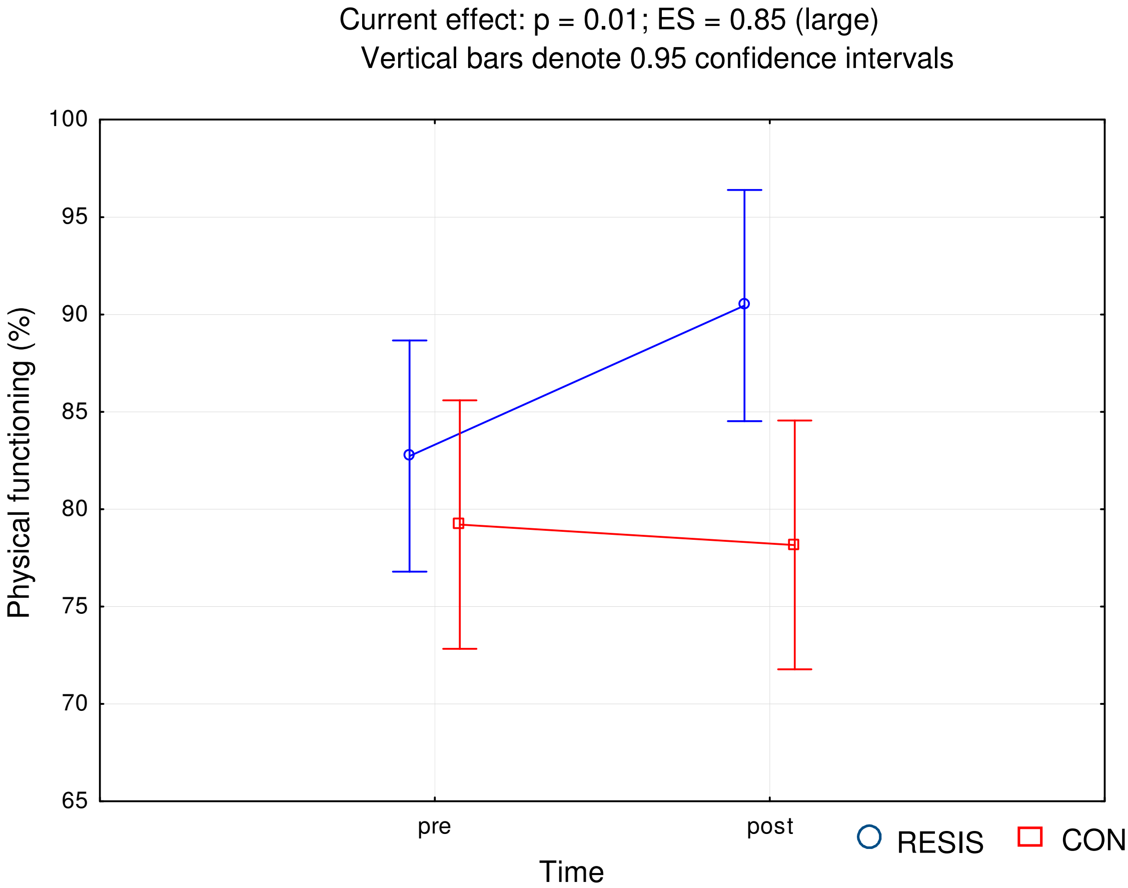

Figure 4.7: Absolute change in the mean scores of physical functioning between the RESIS and CON over the intervention period.

CHAPTER FIVE

DISCUSSION

5.1 INTRODUCTION

Resistance training is recommended for older adults by three major associations, the American Heart Association, the American College of Sport Medicine, and the American Diabetes Association, to prevent and treat the onset of obesity, type two diabetes, dyslipidaemia, physical disability and functional limitations (Braith & Stewart, 2006). However, relevant research is limited in healthy sedentary older adults. The literature also reports contradicting evidence regarding the effect of resistance training on the health and functional status of older adults. Therefore, the purpose of the current study was to investigate the effect of moderate-intensity resistance training on health-related outcomes in healthy sedentary older adults.

The main findings of this study was that moderate-intensity resistance training was effective in improving body composition, as well as functional capacity in older adults, but the 16 week programme did not improve blood lipid profile in healthy sedentary older adults.

5.2 OUTCOME VERIABLES

5.2.1 The effect of moderate-intensity resistance training on body composition in older adults.

Both the experimental (RESIS) and control group (CON) experienced a significant reduction in weight and BMI from pre- to post-testing, and these changes were not statistically significant between the groups. This is in agreement with Poehlman *et al*. (2002), but not with Donnelly *et al*. (1991) and Hunter *et al.* (2008). However, the main difference between these studies is that Donnelly *et al*. (1991) and Hunter *et al.* (2008) combined a moderate-intensity resistance training programme with a calorie restricted diet. Calorie restricted diets have been shown efficacious for rapid weight loss (Stiegler & Cunliffe, 2006), but it is also associated with a decrease in fat-free mass. During calorie restricted dieting, resistance training might help to maintain the loss of fat-free mass, however, in the study of Donnelly *et al*. (1991) reductions in fat-free mass were still evident, which explain the reduction in BMI.

Whether the decrease in weight in the participants in this study was due to changes in their diets is unclear. Both groups completed a non-scientific questionnaire (Appendix J) related to their diet and physical active status after the intervention period. This questionnaire was completed only after the intervention and not before the intervention. Thirty seven percent of the CON reported after the intervention that they followed a healthier diet (reducing calorie intake) and 32% reported that they increased their amount of physical activity during the intervention period even though they were strictly informed not to alter their activities of daily living or diet. However, 27% of the participants in the RESIS reported an increase in their calorie intake due to an elevated appetite during participation in the intervention. Whereas the rest of the RESIS reported no change in their diet during the intervention period. This may suggest that the RESIS, partly lost weight due to the exercise intervention, but possibly also because of calorie restriction.

The significant reduction in weight from pre- to post-testing in the RESIS as a result of the resistance training intervention is not common. However, this study also revealed a significant increase in percentage muscle mass (RESIS, 2.40%; CON, -0.11%) and a significant decrease in body fat percentage (RESIS, -5.06%; CON, 0.02%) and total body fat mass (RESIS, -6.64%; CON, -1.50%). In addition, the magnitude of increase in fat-free mass (RESIS, 0.55%; CON, -1.59%) after the resistance training intervention was practically significant. These findings are consistent with those of Campbell *et al.* (1994) and Hunter *et al.* (2000). However, they did not find a significant reduction in weight. The main differences are that this study found that the percentage decrease in total body fat mass (6.64%) exceeded the percentage increase in fat-free mass (0.55%), thus explaining the weight reduction.

The sample of this study consisted of more women than men (RESIS; women = 15, men = 7) and could be a potential reason why this study did not find a greater increase in fat-free mass. Research has shown that the effect of resistance training on body composition variables differ between men and women (Lemmer *et al.,* 2001). It has been demonstrated that moderate-intensity resistance training significantly increase fat-free mass in both older men and women, however, a greater increase in fat-free mass were evident in the men compared to the women (2.8 kg vs 1.0 kg, respectively) (Hunter *et al*., 2002). Men have a greater potential for increasing fat-free mass compared to women (Hunter *et al.,* 2002), because with aging, blood concentrations of circulating anabolic hormones and growth factors, e.g., testosterone, growth factors and insulin-like growth factor I, are diminished, and more so in women (Hakkinen *et al.,* 2001). This suggests that the decreasing basal level blood testosterone in ageing women over the years may lead to a diminished anabolic effect on muscle mass and an even greater reduction in muscle mass compared to men (Marx *et al.,* 2000). It has been shown that the mean level of individual serum testosterone correlates significantly with the gains in muscle mass (Hakkinen *et al.,* 2001), therefore, it would be expected for men to show a greater increase in muscle mass compared to women. If the RESIS of this study consisted of equal amount of men and women, it is possible that the results in fat-free mass might have been different.

Although the ACSM includes a high BMI as one of the risk factors for cardiovascular disease, the use of BMI during a resistance training intervention without any dietary involvement should be used with caution (Shaw & Shaw, 2006). Most research has shown that moderate-intensity resistance training increases fat-free mass and decreases total body fat mass, which result in an unchanged BMI (Shaw *et al.* 2009; Cauza *et al*., 2005; Hunter *et al.,* 2000; Broeder *et al*., 1992). Therefore, by only using BMI to identify risk status, would be incorrect. Although BMI were not statistically significant different between the two groups in this study, a significant decrease in total body fat mass and abdominal fat mass were still evident, which resulted in a decrease risk for cardiovascular disease as a result of the exercise intervention.

This study found a significant reduction in abdominal fat as measured by waist circumference (RESIS, -2.30%; CON, -0.17%) and is in agreement with Westcott (2012), but not with Shaw *et al*. (2009) and Schmitz *et al*. (2003). The main difference between the studies is that the participants in this study were older than 55 years. Whereas the participants in the study of Shaw *et al*. (2009) and Schmitz *et al*. (2003) were younger than 55 years. Therefore moderate-intensity resistance training is beneficial to reduce abdominal fat as measured by waist circumference in healthy sedentary adults older than 55 years.

This study was one of the few studies that also measured sagittal abdominal diameter. The findings of this study indicated no significant decrease in sagittal abdominal diameter and is in agreement with Fenicchia *et al.* (2004), although they studied a younger group (< 55 years) and over a shorter period of time (six weeks). Therefore, the two studies are not completely comparable. Although sagittal diameter is considered a reliable method for the measurement of abdominal fat (Elrlich & Smith, 2011), it is unusual that this study found a significant reduction in waist circumference of 2.30%, but a non-significant increase in sagittal abdominal diameter of 2.46%. The increase in sagittal abdominal diameter could have been a measurement error, however, there are not enough evidence to explain this result.

Despite the significant reduction in waist circumference in this study, a significant reduction in waist-to-hip ratio was not evident (although the decrease was moderately practically significant). The practical significance is most likely related to a significant reduction in hip circumference of 2.96%, which is considered an unusual finding, considering that only one other study reviewed also found similar significant reductions in both waist and hip circumferences (Misra *et al*., 2008). There is limited evidence to support and explain these results, but the significant reduction in hip circumference in this study is partly as a result of the exercise intervention.

Lastly, the results show that the magnitude of increase in resting energy expenditure had moderate practical significance (RESIS, 0.51%; CON, -1.09%). This is in contrast with Campbell *et al.* (1994) and Hunter *et al.* (2000) who found strong practically significant increases in resting energy expenditure. The main difference is that these studies made use of indirect calorimetry to measure resting energy expenditure. This method for the measurement of resting energy expenditure is considered to be the gold standard with an error lower than 1% (Pinheiro *et al*., 2011). This study made use of BIA to estimate REE, which is considered less accurate as several factors may influence its results such as, hydration state of the participant, fasting state, prior exercise, diuretics, menstrual period, age and nutritional status (Pinheiro *et al.,* 2011).

5.2.2 The effect of moderate-intensity resistance training on blood lipid profile in older adults.

The results indicated that the resistance training had no significant effect on insulin resistance, β-cell function or insulin sensitivity, despite the practically significant increase in fat-free mass (ES = 0.62) and decrease in total body (ES = 0.70) and abdominal fat mass (ES = 0.83). These results are consistent with the findings of Ryan *et al*. (2001), but in contrast with Brooks *et al.* (2007) and Ahmadizad *et al.* (2007). The main differences however, is that type two diabetic older adults and obese men were investigated in the latter studies, in contrast to healthy older adults in this study. Moderate-intensity resistance training does not alter glucose tolerance or glycaemic control regardless of age, unless baseline glucose tolerance is abnormal (Williams *et al*., 2007; Braith & Stewart, 2006; Kitamura *et al.,* 2003). Therefore, it can be concluded that moderate-intensity resistance training can improve insulin resistance in type two diabetic older adults and obese men, but not in healthy sedentary older adults. To improve insulin resistance and glycaemic control in healthy sedentary older adults, resistance training performed at higher intensities might be needed (Thompson *et al.,* 2010)

In addition, the CON showed a significant decrease in fasting glucose levels and significant increase in HOMA2 %B. However, as previously mentioned, 37% of the CON reported after the intervention that they followed a healthier diet (reducing calorie intake) and 32% increased their amount of physical activity during the intervention period. Therefore, these changes could possibly explain the significant improvements seen in the CON. This is supported by Larson-Meyer *et al*. (2006) who found that a calorie-restricted diet alone, or in conjunction with aerobic exercise (e.g. running, walking, cycling) significantly decrease fasting glucose levels and insulin resistance, as well as increase β-cell function.

The results of this study demonstrated no significant improvements in any of the lipoproteins tested. This is in contrast with the results of Cauza *et al.* (2005) and Boardley *et al.* (2007). Moderate-intensity resistance might be a sufficient stimulus to significantly increase HDL cholesterol, and decrease total cholesterol, triglycerides and LDL cholesterol in type two diabetic older adults after 16 weeks, but not in healthy sedentary older adults. Therefore there are three possible reasons for the lack of significant improvements in lipoproteins in this study. Firstly, moderate-intensity resistance training is not a sufficient training stimulus to improve lipoproteins in healthy sedentary older adults and a higher intensity might be needed to achieve these changes (Castaneda *et al.*, 2002; Prabhakaran *et al.,* 1999). Secondly, 16 weeks might be too short to improve blood lipid profile and a longer training regimen might be needed (Smutok *et al.,* 1993). Lastly, this study lacked proper dietary control, which resulted in an increased calorie intake in the RESIS and a decreased in calorie intake in the CON. Evidence exists that moderate-intensity resistance training with proper dietary control improve lipoproteins in healthy sedentary older adults (Hurley *et al.,* 2011).

