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BODY COMPOSTION, METABOLIC PROFILE AND FITNESS  
IN OLDER VERSUS YOUNGER TYPE 2 DIABETIC PARTICIPANTS TO SIX  
MONTHS OF AEROBIC EXERCISE, RESISTANCE EXERCISE OR  
COMBINED AEROBIC AND RESISTANCE EXERCISE

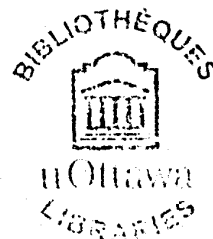
Katherine R. Dittmann, BSc HK

Thesis submitted to the  
Faculty of Graduate Studies and Research  
in partial fulfilment of the requirements for the degree of  
Master's of Arts in Human Kinetics

Faculty of Health Sciences, School of Human Kinetics  
University of Ottawa, Ottawa, Canada

2004

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BODY COMPOSTION, METABOLIC PROFILE AND FITNESS IN OLDER VERSUS  
YOUNGER TYPE 2 DIABETIC PARTICIPANTS TO SIX MONTHS OF AEROBIC  
EXERCISE, RESISTANCE EXERCISE OR COMBINED  
AEROBIC AND RESISTANCE EXERCISE

## ACKNOWLEDGEMENTS

I would like to start by thanking my primary advisor Dr. Glen Kenny, who introduced me to the DARE study and accepted me as a part of the team. I would also like to thank my co-supervisor Dr. Ron Sigal for all of his constructive criticism, help interpreting data and inspirational “word-smithing” abilities. His support, financial and otherwise, and his good-hearted character have not gone unnoticed.

Many thanks extend to the many capable members of the DARE study team who have helped me along the way. Immense gratitude and admiration goes to Alison Jennings. Alison was the first to endure the many of the realities of a Masters degree and she was kind enough to provide valuable guidance, advice and an open-mind to listen to frustrations. I would further like to thank Penny Phillips and Kim Weatherbee who have provided me with direction and patience and have both made valuable contributions to my work. Also, to Heather Tollouch my “in-school” psychology expert who quickly became a close friend.

I was lucky enough to have long-time friends join me as a part of the DARE study and innumerable thanks go to Jane Murrin and Rikst Attema. Besides the countless hours spent at the computer, Jane has been a long-time friend and a pillar of support. And of course to Rikst Attema; I could not have made it without you. We have learned much more than can be read in these pages. I doubt many people are lucky enough to experience such a unique and special friendship and a couple of provinces between us won't change a thing!

Special thanks to Elaine Parker who always keeps things in order and to all DARE study members who have come and gone and made positive impacts. Thank you to the YMCA staffers and the many DARE study trainer who have been a great help along the way. And of course to the many memorable participants who have made impressions on my life. To all current and previous Master students who have provided guidance, friendship and support; Julien Periard, Torrey Parker, Marjorie Pomerleau, Shane Journey, and Jason Fetch. Great thanks to the other school affiliates who have made lasting impressions; Dr. Frank Reardon, Francois Haman, and Dr. Joanna Komorowski.

Support from my family and closest friends have kept me grounded. I would specifically like to thank; my mom and my father, Khara and Owen, Jen and Aaron, and James and Samir. I am thankful for their timely distractions, solid support and in Owen's case,

superior statistical knowledge. I would also like to thank Mr. Graham “the monster” Schuler. Thank you for the comic relief and supportive friendship. I would also like to thank Eleni for providing musical interludes and reminded me that dreams are worth following.

Last but not least, I would like to thank my committee members, Dr. Eric Doucet and Dr. Pascal Imbeault for their time, expertise, constructive critique and their approachable, and helpful demeanour.