This study found a significant reduction in total cholesterol, LDL cholesterol and total cholesterol/HDL cholesterol ratio in both groups. The improvements evident in the CON might be as a result of a healthier diet during the intervention period. Additionally, the RESIS also showed a significant increase in HDL cholesterol, which is an unusual finding. It is possible that the reported increase in calorie intake in the RESIS, might have contributed to the increase in HDL cholesterol. If the current study monitored the diet in both the RESIS and CON throughout the intervention, the outcomes of the lipoprotein profiles of the participants might have been slightly different.

5.2.3 The effect of moderate-intensity resistance training on functional outcomes in older adults.

a. Strength

The results revealed a significant increase of 37% in upper-body strength (via 10-RM bench press), and 167% in lower-body strength (via 10-RM leg press), which resulted in a large practically significant improvements (1.83; 1.90, respectively). This is in agreement with the literature that indicated significant strength increases as a result of 6 to 26 weeks of low-, moderate- and high-intensity resistance training in healthy and diseased adults and older adults between the ages of 18 and 96 years (Appendix B). The high percentage increase in upper- and lower-body strength is an unusual finding for moderate-intensity resistance training, and has not been demonstrated in other research in a similar population. There is only one study that found similar increases in strength of 32% for upper-by strength and 126% for lower-body strength, however the main difference is that the participants were healthy sedentary young women between the ages of 30 and 50 years (Schmitz *et al*., 2003).

There may be two possible reasons for the large increase in both upper- and lower-body strength. Firstly, greater strength increases is evident in adults younger than 70 years compared to adults older than 70 years (Murlasits *et al*., 2012; Strasser *et al.,* 2009). The RESIS of this study consisted of only four individuals who were 70 years and older, with the rest younger than 70 years. Secondly, the RESIS consisted of more women compared to men (women = 15; men = 7) and it is possible that greater strength increases in the women might have contributed to the large magnitude of change in strength. Research has shown greater strength improvements in women compared to men (Ivey *et al*., 2000) and therefore the composition of the group in this study may explain the large increases in strength.

Even though this study found moderate practically significant increases in fat-free mass, an even greater increase in fat-free mass would be expected with the large increases in upper- and lower-body strength. It has been demonstrated that hypertrophy contributes significantly to strength improvements in young and older adults (Macaluso & De Vito, 2004). This study found greater increases in strength compared to Murlasits *et al.* (2012) who found a small increase of 25% in lower-body strength and 21% in upper-body strength. However, this study demonstrated smaller increases in fat-free mass (0.55%) compared to the increase of 1.9% of Murlasits *et al.* (2012). The main difference in the studies is the method used to measure fat-free mass. Murlasits *et al.* (2012) used dual energy x-ray absorptiometry (DEXA) for the measurement of body composition, whereas this study used BIA. It has been reported that relative to DEXA, BIA underestimates fat-free mass (Steiner *et al*., 2002), which could potentially explain the small increase in fat-free mass in this study despite the large increases in strength.

b. Functional capacity

The results demonstrated a significant decrease in Timed-Up-and-Go (TUG) test time, meaning a significant improvement ($p = 0.02$) in functional capacity (EXP, -2.90%; CON, 5.84%). The results also indicated that the increases in functional capacity for between group differences had a large practical significance. Levinger *et al.* (2007) support these findings, however their population consisted of individuals between the ages of 40 and 70 years with a low number of metabolic risk factors. Research has shown that two to 26 weeks of low-, moderate- and high-intensity resistance training had either no effect, or small, non-significant effects on TUG test performance in healthy sedentary adults younger than 83 years. It has been suggested that strength improvements in well-functioning older adults with normal functioning baseline levels, does not directly translate to improvements in functional capacity (Murlasits *et al.*, 2012). To achieve higher levels of functioning in healthy sedentary older adults, it has been suggested that functional training, such as balance training, should be combined with the resistance training (Latham *et al.,* 2004). However, this statement is not supported by the current study as no functional training were included in the intervention, yet the participants showed a significant increase in functional capacity.

The large increase in lower body strength of 167% found in the current study could have been a big contributing factor to the significant improvement in TUG test performance, as the TUG test is based on lower body strength and functionality. This is in contrast with Carmeli *et al.* (2000), however, who used a lower intensity resistance training programme in an older group (78 to 87 years) compared with this study. Therefore, their strength increases were small, albeit significant, and did not correlate with improvements in functional capacity. There are limited research that show significant improvements in functional capacity in healthy sedentary older adults (Marlusits *et al.,* 2012; Latham *et al.*, 2004; Carmeli *et al.,* 2000), and therefore the results of the current study is unique.

c. Perceived health status

The results indicated a significant increase in physical functioning of 10.41% as a result of the resistance training intervention, which is in contrast with Levinger *et al*. (2007). The main difference is that this study used a longer resistance training intervention and found greater increases in strength and functional capacity. It can thus be suggested that the improvements in physical functioning in this study might have been as a result of the large improvements in strength and functional capacity.

The results also demonstrated significant increases in bodily pain ($p < 0.05$), role-emotional (limitations in social activities because of emotional problems) ($p < 0.001$) and mental health

($p < 0.05$) from pre- to post-testing in the RESIS. Moderate-intensity resistance training has been shown to have little or no effect on perceived health status in healthy sedentary older adults, but it has been shown to improve health status in adults at risk for metabolic syndrome (Latham *et al.,* 2004). The lack of significant improvements in perceived health status in this study may be explained by the high initial scores of these domains. The initial scores of older adults at high risk or diagnosed with cardiovascular disease are low, therefore creating a bigger opportunity for improvement. All participants in the RESIS in this study had high pre-testing scores ranging from 73.73% to 88.92% across the eight domains, whereas the CON scores ranged from 66.12% to 90.63% across the eight domains. This might be why the other domains (role-physical, general health, vitality and social functioning) of the SF-36 did not demonstrate significant improvements in this study and this is in agreement with Benjamini *et al.* (1997) and Ng *et al.* (2011). It was suggested previously that in order to achieve further improvements in perceived health status in healthy sedentary older adults, a greater intensity or a longer resistance training intervention (> 16 weeks) might be needed (Levinger *et al.,* 2007).

5.3 CONCLUSION

To my knowledge this is the first study to investigate 16 weeks of moderate-intensity resistance training on all health-related outcomes in healthy sedentary older adults. Most of the studies focussed on specific health or functional outcomes.

The main findings of this study were that moderate-intensity resistance training is beneficial to significantly improve health and functional status in healthy sedentary older adults. Sixteen weeks of moderate-intensity resistance training caused practically significant increases in percentage muscle mass, fat-free mass and resting energy expenditure. Practically significant decreases in body fat percentage, total body and abdominal fat mass were also evident. It can be concluded that moderate-intensity resistance training is effective in improving body composition in healthy sedentary older adults and is therefore beneficial for the prevention of obesity and central obesity.

Moderate-intensity resistance training had no significant effect on blood lipid profile. Not one of the lipoproteins or insulin resistance showed a significant effect as a result of the resistance training intervention. Research has indicated that resistance training may assist in the prevention of type two diabetes and dyslipidaemia, by decreasing insulin resistance and improving blood lipids (Westcott, 2012). However, the results of this study indicate that moderate-intensity resistance training is not a sufficient stimulus to improve blood lipid profile and is not beneficial for the prevention of type two diabetes and dyslipidaemia.

This study also found strong practically significant increases in upper- and lower-body strength, as well as functional capacity. Huge increases in strength of 37% for upper-body and 167% for lower-body were observed. There is not one other study that found similar strength increases as a result of moderate-intensity resistance training in healthy sedentary older adults and therefore the results of this study are novel. The study also found strong practically significant increases in functional capacity. This finding is also considered to be unique and can possibly be attributed to the 167% increase in lower-body strength.

This study found a significant improvement in only one domain of the SF-36, namely the physical functioning domain. This may possibly also be related to the significant increases in strength and functional capacity of the RESIS. For further improvements in perceived health status in healthy sedentary older adults, longer resistance training interventions performed at higher intensities might be needed. However, it can be concluded that moderate-intensity resistance training is beneficial to improve functional status in healthy sedentary older adults.

5.4 SUMMARY

Based on the results of this study, the following conclusions can be made in response to the stated hypotheses in chapter one:

Hypotheses 1: Moderate-intensity resistance training will significantly improve body composition by decreasing weight, BMI, body fat percentage, total body and abdominal fat mass, and by increasing percentage muscle mass, fat-free mass and resting energy expenditure.

Moderate-intensity resistance training resulted in practically significant reductions in body fat percentage (ES = 0.78), total body fat mass (ES = 0.70), and waist and hip circumference (ES = 0.83; ES = 0.77, respectively), as well as practically significant increases in percentage muscle mass (ES = 0.81), fat-free mass (ES = 0.62), and resting energy expenditure (ES = 0.64). Therefore, moderate-intensity resistance training can be used to improve body composition and resting energy expenditure in healthy sedentary older adults. Based on these findings, the hypotheses is accepted.

Hypotheses 2: Moderate-intensity resistance training will significantly improve blood lipid profile by reducing insulin resistance, total cholesterol, triglycerides, LDL cholesterol and total cholesterol/HDL cholesterol ratio, and increasing β-cells function, insulin sensitivity and HDL cholesterol.

Moderate-intensity resistance training had no significant effect on blood lipid profile. Based on these results, the hypotheses is rejected.

Hypotheses 3: Moderate-intensity resistance training will significantly improve functional outcomes by increasing upper- and lower-body strength and perceived health status, and decrease Timed-Up-and-Go test time.

Moderate-intensity resistance training resulted in practically significant increases in upper- and lower-body strength (ES = 1.83; ES = 1.90, respectively), as well as functional capacity (ES = 0.82). Moderate-intensity resistance training also resulted in a significant improvement in perceived physical health status ($p < 0.05$). Therefore, the hypothesis is accepted.

5.5 STUDY LIMITATIONS AND FUTURE RECCOMENDATIONS

The following limitations should be considered when interpreting the results of this study:

- diet and physical active status was not monitored throughout the intervention period. This resulted in an increase in calorie intake by the RESIS, and a reduced calorie intake and an increased amount of physical activity in the CON. This might have affected the outcomes of body composition and blood lipid profile.
- the use of BIA and not DEXA for the measurement of fat-free mass. This might have affected the outcomes of fat-free mass.
- the use of BIA for the measurement of REE which is less accurate compared to indirect calorimetry, the gold standard. This might have affected the outcomes of REE.

The following recommendations can be considered for future studies:

- To investigate the effect of moderate- and high-intensity resistance training on body composition in older men and women, individually. Research has shown that the effect of moderate-intensity resistance training on body composition differ between men and women, due to hormonal factors (Hunter *et al.,* 2002; Lemmer *et al*., 2001).
- to identify what effect resistance training has on sagittal abdominal diameter in healthy sedentary older adults and if it differs from the measurement of waist circumference. There are limited research on the effect of resistance training on sagittal abdominal diameter and it is still unclear if resistance training has a beneficial effect on this measurement. Although sagittal abdominal diameter is considered a reliable method for the measurement of abdominal fat and that it is also strongly correlated to cardiovascular disease risk factors (Elrlich & Smith, 2011; Gustat *et al*., 2000), this study found a significant decrease in waist circumference, not in sagittal abdominal diameter.
- to investigate the effect of high-intensity resistance training performed for longer than 16 weeks on insulin resistance and lipoproteins. It is also important that future studies in this field ensure proper dietary control throughout the intervention period. Most of the research done on the preventative role of resistance training for type two diabetes and dyslipidaemia involve low- and moderate-intensity resistance training. However, the ACSM and AHA recommend moderate- to high-intensity resistance training for individuals with type two diabetes (Thompson *et al.,* 2010).

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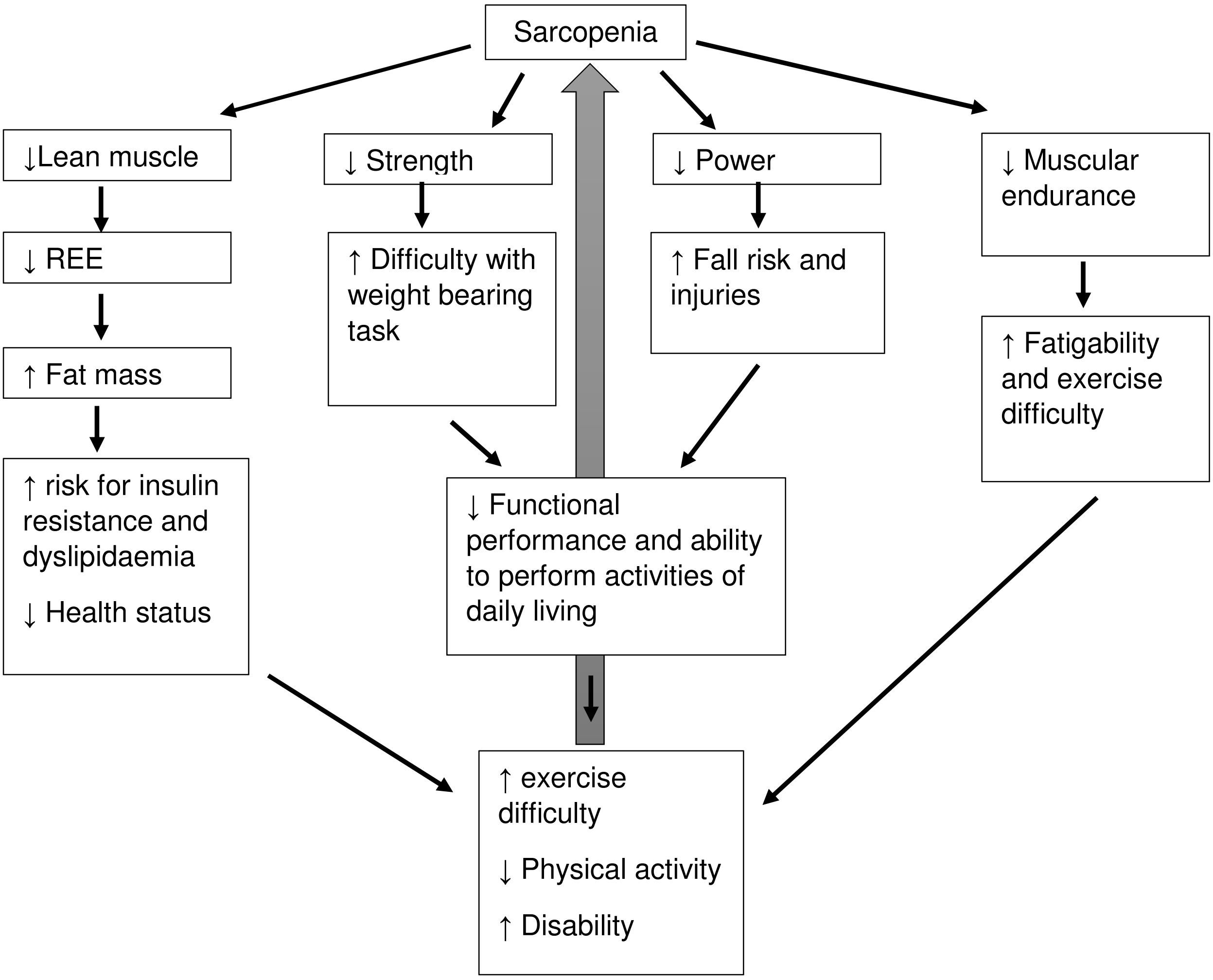
APPENDIX A

<u>The positive feedback loop</u>



APPENDIX B

Study (title & authors)	Participants			Intervention: EXP group			Intervention: CON group	Variables measured	Outcome of the study (Statically significant changes)
	Gender Age	1. Status of participants 2. Specific diet	Sample size	1. Strength or resistance 2. Training supervised	Exercises	Duration Frequency Reps & sets Intensity			
Resistance training and intra-abdominal adipose tissue in older men and woman. Hunter *et al.*, 2002)	Men (n = 12) & women (n = 14) Mean age men 67.9 & woman 65.9 years. Range 61-77 years	1. Sedentary older adults (woman post-menopausal) 2. No specific diet	Total: 26	1. Resistance 2. Supervised sessions	1. Elbow flexion 2. Elbow extension 3. Seated rows 4. Seated overhead press 5. Back extension on the CYBEX 6. Leg extension 7. Leg curls 8. Bench press 9. Bent leg sit-ups 10. Leg press or squats	25 weeks 3 x per week 10 reps (or until failure) x 2 sets 80% of 1-RM	No CON Group 1: men Group 2: Woman	• Upper body strength via elbow flexion • Lower body strength via leg extension • Weight • BMI • % fat • Fat-free mass • Total body fat mass • Intra-abdominal adipose tissue • Subcutaneous adipose tissue	Increase: • Upper body strength ○ Both men & woman (men > woman) • Lower body strength ○ Both men & woman (men > woman) • Fat-free mass ○ Both men & woman (men > woman) Decrease: • % fat ○ Both men & woman • Total body fat mass ○ Both men & woman • Intra-abdominal adipose tissue ○ Woman only • Subcutaneous adipose tissue ○ Woman only
Efficacy of systematic endurance and resistance training on muscle strength and endurance performance	Men (n = 10) & women (n = 32) Mean age 74.67 Range > 70 years	1. Healthy sedentary older adults 2. Not specified	Resistance 15 Aerobic 13 CON 14 Total: 42	1. Resistance 2. Individual supervised sessions	1. Bench press 2. Chest cross 3. Shoulder press 4. Lat pulldown 5. Biceps curl 6. Triceps extension 7. Sit-ups 8. Leg press	24 weeks 2 x per week 10-15 reps x 3-6 sets 60-80% of 1-RM	CON received no exercise	• Upper body strength via bench press & bench pull • Lower body strength via leg press • Weight • BMI • Total body fat mass • Fat-free mass	NB. Only the resistance training group's results. Increase: • Upper body strength for both bench press & bench pull • Lower body strength for leg press

in elderly adults - a randomized controlled trial. (Strasser *et al.*, 2009)									• Fat-free mass
Low-volume circuit versus high-volume periodized resistance training in women. (Marx *et al.*, 2000)	Women Mean age 23.2 years Range not specified	1. Healthy untrained women 2. Diet not specified	EXP 1: 12 (low-volume single-set circuit; SSC) EXP 2: 12 (periodised high-volume multi-set; MS) CON: 10 (no exercise)	1. Resistance 2. Individual supervised sessions	EXP 1 altered between two circuits. Circuit 1: 1. Leg press 2. Bench press 3. Leg curl 4. Seated row 5. Standing calf raises 6. Arm curl 7. Sit-up 8. Pullover 9. Military press 10. Hip abduction/ Adduction Circuit 2: 1. Knee extension 2. Chest fly 3. Leg curl 4. Lateral raises 5. Seated calf raise 6. Triceps pushdown 7. Back extension 8. Upright row 9. Rotator cuff exercises 10. Lat pulldown EXP 2 altered between two programs. Program 1: 1. Hang clean 2. Squats 3. Bench press 4. Push press 5. Leg curl 6. Sit-up 7. Rotator cuff exercises Program 2:	24 weeks Measured @ week 12 & week 24) EXP 1: 2 x per week 8-12 reps x 1 set until failure EXP 2: 4 x per week 2-4 sets Each set was performed until targeted number of reps was performed. Intensity varied between either heavy (3-5 1-RM), Moderate (8-10 1-RM), or light (12-15 1-RM)	CON received no exercise	• Upper body strength via bench press • Lower body strength via leg press • Upper body muscular endurance via maximum bench press reps (80% 1-RM) • Lower body muscular endurance via maximum leg press reps (80% 1-RM) • Lower body power via Wingate anaerobic power test • Lower body power via vertical jump test • Maximal speed via 40-yard sprint test • Weight • % fat • Fat-free mass	*At week 12:* Increase: • Fat-free mass (only in EXP 2) • Upper body strength (in both EXP 1 & EXP 2) • Lower body strength (in both EXP 1 & EXP 2) • Upper body muscular endurance (only in EXP 2) • Lower body muscular endurance (in both EXP 1 & EXP 2) • Lower body power via vertical jump test (in both EXP 1 & EXP 2) Decrease: • % fat (in both EXP 1 & EXP 2) *At week 24:* Increase: • Upper body strength (only in EXP 2) • Lower body strength (only in EXP 2) • Upper body muscular endurance (only in EXP 2) • Lower body muscular endurance (only in EXP 2) • Lower body power via Wingate test (only in EXP 2)

					1. Upright row Dumbbell military press 2. Arm curl 3. Triceps pushdown 4. Seated row 5. Sit-up 6. Side bend 7. Lateral hip flexion 8. Leg curl 9. Calf raise 10. Lunge				• Lower body power via vertical jump test (only in EXP 2) .. Decrease: • % fat (only in EXP 2) • 40-yeard sprint time (only in EXP 2)
Strength training for obesity prevention in midlife women. Schmitz *et al.*, 2003)	Women Mean age 41.9 years Range 30-50 years	1. Sedentary healthy woman 2. Monitored calorie intake pre- and post-intervention	EXP 30 CON 30 Total 60:	1. Strength training 2. Supervised session	On CYBEX: 1. Squats 2. Leg press 3. Leg extension 4. Seated leg curl 5. Curl lat pulldown Free weights: 1. Bench press 2. Overhead press 3. Biceps curl 4. Triceps extension	15 weeks 2 x per week 8-10 reps x 3 sets 100% of 8-RM	CON no exercise Calorie intake was monitored	• Upper body strength (via bench press) • Lower body strength (via leg press) • Weight • % fat • Total body fat mass • Fat-free mass • Waist circumference	Increase: • Upper body strength (via bench press) • Lower body strength (via leg press) • Fat-free mass Decrease: • % fat • Total body fat mass
Effect of resistance training on total, central and abdominal adiposity (Shaw *et al.*, 2009)	Men Mean age 25 years Range: not specified	1. Healthy, physical inactive men 2. Not on an energy-restricted diet, but diet was monitored	EXP 13 CON 12 Total: 25	1. Resistance 2. Supervised individual sessions	1. Shoulder press 2. Lats pull-downs 3. Seated chest press 4. Seated rows 5. Crunches 6. Unilateral leg press 7. Unilateral leg extension 8. Unilateral prone leg curls	16 weeks 3 x per week 15 reps x 3 sets 60% of 1-RM	CON received no exercise Diet was monitored	• Weight • BMI • % body fat via 7 skinfolds • Total body fat mass • Fat-free mass • Central fat distribution • Waist & hip circumference • Waist-to-hip ratio	Increase: • Fat-free mass • Body mass • BMI Decrease: • Total body fat mass • % body fat
Consequence of resistance training on body composition and coronary artery disease risk. (Shaw & Shaw, 2006)	Men Mean age 28 years Range 20-35 years	1. Untrained healthy men 2. Diet was monitored via 3-day dietary records	EXP 13 CON 15 Total: 28	3. Resistance 4. Not specified	1. Dumbbell shoulder shrugs 2. Dumbbell lateral shoulder raise 3. Seated chest press 4. Lat pulldown 5. Seated row 6. Biceps curls 7. Triceps extension 8. Crunches 9. Unilateral leg press	8 weeks 3 x per week 15 reps x 3 sets 60% 0f 1-RM	CON received no exercise	• Weight • BMI • % fat • Total body fat mass • Fat-free mass • Waist circumference • Hip circumference • Waist-to-hip ratio	Increase: • Fat-free mass Decrease: • % fat • Total body fat mass

Effects of strength or aerobic training on body composition, resting metabolic rate, and peak oxygen consumption in obese dieting subjects. (Geliebter *et al.*, 1997)	Men (n = 25) & women (n = 40) Mean age 35.67 years Range 19-48 years	1. Moderately obese sedentary adults 2. All three groups followed a specific diet	Diet plus strength training 20 Diet plus aerobic training 23 Diet only 22 Total: 65	1. Strength training 2. Supervised sessions	1. Leg extension 2. Leg curl 3. Chest press 4. Super pullover 5. Lateral raise 6. Arm flexion 7. Arm extension 8. Leg press	8 weeks 3 x per week 6 reps x 2 sets Last sets = maximal reps	CON diet only	• Weight • Total body fat mass • Fat-free mass • Resting energy expenditure	NB. Only the resistance training group's results. Decrease: • Total body fat mass • Resting energy expenditure Additionally: Significantly smaller loss of fat free mass were seen in the strength-training group compared to the other two groups.
Resistance training increases total energy expenditure and free-living physical activity in older adults. (Hunter *et al.*, 2000)	Men (n = 7) & Women (n = 8) Mean age 66.8 years Range 61-77 years	1. Healthy sedentary older adults 2. Not specified	Total: 15	1. Resistance 2. Supervised sessions	1. Elbow flexion 2. Elbow extension 3. Lateral pulldown 4. Seated row 5. Chest press 6. Leg extension 7. Leg curl 8. Seated press 9. Back extension 10. Bent-leg sit-ups 11. Leg press 12. Squats	26 weeks 3 x per week 10 reps x 2 sets 65-80% of 1-RM	No CON	• Upper body strength (via Chest press, elbow flexion & seated press) • Lower body strength (via leg press, leg extension & leg curl) • Weight • % fat • Total body fat mass • Fat-free mass • Total energy expenditure • Resting energy expenditure • Average energy expenditure • Respiratory exchange ratio • Resting energy expenditure to fat free mass ratio	Increase: • Upper body strength (average of the 3 exercises) • Lower body strength (average of the 3 exercises) • Resting energy expenditure • Total energy expenditure • Fat-free mass • Resting energy expenditure to fat free mass ratio Decrease: • % fat • Total body fat mass • Respiratory exchange ratio
Increased energy requirements and changes in body composition with resistance	Men (n = 8) & women (n = 4 postmenopausal) Mean age 65 years	1. Sedentary healthy older adults 2. Participants followed a specific protein diet	Low-protein diet & resistance training group 6 High-protein diet & resistance	1. Progressive resistance 2. Individual supervised sessions	1. Chest press 2. Front pulldown 3. Knee flexion 4. Knee extension	12 weeks 3 x per week 8 reps x 2 sets & last set 12 reps or until voluntary muscular fatigue 80% 0f 1-RM	No CON	• Upper body strength (via chest press & Front pulldown) • Lower body strength (Knee flexion & extension) • Weight • BMI	Increase: • Upper body strength for chest press & frontal pulldown (for both groups) • Lower body strength for leg flexion & extension (for both groups)

training in older adults. (Campbell *et al.,* 1994)	Range 56-80 years		training group 6 Total: 12					• % fat (via skinfolds) • Total body fat mass • Fat-free mass • Resting metabolic rate Fasting: • Blood glucose • Blood insulin	• Fat-free mass (for both groups) • Resting energy expenditure (for both groups) <u>Decrease:</u> • % fat (for both groups) • Total body fat mass (for both groups) <u>Additionally:</u> Dietary protein intake did not influence these results.
Effect of strength training on resting metabolic rate and physical activity: age and gender comparison. (Lemmer *et al.*, 2001)	Young men (n = 10) & young women (n = 9) Older men (n = 11) & older women (n = 10) Mean age of young adults 25.5 years Range of young adults 20-30 years Mean age of older adults 68.5 years Range of older adults 65-70 years	1. Healthy sedentary young & old men & women 2. Participants were asked to maintain their normal diet	*4 groups:* 1. Young men 10 2. Young women 9 3. Older men 11 4. Older women 10 Total: 40	1. Strength training 2. Supervised sessions	1. Unilateral leg press 2. Unilateral leg curl 3. Unilateral leg extension 4. Chest press 5. Lat pulldown 6. Military press 7. Upper back 8. Triceps pushdown 9. Biceps curl 10. Abdominal crunch	24 weeks 3 x per week 6-15 reps x 2 sets 50% of 1-RM	No CON	• Upper body strength (via chest press) • Lower body strength (via leg press) • % fat • Total body fat mass • Fat-free mass • Resting energy expenditure • Resting energy expenditure/ fat free mass ratio • Total energy expenditure • Energy expenditure of physical activity	<u>Increase:</u> • Fat-free mass (in all groups compared to baseline) ○ Great increase in fat free mass in young men & women compared to older men & women • Strength of all exercises (in all groups compared to baseline) • Lower body strength (in all groups compared to baseline) ○ Great increase in lower body strength in young men & women compared to older men & women • Upper body strength (in all groups compared to baseline) ○ Greater increase in upper body strength in young

									men & women compared to older men & women ○ Greater increase in upper body strength in young & older men compared to young and older women • Resting energy expenditure (only in young & older men) • Resting energy expenditure/ fat free mass ration (only in young & older men) <u>Decrease:</u> • Total body fat mass (only in young & older men pooled together) All groups pooled together: • Positive correlation between resting metabolic rate & changes in body fat mass & % fat in men
Effects of endurance and resistance training on total energy expenditure In young women: a controlled randomized trial. (Poehlman *et al.*, 2002)	Women Mean age 28 years Range 18-35 years	1. Healthy sedentary young women (premenopausal) 2. Diet was monitored	Resistance 16 Endurance 13 CON 19	1. Resistance 2. Supervised sessions	1. Leg press 2. Bench press 3. Leg extension 4. Shoulder press 5. Sit-ups 6. Seated row 7. Triceps extension 8. Arm curl 9. Leg curl	24 weeks 3 x per week 10 reps & sets not specified 60-80% of 1-RM	CON received no exercise	• Upper body strength (via bench press, shoulder press & seated row) • Lower body strength (via leg press) • Weight • BMI • Total body fat mass • Fat-free mass • Total energy expenditure • Resting energy expenditure • Physical activity energy expenditure	NB. Only the resistance training group's results. <u>Increase:</u> • Upper body strength • Lower body strength • Fat-free mass • Resting energy expenditure

Resistance training conserves fat-free mass and resting energy expenditure following weight loss. (Hunter *et al.*, 2008)	Women Mean age 35 years Range not specified	1. Overweight premenopausal woman 2. Diet induced weight-loss program	Resistance 37 Aerobic 30 CON 27 Total: 94	1. Resistance 2. Not specified	1. Squats 2. Leg extension 3. Leg curl 4. Elbow flexion 5. Triceps extension 6. Lateral pull-down 7. Bench press 8. Military press 9. Lower back extensions 10. Bent leg sit-ups.	Specific duration not specified (over a period of 1 year) 3 x per week 10 reps x 2 sets 65% - 80% of 1-RM	Con received no exercise Aerobics group Resistance group	• Strength • Weight • BMI • % fat • Total body fat mass • Fat-free mass • Resting energy expenditure	<u>Maintained:</u> • Strength • Fat-free mass • Resting energy expenditure <u>Decrease:</u> • Weight • % fat • Total body fat mass (Results found due to resistance training intervention as well as weight loss program)
Effects of a very-low-calorie diet and physical regimens on body composition and resting metabolic rate in obese females. (Donnelly *et al.*, 1991)	Women Age is not specified, but participants were classified as adults	1. Obese women 2. Participants were on a very-low-calorie diet	Weight 18 Endurance 16 Weight & endurance 9 CON 26 Total: 69	1. Weight training 2. Not specified	Exercises not specified	12 weeks 4 x per week 6-8 reps x 2-3 sets 70-80% 0f 1-RM	CON diet only	• Upper body strength (via Bench press & later pulldown) • Lower body strength (via knee extension & knee flexion) • Weight • BMI • % fat • Total body fat mass • Fat-free mass • Resting energy expenditure	NB. Only the resistance training group's results. <u>Increase:</u> • Upper body strength • Lower body strength <u>Decrease:</u> • Weight • % fat • Total body fat mass • Fat-free mass • Resting energy expenditure
Exercise in the treatment of obesity. Effect of four interventions on body composition, resting energy expenditure, appetite and mood. (Wadden *et al.*, 1997)	Women Mean age 41 years Range not specified	1. Obese women 2. Calorie restricted diet	Diet & resistance Diet & aerobics Diet & resistance & aerobics Diet alone Total: 128	1. Resistance 2. Group supervised sessions	1. Bench press 2. Lat pulldown 3. Chest fly's 4. Shoulder press 5. Leg extension 6. Leg curl 7. Leg press 8. Arm curl 9. Arm extension 10. Sit-ups 11. Back extension	48 weeks 3 x per week 10-15 reps x 2 sets Intensity not specified	CON diet alone	• Weight • Total body fat mass • Fat-free mass • Resting energy expenditure	No differences found between groups
One-set resistance training	Men	1. Untrained overweight men	Total: 8	1. Resistance	1. Leg press 2. Leg curl 3. Calf raise	Single session One-set & three-set	No CON	• Weight • BMI	• The three-set protocol burned

elevates energy expenditure for 72 h similar to three sets. (Heden *et al.*, 2011)	Mean age 21 years Range not specified	2. Diet was monitored		2. Supervised sessions	4. Bench press 5. Lat pulldown 6. Shoulder press 7. Biceps curl 8. Triceps extension 9. Abdominal crunch 10. Back extension	protocol @ 10-RM were done on separate days. REE & RER were measured 24, 48 & 72 hours after the resistance protocol		• % fat • Total body fat mass • Fat-free mass • Resting energy expenditure • Substrate oxidation expressed as respiratory exchange ratio (RER)	significantly greater amount of energy during the RT compared to the one-set. <u>Increase:</u> • Resting energy expenditure at 24h, 48h & 72h for both one-set & three-set protocols (compared to baseline)
Effect of an 18-wk weight-training program on energy expenditure and physical activity. (van Etten *et al.*, 1997)	Men Mean age 33 years Range 23-41 years	1. Healthy sedentary men 2. Diet was monitored via 3-day food records	EXP 18 CON 8 Total: 26	1. Weight-training 2. Supervised sessions	1. Bench press 2. Flies 3. Squats 4. Leg curl 5. Leg extension 6. Seated row 7. Lat pulldown 8. Dumbbell curl 9. Triceps pushdown 10. Situps	18 weeks 2 x per week 15 reps x 3 sets Intensity not specified	CON received no exercise	• Weight • BMI • % fat • Total body fat mass • Fat-free mass • Resting energy expenditure • Sleeping metabolic rate • Energy expenditure during exercise sessions	<u>Increase:</u> • Fat-free mass • Resting energy expenditure <u>Decrease:</u> • % fat • Total body fat mass
The effect of either high-intensity resistance or endurance training on resting metabolic rate. (Broeder *et al.*, 1992)	Men Range 18-35 years	1. Healthy men 2. Diet was monitored via 3-day diet records	Resistance 22 Aerobic 22 CON 20 Total: 47	1. Resistance 2. Supervised sessions	1. Bench press 2. Parallel dip 3. Behind-neck press 4. Upright row 5. Triceps pushdown 6. Leg press 7. Leg extension 8. Leg curl 9. Lat pulldown 10. Barbell curl 11. Abdominal crunch	12 weeks 4 x per week Week 1-2: 10-12 reps x 3 sets Week 2-12: 6-12 reps x 3 sets 100% of 12-RM	CON received no exercise	• Upper body strength (via bench press, barbell curl & triceps pushdown) • Lower body strength (via Leg press, leg extension & leg curl) • Weight • % fat • Total body fat mass • Fat-free mass • Waist-to-hip ratio • Resting energy expenditure	NB. Only the resistance training group's results. <u>Increase:</u> • Upper body strength • Lower body strength • Fat-free mass <u>Decrease:</u> • % fat • Total body fat mass • Waist-to-hip ratio
The impact of exercise training on blood lipids in older adults.	Men (n = 36) & women (n = 95) Mean age 74.6 years	1. Sedentary healthy older adults 2. Diet was monitored.	Resistance 31 Aerobic 33	1. Resistance 2. Sessions were not supervised. Participants	*Thera-bands were used to provide resistance:* 1. Chair squats 2. Hip flexion 3. Hip extension	16 weeks 3 x per week Week 1 & 2: 10 reps x 1 set Week 3-16: 12 reps x 2 sets	CON received no exercise	• Weight • BMI Fasting: • Total cholesterol • Triglycerides • HDL cholesterol	<u>Decrease in all groups:</u> • Total cholesterol • Triglycerides • HDL cholesterol • LDL cholesterol

(Boardley *et al.*, 2007)	Range > 65 years	Participants kept a 3-day day diet records	Combined resistance & aerobic 32 CON 35 Total:131	received a group program	4. Standing abduction 5. Standing adduction 6. Chest press 7. Lateral shoulder raise 8. Seated row 9. Abdominal curl-up 10. Biceps curl 11. Triceps extension 12. Calf raises 13. Toe raises	Thera-bands were used which provided different resistance suitable for each participant		• LDL cholesterol • Total cholesterol/HDL cholesterol	• Total cholesterol/HDL cholesterol
Effects of endurance training and resistance training on plasma lipoprotein profiles in elderly women. (Fahlman *et al.*, 2002)	Women Mean age 74.3 years Range 70-78 years	1. Healthy sedentary elderly women 2. Diet was monitored	Resistance 15 Aerobic 15 CON 15 Total: 45	1. Resistance 2. Supervised sessions	1. Le extension 2. Leg curl 3. Hip flexion 4. Hip extension 5. Hip abduction 6. Hip adduction 7. Plantar flexion 8. Dorsi flexion	10 weeks 3 x per week 8 reps x 3 sets of leg extension, leg curl & plantar/dorsi flexion, 2 sets of Hip flexion & extension, & 1 set of Hip abduction & adduction Intensity: last set until volitional fatigue	CON maintain normal activity level	• Lower body strength • Weight • BMI Fasting: • Total cholesterol • Triglycerides • HDL cholesterol • LDL cholesterol	NB. Only the resistance training group's results. <u>Increase:</u> • Lower body strength <u>Decrease:</u> • Total cholesterol • LDL cholesterol
Effect of 14 weeks of resistance training in lipid profile and body fat percentage in premenopaus al women. (Prabhakaran *et al.,* 1999)	Women Mean age 27 years Range not specified	1. Healthy sedentary premenopausal women 2. Diet was monitored	EXP 12 CON 12 Total: 24	1. Resistance 2. Sessions were not supervised	1. Bench press 2. Leg press 3. Leg extension 4. Leg curl 5. Lat pulldown 6. Biceps curl 7. Triceps extension 8. Military press	14 weeks 3 x per week 8 reps x 2 sets, 3 set until failure 85% of 1-RM	CON received no exercise	• Upper body strength (via lat pulldown, military press, bench press, biceps curl, triceps extension) • Lower body strength (via Leg press, leg extension, leg curl) • Weight • % fat Fasting: • Total cholesterol • Triglycerides • HDL cholesterol • LDL cholesterol • HDL cholesterol/ total cholesterol	<u>Increase:</u> • Upper body strength (for all exercises) • Lower body strength (for all exercises) <u>Decrease:</u> • Total cholesterol • LDL cholesterol • total cholesterol/HDL cholesetrol • % fat
Resistance training and lipoproteins in	Women	1. Obese postmenopaus al woman	EXP 9 CON 12	1. Resistance	1. Chest press 2. Lat pull-down 3. Shoulder press	12 week 3 x per week	CON received no exercise	• Muscle strength • Weight • BMI	<u>Increase:</u> • Muscle strength

postmenopausal woman. (Wooten *et al.*, 2011)	Mean age 65.9 years Range 60-70 years	2. All participants were ask to maintain their normal diet & was monitored	Total: 21	2. Supervised exercise sessions	4. Seated rows 5. Leg abduction 6. Leg adduction 7. Chest flies 8. Leg press 9. Leg curl 10. Leg extension	8 reps x 2 & 3 sets to failure 50% of 1-RM		• % fat Fasting: • Total cholesterol • Triglycerides • LDL cholesterol • HDL cholesterol • Non-HDL cholesetrol • TC:HDL cholesterol • LDL:HDL cholesterol	Decrease: • Total cholesterol • LDL cholesterol • Non-HDL cholesterol
Effects of a high-intensity resistance training on untrained older men. I. Strength, cardiovascular, and metabolic responses. (Hagerman *et al.*, 2000)	Men Mean not specified Range 60-75 years	1. Healthy physical active men with no weight training experience 2. Not specified	EXP 9 CON 9 Total: 18	1. Resistance 2. Supervised individual sessions	1. Leg press 2. Half squat 3. Leg extension	16 weeks 2 x per week 6-8 reps x 3 sets 85-90% of 1-RM	CON received no exercise	• Lower body strength (via leg press, half squat & leg extension) • Weight • % fat • Cross-sectional areas of fibre type I, IIA & IIB Fasting: • Total cholesterol • Triglycerides • LDL cholesterol • HDL cholesterol • Cholesterol/ HDL cholesterol	Increase: • Lower body strength in all 3 exercises • Cross-sectional areas of fibre type I, IIA & IIB Decrease: • % fat
Insulin action after resistive training in insulin resistant older men and women. (Ryan *et al.*, 2001)	Men (n = 10) & women (n = 8) Mean age Range 65-74 years 69.33 years	1. Healthy sedentary men & women (post-menopausal) 2. Not specified	Total: 18	1. Resistive training 2. Supervised session	1. Leg press 2. Chest press 3. Leg curl 4. Lat pulldown 5. Leg extension 6. Military press 7. Seated row 8. Triceps pushdown 9. Biceps curl 10. Abdominal crunch 11. Sit-ups	24 weeks 3 x per week 8-15 reps x 1-3 sets Intensity 8 – 10-RM	No CON there was only one group which served as EXP	• Upper body strength (via Chest press, Lat pulldown, triceps pushdown, biceps curl) • Lower body strength (via leg press & leg extension) • Weight • BMI • Total body fat mass • Fat-free mass Fasting: • Blood glucose levels • Blood insulin levels • Insulin sensitivity (via hyperinsulinemic-euglycemic clamps)	Increase: • Upper body strength • Lower body strength • Fat-free mass
The effect of 12 weeks of aerobic,	Men (n = 16) & women (n = 81)	1. Overweight or obese	CON 16 Aerobic 15	1. Resistance 2. Not specified	1. Leg press 2. Leg curl 3. Leg extension	12 weeks 5 x per week 8-12 reps x 4 sets	4 Groups: 1. CON 2. Aerobic 3. Resistance	• Weight • BMI • Waist circumference	NB. Only the resistance training group's results.

resistance or combination exercise training on cardiovascular risk factors in the overweight and obese in a randomized trial. (Ho *et al.*, 2011)	Mean age 52 years Range 40-66 years	sedentary adults. 2. Diet was monitored and supplementation was given	Resistance 16 Combination (aerobic & resistance) 17 Total: 64		4. Bench press 5. Rear deltoid row	10RM was used (~75% of 1RM)	4. Combination of aerobic & resistance exercise	• Hip circumference • Abdominal & total body fat (via DXA) Fasting: • Triglyceride • Total cholesterol • HDL-cholesterol • LDL cholesterol • Blood glucose levels • Blood insulin levels • Insulin resistance via HOMA2-IR	<u>Increase:</u> • HDL-cholesterol <u>Decrease:</u> • Waist circumference
A randomized controlled trial of resistance exercise training to improve glycemic control in older adults with type 2 diabetes. (Castaneda *et al.*, 2002)	Men (n = 22) & women (n = 40) Mean age 66 years Range > 55 years	1. Sedentary type 2 diabetic older adults 2. Diet was monitored	EXP 31 CON 31 Total: 62	1. Resistance 2. Supervised sessions	1. Chest press 2. Leg press 3. Upper back 4. Knee extension 5. Knee flexion	16 weeks 3 x per week 8 reps x 3 sets Week 1-8 @ 60-80% of 1-RM Week 8-16 @ 70-80% of 1-RM	CON received no exercise & no dietary counselling	• Upper body strength • Lower body strength • Weight • BMI • Waist circumference • Trunk fat mass • Total body fat mass • Fat-free mass • Total cholesterol • Triglycerides • LDL cholesterol • HDL cholesterol • Plasma glycosylated haemoglobin levels • Plasma glucose	<u>Increase:</u> • Upper body strength • Lower body strength • Fat-free mass <u>Decrease:</u> • Trunk fat mass • Plasma glycosylated haemoglobin levels
The relative benefits of endurance and strength training on metabolic factors and muscle function of people with type 2 diabetes. (Cauza *et al.*, 2005)	Men (n = 22) & women (n = 21) Mean age 57 years Range 50-70 years	1. Type 2 diabetic patients 2. Not specified	Strength 22 Endurance 17 Total: 39	3. Strength training 4. Supervised sessions	1. Bench press 2. Chest cross 3. Shoulder press 4. Lat pulldown 5. Biceps curl 6. Triceps extension 7. Sit-ups 8. Leg press 9. Calf raises 10. Leg extension	16 weeks 3 x per week 10-15 reps x 3 sets Moderate intensity	No CON	• Upper body strength (via bench press & rowing) • Lower body strength (via leg press) • Weight • BMI • % fat • Total body fat mass • Fat-free mass Fasting: • Total cholesterol • Triglycerides • LDL cholesterol • HDL cholesterol • Blood glucose levels • Blood insulin levels	NB. Only the resistance training group's results. <u>Increase:</u> • Upper body strength • Lower body strength • Fat-free mass • HDL cholesterol <u>Decrease:</u> • Total cholesterol • Triglycerides • LDL cholesterol • Blood glucose • Blood insulin • Blood glucose via haemoglobin A_{1c}

								• Blood glucose via haemoglobin A_{1c} • Insulin resistance (via HOMA-IR)	• Insulin resistance via HOMA-IR • % fat • Total body fat mass
High-intensity resistance training improves glycemic control in older patients with type 2 diabetes. (Dunstan *et al.*, 2002)	Men & women Mean age not specified Range 60-80 years	1. Sedentary overweight type 2 diabetes patients 2. Participants followed a specific diet	Resistance training with weight loss 19 CON weight loss only 17 Total: 36	1. Resistance 2. Supervised sessions	1. Bench press 2. Leg extension 3. Upright row 4. Lateral pulldown 5. Standing leg curl 6. Dumbbell seated shoulder press 7. Dumbbell seated biceps curl 8. Dumbbell triceps kickback 9. Abdominal curl	24 weeks 3 x per week 8-10 reps x 3 sets 1-2 weeks: 50-60% 0f 1-RM 3-24 weeks: 75-85 of 1-RM	CON weight loss alone	• Upper body strength (via bench press) • Lower body strength (via leg extension) • Weight • BMI • Waist circumference • Total body fat mass • Fat-free mass Fasting: • Total cholesterol • Triglycerides • LDL cholesterol • HDL cholesterol • Blood glucose levels • Blood insulin levels • Insulin resistance (via HOMA) • Blood glucose via haemoglobin A_{1c}	Increase: • Upper body strength • Lower body strength • Fat-free mass Decrease: • Weight • Waist circumference • Total body fat mass • Blood glucose via haemoglobin A1c
Effects of aerobic training, resistance training, or both on glycemic control in type 2 diabetes. (Sigal *et al.*, 2007)	Men (n = 160) & women (n = 91 Mean age 54.23 years Range 39-70 years	1. Type two diabetic patients 2. A specific diet was recommended to all participants	Resistance 64 Aerobic 60 Combination (aerobic & resistance) 64 CON 63 Total: 251	1. Resistance 2. Weekly supervision for the first 4 week. Thereafter supervision was randomized and biweekly.	7 different exercises on weight machines. Specific exercises is not specified	24 weeks 3 x per week 7-9 reps x 2-3 sets Maximum weight that could be lifted 7-9 times.	4 Groups: 1. CON 2. Aerobic 3. Resistance 4. Combination of aerobic & resistance exercise	• Weight • BMI • Waist circumference • Abdominal subcutaneous fat • Abdominal visceral fat • % fat • Total boy fat mass • Fat-free mass Fasting: • Triglycerides • Total cholesterol • LDL-cholesterol • HDL-cholesterol • Blood glucose via haemoglobin A_{1c}	NB. Only the resistance training group's results (compared to CON). Decrease: • Blood glucose levels measured via haemoglobin A_{1c} • Abdominal subcutaneous fat
Metabolic effects of aerobic training and resistance training in type	Men (n = 28) & women (n = 12) Mean age not specified	1. Untrained, overweight or obese type 2 diabetic adults.	Resistance 20 Aerobic 20 Total: 40	1. Resistance 2. Individual supervised sessions	Weight machines and free weights Nine exercises involving the major muscle groups,	16 weeks 3 x per week 10 reps x 3 sets 30-50% of 1RM & was	No CON group Aerobic or resistance group	• Weight • BMI • Waist circumference • Total body fat mass • Fat-free mass of legs • Fat-free mass	NB. Only the resistance training group's results. Increase: • Chest press (Upper body strength)

2 Diabetic subjects. (Bacchi *et al.*, 2012)	Range 40-70 years	2. Diet and medication was monitored			alternating lower body, upper body and core	gradually increased to 70-80% of 1RM		Fasting: • Triglyceride • Total cholesterol • HDL cholesterol • LDL cholesterol • Plasma glucose	• Leg extension (lower body strength) • Fat-free mass of legs • HDL cholesterol <u>Decrease:</u> • Triglycerides • BMI • Waist circumference • Total body fat mass
Effects of resistance or aerobic exercises on metabolic parameters in obese women who are not on a diet. (Fenkci *et al.*, 2006)	Women Mean age 43.17 years Range not specified	1. Obese women with severe eating disorder 2. Diet was not monitored. Participants followed their normal diet	Resistance 20 Aerobic 20 CON 20 Total: 60	1. Resistance 2. Not specified	1. Leg extension 2. Chest press 3. Arm flexion 4. Arm extension 5. Abdominal crunch 6. Twisting oblique	12 weeks 3 x per week Week 1: 10 reps x 1 set @ 40-60% of 1-RM Week 2: 10 reps x 2 sets @ 40-60% of 1-RM Week 3: 10 reps x 3 sets @ 40-60% of 1-RM Week 4-12: 10 reps x 3 sets @ 75-85% of 1-RM	CON received no exercise	• Weight • Waist circumference • Hip circumference • Waist-to-hip ratio • % fat • Total body fat mass • Fat-free mass Fasting: • Total cholesterol • Triglycerides • LDL cholesterol • HDL cholesterol • Insulin resistance via HOMO-IR	NB. Only the resistance training group's results. <u>Decrease:</u> • Weight • BMI • Waist circumference • Total cholesterol • Triglycerides
Diet and exercise treatment of obesity. Effects of 3 interventions on insulin resistance. (Weinstock *et al.*, 1998)	Women Mean age 43.3 years Range not specified	1. Obese sedentary women 2. Participants followed a specific diet	CON 15 Diet & resistance 16 Diet & aerobic 14 Total: 45	1. Resistance 2. Groups (7-10) supervised sessions	1. Bench press 2. Lat pulldown 3. Chest fly 4. Shoulder press 5. Leg extension 6. Leg curl 7. Leg press 8. Arm curl 9. Arm extension 10. Sit-ups 11. Back extension	48 weeks Week 1-28: 3 x per week Week 28-48: 2 x per week 10 – not more than 14 reps x 2 sets Intensity not specified	CON diet alone	• Weight • BMI Fasting: • Blood glucose levels • Blood insulin levels	*No results*
Twice-weekly progressive	Men	1. Sedentary type 2 diabetic men	Total: 9	3. Resistance	1. Leg press 2. Leg extension	16 weeks 2 x per week	NO CON	• Upper body strength (via bench press)	<u>Increase:</u> • Upper body strength

resistance training decrease abdominal fat and improves insulin sensitivity in older men with type 2 diabetes. (Ibanez *et al.*, 2005)	Mean age 66.6 years Range not specified	2. Diet was monitored. Three-day dietary food records were taken		4. Supervised	3. Bench press Plus 5 general overall body exercises: not specified	Week 1-8: 10-15 reps x 3-4 sets @ 50-70% of 1-RM Week 8-16: 5-6 reps x 3-5 sets @ 70-80% of 1-RM		• Lower body strength (via half-squat) • Weight • % fat • Visceral adipose tissue • Subcutaneous adipose tissue Fasting: • Blood glucose levels • Blood insulin levels • Insulin sensitivity	• Lower body strength • Insulin sensitivity Decrease: • % fat • Visceral adipose tissue • Subcutaneous adipose tissue • Blood glucose levels
Resistance training improves glycaemic control in obese type 2 diabetic men. (Baldi & Snowling, 2003)	Men Mean age 47.9 years Range not specified	1. Sedentary obese type 2 diabetic men 2. Not specified	EXP 9 CON 9 Total: 18	1. Resistance 2. Not specified	Type of exercises not specified	10 weeks 3 x per week 12 reps of 2 sets Starting weight 10-RM for upper body exercises & 15-RM for lower body exercises. Resistance was increased with 5% if they could lift 12 reps x 2 sets successfully.	CON received no exercise	• Upper body strength (via arm flexion/extension) • Lower body strength (via leg flexion/extension) • Weight • BMI • % fat • Total body fat mass • Fat-free mass Fasting: • Total cholesterol • Triglycerides • HDL cholesterol • LDL cholesterol • Blood glucose levels (via glycosylated haemoglobin) • Blood insulin levels • Insulin sensitivity (via insulin sensitivity index)	Increase: • Upper body strength • Lower body strength • Weight • Fat-free mass Decrease: • Blood glucose levels • Blood insulin levels
Effect of supervised progressive resistance-exercise training protocol on insulin sensitivity, glycemia, lipids, and body	Men (n = 22) & women (n = 8) Mean age 40.8 years Range 24-50 years	1. Asian Indians with type 2 diabetes 2. Participants was advised not to change diet	Resistance 30 Total: 30	1. Resistance 2. Individual supervised	1. Bicep flexion 2. Shoulder flexion 3. Finger grip 4. Hip flexion 5. Knee extension 6. Heel raises	12 weeks 3 x per week 10 reps x 2 sets Moderate intensity (specific intensity not specified)	No CON group	• Weight • BMI • Hip circumference • Waist circumference • Waist-to-hip ratio • Fat % • Fat-free mass Fasting: • Total cholesterol • Triglycerides	Increase: • Insulin sensitivity Decrease: • Total cholesterol • Triglycerides • Waist circumference • Hip circumference

composition in Asian Indians with type 2 diabetes. (Misra *et al.*, 2008)								• HDL cholesterol • LDL cholesterol • Insulin sensitivity (via short insulin tolerance test)	
Aerobic versus strength training for risk factor intervention in middle-aged men at high risk for coronary heart disease. (Smutok, *et al.*, 1993)	Men Mean age 50 years Range not specified	1. Sedentary men at high risk for cardiovascular disease 2. Diet was monitored. Participants were instruction to keep food records	Strength training 14 Aerobic 13 CON 10 Total: 44	1. Strength training 2. Supervised sessions	1. Duo squat 2. Leg extension 3. Leg curl 4. Hip & back 5. Decline press 6. Lateral raise 7. Rowing torso 8. Pullover 9. Arm cross 10. Behind-the-neck pullover 11. Overhead press 12. Sit-ups	20 weeks 3 x per week 12-15 reps x 2 sets 100% of 12 to 15-RM	CON received no exercise	• Upper body strength • Lower body strength • Weight • % fat • Fat-free mass Fasting: • Total cholesterol • Triglycerides • DHL cholesterol • LDL cholesterol • Blood glucose levels • Blood insulin levels	NB. Only the resistance training group's results. <u>Increase:</u> • Upper body strength • Lower body strength <u>Decrease:</u> • Blood glucose • Blood insulin levels
Strength training improves muscle quality and insulin sensitivity in Hispanic older adults with type 2 diabetes. (Ho *et al.*, 2007)	Men (n = 40) & women (n = 22) Mean age 66 years Range > 55 years	1. Hispanic older adults with type 2 diabetes 2. Diet & medication was monitored	Strength training 31 CON 31 Total: 62	1. Strength training 2. Supervised sessions	Pneumatic machines: 1. Upper back 2. Chest press 3. Leg press 4. Knee extension 5. Knee flexion	16 weeks 3 x per week 8 reps x 3 sets Week 1-8: 60-80% of 1-RM Week 10-14: 70-80% of 1-RM	CON received no exercise	• Upper body strength (via sum of Upper back & chest press 1-RM) • Lower body strength (via sum of Leg press, Knee extension & flexion) • Muscle quality (Leg 1-RM strength in kg divided by lean muscle mass of the leg in kg) • Weight • BMI • Waist circumference • Total body fat mass • Fat-free mass Fasting: • Blood glucose via glycosylated haemoglobin A_{1c} levels • Blood insulin levels • Insulin resistance via HOMA-IR	<u>Increase:</u> • Upper body strength • Lower body strength • Muscle quality • Fat-free mass *Additional:* • Hypertrophy was observed of both type 1 & 2 fibre cross sectional area <u>Decrease:</u> • Glycosylated hemoglobin concentration (thus improved glycaemic control) • Insulin resistance via HOMA-IR

Resistance training improves insulin sensitivity in NIDDM subjects without alternating maximal oxygen uptake. (Ishil *et al*., 1998)	Men or women not specified Mean age 46.8 years Range 39 – 70 years	1. Nonobese non-insulin dependent diabetes mellitus 2. Diet controlled	Resistance 9 CON 8 Total: 17	1. Resistance 2. Supervised	1. Arm curls 2. Military press 3. Push-ups 4. Squats 5. Knee extensions 6. Heel raises 7. Back extensions 8. Bent knee sit-ups 9. Upright rowing	4-6 weeks 5 x per weeks 10-20 reps x 2 sets 40-50% of 1-RM	CON sedentary controlled	• Quadriceps strength • Weight • BMI • % fat • Fat-free mass Fasting: • Insulin sensitivity (via hyperinsulinemic-euglycemic lamps)	<u>Increase:</u> • Quadriceps strength • Insulin sensitivity
Influence of resistance exercise training on glucose control in women with type 2 diabetes. (Fenicchia *et al*., 2004)	Women Mean age 49 Range not specified	1. EXP 1 sedentary Type 2 diabetic women CON (EXP 2) sedentary women with normal glucose tolerance 2. Not specified	Resistance 7 CON 8 Total: 14	1. Resistance 2. Supervised sessions	1. Chest press 2. Shoulder press 3. Lat pulldown 4. Leg curl 5. Leg extension 6. Leg press 7. Triceps extension 8. Abdominal crunches	6 weeks 3 x per week 8-12 reps to failure x 3 sets 80% of 3-RM	(EXP 2) Participated also in the resistance training intervention, served as CON	• Upper body strength • Lower body strength • Weight • BMI • Waist circumference • % fat • Total body fat mass • Fat-free mass • Sagittal abdominal diameter • Blood glucose levels • Blood insulin levels	<u>Increase:</u> • Upper body strength in all exercises (in both EXP 1 & CON) • Lower body strength in all exercises (in both EXP 1 & CON) • Fat-free mass (only in CON) <u>Decrease:</u> • Total body fat mass (only in EXP2)
Effect of an aerobic vs. resistance training on visceral and liver fat stores, liver enzymes, and insulin resistance by HOMA in overweight adults from STRRIDE AT/RT. (Slentz *et al*., 2011)	Men (n = 81) & women (n = 63) Mean age not specified Range 18-70 years	1. Sedentary, overweight, with moderate dyslipidaemia 2. Calorie intake was monitored	Resistance 52 Aerobic 48 Combination of aerobic & resistance 44 Total: 144	1. Resistance 2. Supervised sessions	Eight Cybex weightlifting machines were used, designed to target all major muscle groups	8 weeks Week 1-2 = 1-2 x per week Week 3-4 = build up to 3 x per week Week 5 = 3 x per week 8-12 reps x 3 sets Intensity not specified	No CON group 1. Aerobic 2. Resistance 3. Combination of aerobic & resistance	• Weight • Total and subcutaneous abdominal fat • Fasting insulin resistance via HOMA-IR	NB. Only the resistance training group's results. <u>Increase:</u> • Weight <u>Decrease:</u> • Subcutaneous abdominal fat

Effects of aerobic and resistance exercises training on insulin action in the elderly. (Kitamura *et al.*, 2003)	Men Mean age 68.5 years Range 65-73 years	1. Healthy sedentary men 2. Not specified	Resistance 7 Combined resistance & aerobics 7 Total: 14	1. Resistance 2. Supervised sessions	*Hydraulic equipment:* 1. Knee extension 2. Knee flexion 3. Dips 4. Shrugs 5. Arm curl 6. Shoulder press 7. Shoulder pull 8. Chest press 9. Chest pull 10. Squats 11. Back extension 12. Back flexion 13. Hip abduction 14. Hip adduction	12 weeks 3 x per week 20 reps x 2 sets 30-60% of 1-RM	No CON	• Upper body strength via chest press, Shoulder press & back extension • Lower body strength via knee extension • Weight • BMI • % fat • Fat-free mass Fasting: • Blood glucose levels • Blood insulin levels • Insulin resistance ia hyperinsulinemic-euglycemic clamp	NB. Only the resistance training group's results. <u>Increase:</u> • Upper body strength via shoulder press & back extension • Lower body strength via leg extension <u>Decrease:</u> • % fat
Effects of aerobic or resistance exercise and/or diet on glucose tolerance and plasma insulin levels in obese men. (Rice *et al.*, 1999)	Men Mean age 43.9 years Range not specified	1. Healthy obese men 2. Participants followed a specific diet	Resistance & diet 10 Aerobic & diet Diet alone 9 Total 29	1. Resistance 2. Not specified	1. Leg extension 2. Leg flexion 3. Super pullover 4. Bench press 5. Shoulder press 6. Triceps extension 7. Biceps curl	16 weeks 3 x per week 8-12 reps x 1 set Intensity not specified	CON diet alone	• Upper body strength • Lower body strength • Weight • Waist circumference • Hip circumference • Waist-to-hip ratio • Total adipose tissue • Subcutaneous abdominal adipose tissue • Subcutaneous lower body adipose tissue • Visceral adipose tissue Fasting: • Blood glucose levels • Blood insulin levels	NB. Only the resistance training group's results. <u>Increase:</u> • Upper body strength • Lower body strength <u>Decrease:</u> • Weight • BMI • Waist circumference • Waist-to-hip ratio • Total adipose tissue • Subcutaneous abdominal adipose tissue • Subcutaneous lower body adipose tissue • Visceral adipose • blood insulin levels
Effect of resistance versus endurance training on serum adiponectin and insulin resistance index.	Men Mean 40.27 years Range 35-48 years	1. Sedentary obese men 2. Diet not specified	Resistance 8 Aerobic 8 CON 8 Total: 24	1. Resistance 2. Not specified	Circuit training with 11 stations. Specific exercises is not specified.	12 weeks 3 x per week 12 reps x 4 sets 50-60% of 1-RM	CON received no exercise	• Weight • BMI • Waist circumference • Hip circumference • Waist-to-hip ratio • Total body fat mass • % fat Fasting: • Serum glucose concentration	NB. Only the resistance training group's results. <u>Decrease:</u> • % fat • Serum insulin concentration • Insulin resistance via HOMA-IR

(Ahmadizad *et al.*, 2007)								• Serum insulin concentration • Insulin resistance via HOMA-IR	
Aerobic versus resistance exercise training in modulation of insulin resistance, adipocytokines and inflammatory cytokine levels in obese type 2 diabetic patients. (El-Kader, 2010)	Men & women (n not specified) Mean age not specified Range 34-56 years	1. Obese type 2 diabetic 2. Not specified	Resistance 20 Aerobics 20 Total: 40	1. Resistance 2. Not specified	1. Chest press 2. Biceps curls 3. Triceps extension 4. Lower back 5. Abdominals 6. Leg press 7. Leg curl 8. Leg extension	12 weeks 3 x per week 8 reps x 3 sets 60% - 80% of 1-RM	No CON Resistance or aerobic group	• Insulin resistance via HOMA-IR	NB. Only the resistance training group's results. <u>Decrease:</u> • Insulin resistance via HOMA-IR
Health status of older adults with type 2 diabetes mellitus after aerobic or resistance training: a randomised trial. (Ng *et al.*, 2011)	Men (n = 19) & women (n = 41) Mean age 58 years Range not specified	1. Type 2 diabetes 2. Diet was not specified	Resistance 30 Aerobic 30 Total: 60	1. Progressive resistance training 2. Supervision not specified	Nine resistive exercises. Type of exercise not specified	8 weeks Session per week not specified 10 reps x 3 sets 65% of 1RM	No CON group Only resistance & aerobic group	• Weight • BMI • Body % fat • Waist circumference • Plasma glucose • Perceived health status via SF-36 health survey	Resistance group showed significant improvement of the SF-36 health survey domains in • Physical functioning • Mental health <u>Decrease:</u> • % fat
The effect of resistance training on functional capacity and quality of life in individuals with high and low numbers of metabolic risk factors.	Men (n = 28) & women (n = 27) Mean age 50.8 years Range 40-69 years	1. Untrained participants with a high and low (LoMRF) number of metabolic risk factors (HiMRF). 2. Three day dietary log prior to intervention	EXP low number of metabolic risk factors 12 EXP high number of metabolic risk factors 15	1. Resistance 2. Supervised sessions	1. Chest press 2. Leg press 3. Lateral pulldown 4. Triceps push down 5. Knee extension 6. Seated rows 7. Biceps curls 8. Abdominal curl	10 weeks 3 x per week Week 1: 15-20 reps x 2 sets @ 40-50% of 1-RM Week 2: 15-20 reps x 3 sets @ 50-60% of 1-RM	CON group 1 with low number of metabolic risk factors CON group 2 with high number of metabolic risk factors	• Muscle strength • Weight • Waist circumference • % fat • Total body fat mass • Fat-free mass Fasting: • Triglycerides • HDL cholesterol • Glucose • Insulin	<u>Increase:</u> • Muscle strength (in both LoMRF & HiMRF) • Fat-free mass (in both LoMRF & HiMRF) • Self-perceived physical and mental health (only for HiMRF) ○ Physical function

(Levinger *et al.*, 2007)			CON group 1 13 CON group 2 15 Total: 55			Week 3-6: 12-15 reps x 3 sets @ 60-75% of 1-RM Week 6-10: 8-12 reps x 3 sets @ 75-85% of 1-RM		• Time-Up-and-Go test • SF-36 health survey	○ General health ○ Social function Decrease: • Time-up-and-Go test (in both LoMRF & HiMRF)
Evaluation of resistance training program for adults with or at risk of developing diabetes: an effectiveness study in a community setting. (Minges *et al.*, 2011)	8 weeks: Men (n = 27) & women (n = 59) Mean age 66.4 years Range 45-93 years 24 weeks: Men (n = 8) & women (n = 24) Mean age of 65.1 years Range 45-75 years	1. Adults with or at risk of developing type 2 diabetes 2. Was not monitored	8 weeks: EXP 86 24 weeks: EXP 32	1. Resistance 2. Supervised group sessions	Pin weighted machines & free weights Type of exercises not specified	Total of 24 weeks Tested at week 8, 16 & 24 1-8 week: 2 x per week 8-24 weeks: 3 x week Reps, sets & intensity not specified	No CON group	• Upper body strength via arm curl test • Waist circumference • Sit-to-stand test (lower body strength) • Timed-Up-and-Go test	Week 8 & 24 Increase: • Sit-to-stand (n) • Arm curl (n) Decrease: • Waist circumference • Timed-Up-and-Go tine NB largest changes were observed at the 24 week assessment
Effect of resistance training frequency on physiological adaptations in older adults. (Murlasits *et al.*, 2012)	Men (n = 11) & women (18) Mean age 65 years Range > 60 years	1. Healthy sedentary older adults 2. Participants were asked not to alter their diet or medication usage during the intervention	EXP 1: 15 (2 x per week) EXP 2: 14 (3 x per week) Total: 29	1. Resistance 2. Individual supervised sessions	1. Leg press 2. Leg curl 3. Chest press 4. Lat pulldown 5. Shoulder press 6. Biceps curl 7. Abdominal crunches	8 weeks EXP 1: 2 x per week EXP 2: 3 x per week 8 reps x 3 sets ~75% of 1-RM		• Upper body strength via bench press • Lower body strength via leg press • Weight • Fat-free mass • Timed-up-and-Go test	Increase: • Upper body strength via bench press (in bot EXP 1 & EXP 2) • Lower body strength via leg press (in both EXP 1 & EXP 2) • Fat-free mass (in both EXP 1 & EXP 2)
Muscle strength and mass of lower extremities in relation to functional abilities in elderly adults.	Men (n = 13) & women (n = 18) Mean age 82.7 years Range 78-87 years	1. Sedentary older adults with no acute disease or uncontrolled chronic conditions 2. Not specified	EXP A1: 7 (male 79-83 years) EXP A2: 5 (male 84-86 years)	1. Resistance 2. Supervised sessions	3. Shoulder abduction 4. Shoulder adduction 5. Biceps curls 6. Triceps extension 7. Shoulder rotation 8. Squat 9. Calf raises 10. Leg extension	12 weeks 3 x per week 6 reps x 3 sets Low loading	CON received no exercises	• Strength • Weight • BMI • % fat • Thigh circumference • Timed-Up-and-Go test • 3 min distance walk time	Increase: • Strength (all groups) Decrease: • Timed-Up-and-Go test time (in group A2 and B2) • 3 min distance walk time (in group A2 and B2)

(Carmeli *et al.*, 2000)			EXP B1: 10 (female 78-83 years) EXP B2: 10 (female 84-87 years) CON: 29 Total: 61		Additional: balance exercises				
High-intensity strength training in nonagenarian s. (Fiatarone *et al.*, 1990)	Men (n = 6) & women (n = 4) Mean age of 90 years Range 86-96 years	1. Frail elderly 2. Diet was monitored. Three-day diet records were kept	Total: 10	1. Strength training 2. Individual supervised sessions	1. Leg extension	8 weeks 3 x per week 8 reps x 3 sets 80% of 1-RM	No CON	• Lower body strength (via leg extension) • Weight • Subcutaneous adipose tissue • Intramuscular adipose tissue • Lean muscle mass of leg (quadriceps, hip adductor & hamstring) • Functional capacity (6m walk test)	<u>Increase:</u> • Lower body strength • Lean muscle mass of quadriceps, hip adductor & hamstring area • Functional capacity (increase in total distance during 6 min)
The effects of aerobic and resistance exercises in obese women. (Sarsan *et al.*, 2006)	Women Mean age 42.6 years Range 20-60 years	1. Obese women 2. Not on an energy restricted diet	Resistance 20 Aerobic 20 CON 20 Total: 60	3. Resistance 4. Supervised sessions	1. Leg extension 2. Chest press 3. Arm flexion 4. Arm extension 5. Abdominal crunch 6. Abdominal twisting oblique 7. Hip abduction 8.	12 weeks 3 x per week 10 reps x 3 sets 75-80% of 1-RM	CON received no exercise	• Upper body strength • Lower body strength • Weight • BMI • Waist circumference • Hip circumference • Waist-to-hip ratio • 6 min walk test	NB. Only the resistance training group's results. <u>Increase:</u> • Upper body strength • Lower body strength • Functional capacity (increase in total distance during 6 min)

APPENDIX C

HEALTH SCREENING FORM

Voltooi die volgende vrae so akkuraat as moontlik. Maak 'n regmerkie in die toepaslike blokkie (ﻕ). Dit is tot u eie voordeel om die vrae so eerlik as moontlik te beantwoord. / *Complete the following questions as accurately as possible. Check the applicable block* (ﻕ). *It is to your own benefit to complete the questions as honest as possible.*

1. Laastemedieseondersoek / *Last medical exam:* ________________________________(Jaar / *Year*)
   Laastefiksheidstoets / *Last fitness test:* ______________________________________(Jaar / *Year*)

2. Het u 'n geskiedenis van enige van die volgende / *Do you have a history of any of the following?*
   ﻕHartaanval / *Heart attack* ﻕKoronêretrombose / *Coronary thrombosis*
   ﻕVernoude are / *Narrowing arteries* ﻕHoë cholesterol / *High cholesterol*
   ﻕHoëbloeddruk / *High blood pressure* ﻕRumatiekkoors / *Rheumatic fever*
   ﻕ Beroerte aanval / *Stroke* ﻕ Angina (Borspyne) / *Chest pains*
   ﻕ Lekkende hartklep / *Leaking heart valve* ﻕ Diabetes / *Diabetes*
   ﻕ Artritis / *Arthritis* ﻕ Epilepsie / *Epilepsy*
   ﻕ Kardiovaskulêre siekte / *Cardiovascular diseas* ﻕ Palpitasies / *Palpitations*
   ﻕ Pulmonale siekte / *Pulmonary disease* ﻕ Geswelde enkels / *Ankle edema*
   ﻕ Metaboliese siekte / *Metabolic disease* ﻕ Dispnee (asemnood) / *Dyspnea*
   ﻕ Hartgeruis / *Heart murmur* ﻕ Intermittende klaudikasie / *Intermittent claudication*

3. Het u 'n familiegeskiedenis van een van die volgende / *Do you have a family history of any of the following?*
   ﻕHartaanval / *Heart attack* ﻕKoronêrehartsiekte< 60jr / *Coronary heart disease < 60yrs*
   ﻕ Hoë cholesterol / *High cholesterol* ﻕ Hoë bloeddruk / *High blood pressure*
   ﻕ Beroerte aanval / *Stroke* ﻕ Oorgewig / *Overweight*
   ﻕSuikersiekte / *Diabetes*

4. Het u enige allergieë / *Do you have any allergies?* ﻕ Ja / *Yes* ﻕ Nee / *No*
   Indien ja, noem dit / *If yes, name it:*____

5. Merk een van die volgende. Gedurende 'n normale dag is ek: / *Check one of the following. During a normal day I am:*
   ﻕNooitgespanne / *Never tense* ﻕWeiniggespanne / *Seldom tense*ﻕ Van tyd tot tydgespanne / *Tense from time to time* ﻕGereeldgespanne of angstig / *Often tense or anxious*
   ﻕGewoonlikgespanne of angstig / *Normally tense or anxious*

6. Hoe gereeldneem u aanfisiekeaktiwiteite of oefeningdeel / *How often do you participate in physical activity or exercise?*
   Keer per week / *Times per week:*______Duur / *Duration:*___________Tipe / *Type:*______________________
   ____

7. Voel u ooit / *Do you ever experience:*
   Kort van asemtydensrus of met ligteoefening? / *Shortness of breath at rest or with mild exertion?*_________
   Moeg of kort van asem met daaglikseaktiwiteite? / *Unusual fatigue or shortness of breath with daily activities?*
   ____

8. Beskryfasseblief u rook geskiedenis / *Please describe you history of smoking:* ____________________

9. Het u 'n geskiedenis van enigegewrigs- of spierbeserings / *Do you have a history of any joint or muscle injury?*

ٱ Nek / *Neck* ٱ Bo-rug / *Upper back* ٱLae rug / *Lower back* ٱHeup / *Hip*
ٱBobeen / *Thigh* ٱKnie / *Knee* ٱOnder-been / *Lower leg* ٱEnkel / *Ankle*
ٱVoet / *Foot* ٱSkouer / *Shoulder*ٱElmboog / *Elbow* ٱ Pols of gewrig / *Wrist or hand*

10. Gebruik u gereelde medikasie / *Are you on regular medication?* ٱ Ja / *Yes* ٱ Nee / *No*
Indien ja, wat is die naam, dosis en die gebruik daarvan / *If yes, what is the name, dosage and use thereof? :*___

Kondisie: bv. Cholesterol	*Medikasie: bv. Lipitor*	*Dosis: bv. 10mg / dag*
____________________	__________________	__________________
____________________	__________________	__________________
____________________	__________________	__________________
____________________	__________________	__________________

11. Het u dokter voorheen aangedui dat u enige ander kondisie het waarvan ons moet kennis neem / *Have your doctor previously indicated any other conditions that we should be aware of?*________________________________
____
____

PAR-Q & YOU

Common sense is your best guide when you answer the following questions. Please read the questions carefully and answer each one.

ٱ Yes ٱ No Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
ٱ Yes ٱ No Do you feel pain in your chest when you do physical activity?
ٱ Yes ٱ No In the past month, have you had chest pain when you were not doing physical activity?
ٱ Yes ٱNo Do you lose your balance because of dizziness or do you ever lose consciousness?
ٱ Yes ٱ No Do you have a bone or joint problem that could be made worse by a change in your physical activity?
ٱ Yes ٱ No Is your doctor currently prescribing drugs (for example water pills for blood pressure or heart conditions)?
ٱ Yes ٱ No Do you know of any other reason why you should not do physical activity?

Hiermee verklaar ek dat ek die prosedure van evaluasie verstaan en dat ek die geleentheid gehad het om al die relevante vrae betreffende die evaluasie met die Biokinetikus te bespreek. Ekneem op eierisikodeelaan die evaluasie. *I hereby declare that I fully understand the procedure of the evaluation and that I had the opportunity to discuss any questions relevant to the evaluation with the Biokineticist. I participate in this evaluation at my own risk.*

______________________________ ______________________

PasiëntHandtekening / *Patient Signature* Datum / *Date*

______________________________ ______________________

Biokinetikus / *Biokineticist* Datum / *Date*

APPENDIX D

ATHEROSCLEROTIC CARDIOVASCULAR DISEASE RISK FACTOR THRESHOLDS FOR USE WITH ACSM RISK STRATIFICATION:

POSITIVE RISK FACTORS	**DEFINING CRITERIA**
Age	Men ≥ 45 years; Women ≥ 55 years.
Family history	Myocardial infarction, coronary revascularization, or sudden death before 55 years of age in father or other male first-degree relative, or before 65 years of age in mother or other female first-degree relative.
Current smoking	Current cigarette smoker or those who quit within the previous six months or exposure to environmental tobacco smoke.
Sedentary lifestyle	Not participating in at least 30 minutes of moderate intensity (40%-60% VO_2R) physical activity on at least three days of the week for at least three months.
Obesity	Body mass index ≥ 30kg.m^{-2} *or* waist girth > 102 cm for men and > 88 cm for women.
Hypertension	Systolic blood pressure ≥ 140 mmHg and/or diastolic ≥ 90 mmHg, confirmed by measurements on at least two separate occasions, *or* on any antihypertensive medication.
Dyslipidemia	Low-density lipoprotein cholesterol ≥ 3.37 mmol.L^{-1} *or* high-density lipoprotein (HDL) cholesterol < 1.04 mmol.L^{-1} *or* on lipid-lowering medication. If total serum cholesterol is all that is available use ≥ 5.18 mmol.L^{-1}.
Prediabetes	Impaired fasting glucose = fasting plasma glucose ≥ 5.50 mmol.L^{-1} but < 6.93 mmol.L^{-1} *or* impaired glucose tolerance = 2-hour values in oral glucose tolerance test ≥ 7.70 mmol.L^{-1} but < 11.00 mmol.L^{-1} confirmed by measurements on at least two separate occasions.
NEGATIVE RISK FACTOR	**DEFINING CRITERIA**
High-serum HDL cholesterol	≥ 1.55 mmol.L^{-1}

APPENDIX E

SCREENING FORM

Name: ……………………………………………………………………..
Date: ……………………………………………………………………….

Resting BP (mmHg)	**1.**		
	2.		
	3.		
	Average:		
Resting heart rate (beats/min)			
Height (cm)		**Weight (kg)**	
Circumferences:	**Waist**		
	Hip		
Non-fasting Glucose (mmol/L)		**Tot. Cholesterol (mmol/L)**	

Approve: yes ☐ No ☐

_____________________________ ____________________

Biokinetikus / *Biokineticist* Datum / *Date*

_____________________________ ____________________

Getyenis/ *Witness* Datum / *Date*

APPENDIX F

UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot • your knowledge partner

UNIVERSITEIT STELLENBOSCH
INWILLIGING OM DEEL TE NEEM AAN NAVORSING

Die dosis-respons verhouding van weerstandsoefening op die gesondheid en funksionele kapasiteit van ouer individue

U word gevra om aan 'n navorsingstudie deel te neem van Prof E Terblanche (PhD) en Dr P Olivier (PhD) van die Departement Sportwetenskap, Universiteit Stellenbosch. Aspekte van hierdie navorsingsprojek maak deel uit van die tesisse van twee Meesters in Sportwetenskapstudente in die Departement Sportwetenskap (Carla Coetsee, 15365484 en Anzerie Naude, 15659895). U is as moontlike deelnemer aan die studie gekies omdat u tussen die ouderdom van 55 en 75 jaar is.

1. DOEL VAN DIE STUDIE

Die doel van hierdie studie is om ondersoek in te stel na die verband tussen die frekwensie van oefening en die aanpassings wat in die gesondheidsuitkomste en funksionele kapasiteit van ouer volwassenes gemaak word. Die vraag word dus gevra wat die minimum hoeveelheid oefening is wat 'n persoon moet doen om die voordele daarvan te geniet.

2. PROSEDURES

Indien u inwillig om aan die studie deel te neem, vra ons dat u die volgende tydens besoeke aan die Sportfisiologie laboratorium doen:

1. metings van rustende bloeddruk, hartspoed, glukose, lengte en gewig, statiese en dinamiese balans;
2. 'n Bloedmonster van 10 mL verskaf (geneem deur 'n gekwalifiseerde verpleegster) waarmee u cholesterolwaardes bepaal sal word;
3. vraelyste voltooi oor u gesondheid, aktiwiteitsvlak en geestelike welstand;
4. 'n rustende EKG toets;
5. spierkragtoetse van u boonste en onderste ledemate;
6. die "Timed-Up-and-Go" (TUG) toets om te kyk hoe vinnig u kan opstaan uit 'n stoel, 'n afstand van drie meter aflê, omdraai, terugloop en weer gaan sit op die stoel;
7. 'n staptoets op 'n trapmeul waartydens die spoed en helling progressief moeiliker raak en u suurstofverbruik gemeet word totdat u 'n bepaalde hartspoed bereik;
8. 'n toets op 'n rekenaar voltooi wat bepaal hoe vinnig u op 'n visuele stimulus reageer;
9. metings van brein bloedvloei voltooi wat met behulp van plakkers op u voorkop gedoen sal word.

Bogenoemde toetse sal oor twee dae voltooi word. Hierna sal u lukraak in 'n spesifieke groep verdeel word. Indien u in die kontrole groep ingedeel word, sal ons u versoek om vir 16 weke u normale daaglikse aktiwiteite te volg en nie aan enige gestruktureerde oefenprogram deelneem nie. Na afloop van die 16 weke, sal al die toetse soos hierbo uiteengesit, herhaal word. Hierna sal u begin met 'n oefenprogram.

Indien u in 'n oefengroep ingedeel word, sal u versoek word om 3 keer per week die Biokinetika Sentrum te besoek vir 'n oefensessie. Hierdie oefenprogram sal 16 weke duur. Die oefensessies sal 60 minute duur, sal 'n matige intensiteit wees en sal uit weerstandsoefeninge bestaan. Die toerusting wat gebruik gaan word sluit gewigte en masjiene in. Elke vier weke sal sekere van die toetse soos hierbo beskryf, herhaal word (bv. funksionele kapasiteit, brein bloedvloei en die rekenaartoets). Nadat u die oefenprogram van 16 weke voltooi het, sal al die toetse soos hierbo beskryf is, herhaal word.

3. MOONTLIKE RISIKO'S EN ONGEMAKLIKHEID

Daar is geen ernstige risiko's verbonde aan die toetse of die oefenprogram nie. U mag wel lighoofdigheid en naarheid ervaar tydens die oefening op die trapmeul. Indien wel, sal die oefening dadelik gestaak word. U mag ook tydelike ongemak, soos spierseerheid en spierstyfheid, na die eerste paar oefensessies ervaar.

4. MOONTLIKE VOORDELE VIR PROEFPERSONE EN/OF VIR DIE SAMELEWING

Die uitslae van alle metings en toetse sal aan u bekend gemaak word wat sal lei tot persoonlike verryking. Deelname aan die oefenprogram sal lei tot 'n verbetering in u fiksheid en funksionele kapasiteit.

5. VERGOEDING VIR DEELNAME

U sal geen vergoeding ontvang vir deelname aan die studie nie. U sal wel gratis oefensessies vir 16 weke in die Biokinetika Sentrum ontvang.

Indien u enige navorsingsverwante besering of insident opdoen, sal alle koste wat hiermee geassosieer word, deur die versekering van Stellenbosch Universiteit gedek word. U is welkom om Mnr van Kerwel (wvankerwel@sun.ac.za) te kontak vir inligting oor kompensasie en dekking van mediese uitgawes in die geval van 'n navorsingsverwante besering of insident.

6. VERTROULIKHEID

Enige inligting wat deur middel van die navorsing verkry word en wat met u in verband gebring kan word, sal vertroulik bly en slegs met u toestemming bekend gemaak word of soos deur die wet vereis. Vertroulikheid sal gehandhaaf word deur middel van die aanwysing van 'n kode vir elke deelnemer. Hierdie kode sal gebruik word eerder as om u naam te gebruik. Data sal op 'n persoonlike rekenaar gehou word wat deur 'n wagwoord beskerm word. Hierdie rekenaar sal slegs vir die navorsers en meestersstudente toegangklik wees. Die rekenaar sal in 'n kantoor toegesluit word.

Na afloop van die intervensie sal u 'n verslag van u eie resultate ontvang. Die resultate van die studie (groepresultate) sal in wetenskaplike joernale gepubliseer word en vertroulikheid sal gehandhaaf word deurdat u naam (of dié van enige deelnemer) nie genoem sal word nie. Sekere resultate sal deel uitmaak van die navorsingstesisse van die twee meestersstudente. Die Departement sal die data vir 'n periode van 5 jaar bewaar en sal dit daarna vernietig.

7. DEELNAME EN ONTTREKKING

U kan self besluit of u aan die studie wil deelneem of nie. Indien u inwillig om aan die studie deel te neem, kan u te eniger tyd u daaraan onttrek sonder enige nadelige gevolge. U kan ook weier om op bepaalde vrae te antwoord, maar steeds aan die studie deelneem. Die navorsers kan u ook aan die studie onttrek indien omstandighede dit vereis. Dit mag bv. gebeur indien u siek word, u 'n besering kry of enige nadelige effekte tydens of na die oefentoetse of oefensessies ervaar. Indien u versuim om vier agtereenvolgende oefensessies by te woon, sal u uit die studie onttrek word.

8. IDENTIFIKASIE VAN ONDERSOEKERS

Indien u enige vrae of besorgdheid omtrent die navorsing het, staan dit u vry om met enige van die volgende persone in verbinding te tree:

Prof E. Terblanche (Hoofnavorser) by 021 808 4817. E-pos: et2@sun.ac.za.
Dr P Olivier (mede-Navorser) by 021 808 4718. E-pos: polivier@sun.ac.za
Me Carla Coetsee (MSc-student) by 021 808 2818. E-pos: 15365484@sun.ac.za
Me Anzerie Naude (MSc-student) by 021 808 2818. E-pos: 15659895@sun.ac.za

9. REGTE VAN PROEFPERSONE

U kan te eniger tyd u inwilliging terugtrek en u deelname beëindig, sonder enige nadelige gevolge vir u. Deur deel te neem aan die navorsing doen u geensins afstand van enige wetlike regte, eise of regsmiddel nie. Indien u vrae het oor u regte as proefpersoon by navorsing, skakel met Me Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] van die Afdeling Navorsingsontwikkeling.

VERKLARING DEUR PROEFPERSOON OF SY/HAAR REGSVERTEENWOORDIGER

Die bostaande inligting is aan my,________________________________, gegee en verduidelik deur ________________________ in ____________(taal) en ek is dié taal magtig of dit is bevredigend vir my vertaal. Ek is die geleentheid gebied om vrae te stel en my vrae is tot my bevrediging beantwoord.

Ek willig hiermee vrywillig in om deel te neem aan die studie. 'n Afskrif van hierdie vorm is aan my gegee.

____
Naam van proefpersoon/deelnemer

____
Naam van regsverteenwoordiger (indien van toepassing)

______________________________ ______________
Handtekening van proefpersoon/deelnemer of regsverteenwoordiger **Datum**

VERKLARING DEUR ONDERSOEKER

Ek verklaar dat ek die inligting in hierdie dokument vervat verduidelik het aan ____________________ en/of sy/haar regsverteenwoordiger ____________________. Hy/sy is aangemoedig en oorgenoeg tyd gegee om vrae aan my te stel. Dié gesprek is in Afrikaans/Engels gevoer en geen vertaler is gebruik nie.

______________________________ ______________
Handtekening van ondersoeker **Datum**

APPENDIX G

BASELINE TESTING

Date: …………………………………………….. Time: ……………………………………….

Name: ………………………………………………………………………………………………….

Tests:

BIA – Measurements:

BIA no. of download:		
Training per week	Very low (0 – 1 x); Low/med (1 – 2 x); Medium (3 – 4 x); Med/high (4 – 5 x); Very high (> 6 x)	
Age		
Height (cm)		
Weight (kg)		
DATA COLLECTED	**Values**	**Normative ranges**
Weight (kg)		
% Body fat		
% Lean Body Mass	**kcal**	**KJ**
Resting Energy Consumption	**Kcal**	**KJ**
Energy Required		
H2O Content		
BMI		
BFMI		
FFMI		

Tests:

Time Up and Go (TUG):	
1.	
2.	
3.	
Best time:	
Grip strength:	

1.	
2.	
3.	
Best:	
Leg press (6 RM):	**kg**
Bench press (6 RM):	**kg**

____

Biokinetikus / *Biokineticist*

____

Datum / *Date*

____

Getyenis/ *Witness*

____

Datum / *Date*

APPENDIX H

RATING OF PERCEIVED EXERTION SCALE

rating	description
0	NOTHING AT ALL
0.5	VERY, VERY LIGHT
1	VERY LIGHT
2	FAIRLY LIGHT
3	MODERATE
4	SOMEWHAT HARD
5	HARD
6	
7	VERY HARD
8	
9	
10	VERY VERY HARD (MAXIMAL)

APPENDIX I

EXERCISE-INDUCED FEELING INVENTORY

EXERCISE-INDUCED FEELING (EFI) INVENTORY

0 = Do Not Feel (DNF)
1 = Feel Slightly
2 = Feel Moderately
3 = Feel Strongly
4 = Feel Very Strongly (FVS)

Instructions:
Please use the following scale to indicate the extent to which each word listed describes how you feel at this moment in time. Record your responses by c hecking the appropriate box next to each word.

			0	1	2	3	4	
1.	Refreshed	DNF	[ ]	[ ]	[ ]	[ ]	[ ]	FVS
2.	Calm	DNF	[ ]	[ ]	[ ]	[ ]	[ ]	FVS
3.	Fatigued	DNF	[ ]	[ ]	[ ]	[ ]	[ ]	FVS
4.	Enthusiastic	DNF	[ ]	[ ]	[ ]	[ ]	[ ]	FVS
5.	Relaxed	DNF	[ ]	[ ]	[ ]	[ ]	[ ]	FVS
6.	Energetic	DNF	[ ]	[ ]	[ ]	[ ]	[ ]	FVS

			0	1	2	3	4	
7.	Happy	DNF	[ ]	[ ]	[ ]	[ ]	[ ]	FVS
8.	Tired	DNF	[ ]	[ ]	[ ]	[ ]	[ ]	FVS
9.	Revived	DNF	[ ]	[ ]	[ ]	[ ]	[ ]	FVS
10.	Peaceful	DNF	[ ]	[ ]	[ ]	[ ]	[ ]	FVS
11.	Worn-out	DNF	[ ]	[ ]	[ ]	[ ]	[ ]	FVS
12.	Upbeat	DNF	[ ]	[ ]	[ ]	[ ]	[ ]	FVS

APPENDIX J

<u>After completion of the study intervention:</u>

Name:………………………………………………………………

Did you alter your diet during the intervention period?

Yes	No

If yes, please explain how your diet and eating patterns changed:

Did you increase or decrease your calorie intake?

……
……
……
……
……
……
……
……

Did you alter you amount of physical activity during the intervention period?

Yes	No

If yes, please explain how your participation in physical activity changed:

Did you increase of decrease your participation in physical activity?

……
……
……
……
……
……
……

………………………………… ……./……./……….

Signature **Date**