## LIST OF TABLES AND FIGURES

### TABLES:

Table 1. Number of participants per group .....	71
Table 2. Group A and Group B exercises .....	72
Table 3. Exercise protocol .....	73
Table 4. Baseline and 6-month characteristic table .....	74
Table 5. Baseline and 6-month strength values .....	75
Table 6. Baseline and 6-month nutrition data .....	76

### FIGURES :

Figure 1. Schematic representation of study protocol .....	77
Figure 2. Compliance .....	79
Figure 3. Change in body weight .....	81
Figure 4. Change in mid-thigh cross-sectional area .....	83
Figure 5. Change in abdominal subcutaneous adipose tissue .....	85
Figure 6. Change in abdominal visceral adipose tissue .....	87
Figure 7. Strength change measured by bench press .....	89
Figure 8. Strength change measured by seated row .....	91
Figure 9. Strength change measured by leg press .....	93
Figure 10. Change in V02peak .....	95
Figure 11. Change in HOMA .....	97
Figure 12. Change in HbA1c .....	99

## Table of Contents

<b>Introduction Page .....</b>	<b>i</b>
<b>Acknowledgements .....</b>	<b>ii</b>
<b>List of Figures .....</b>	<b>iv</b>
<b>Chapter 1: Introduction</b>	
1.1 General Problem .....	1
1.2 Specific Problem .....	3
1.3 Objectives .....	4
1.4 Hypotheses .....	4
1.5 Significance .....	5
1.6 Limitations and Delimitations .....	5
1.7 Definitions.....	5
<b>Chapter II: Literature Review</b>	
2.1 Introduction .....	7
2.2 Body Composition and Aging.....	7
2.3 The Effects of Exercise on Fat Composition and Fat Free Mass.....	9
2.3.1 Aerobic Training.....	10
2.3.2 Resistance Training.....	12
2.3.3 Combined Aerobic and Resistance Training.....	14
2.4 Age Differences in Lean Body Mass and Strength .....	15
2.5 The Effects of Exercise on Strength .....	16
2.5.1 Resistance Training.....	17
2.5.2 Aerobic Training.....	18

2.5.3 Combined Resistance/Aerobic Training .....	19
2.6 Age Differences in Glycemic Control .....	20
2.7 Adipose Tissue and Glycemic Control .....	20
2.8 Exercise and Glycemic Control .....	22
2.9 Conclusion .....	25
<b>ChapterIII: Article .....</b>	<b>27</b>
Abstract .....	28
Introduction .....	30
Methodology .....	33
Subjects .....	33
Experimental Design .....	33
Anthropometric Measurements .....	34
Blood Sampling .....	34
V02peak .....	35
Strength Testing .....	35
Computed Tomography .....	36
Diet .....	36
Exercise Intervention .....	37
Statistical Analysis.....	38
Results .....	39
Body Composition .....	40
Strength .....	41
V02peak .....	42

Glycemic Control .....	42
Dietary Intake .....	43
Discussion .....	44
Aerobic Exercise .....	44
Resistance Exercise .....	47
Combined Aerobic and Resistance Exercise .....	51
Overall .....	52
Statement of Contribution of Collaborators .....	57
References .....	58
Tables .....	71
Figures .....	77

## CHAPTER I

### 1.0 Introduction

#### 1.1 General Problem

Diabetes mellitus is one of the greatest risk factors that lead to morbidity and mortality (Harris, 1998). This increased risk can be attributed to both hyperglycemia and a cluster of other metabolic disturbances in type 2 diabetes that are also associated with obesity. Type 2 diabetes mellitus (T2DM) is the most common form of diabetes and is present in 90% of diabetic cases. Health care costs in the US reached an estimated \$98 billion in 1997 for concerns directly and indirectly related to T2DM (ADA, 1998). With near epidemic proportions, effective treatment is fundamental.

Insulin resistance,  $\beta$ -cell defect and consequent hyperglycemia characterize T2DM. Unlike type 1 diabetes mellitus, the  $\beta$ -cells of the pancreas continue to produce insulin in T2DM although a defect is present and insulin sensitivity is reduced. In healthy individuals, high blood glucose levels lead to increased insulin secretion of the  $\beta$ -cells and subsequent uptake of glucose in target tissues, reducing blood glucose levels. Elevated insulin levels are often found in obese, insulin resistant individuals to maintain normal blood glucose levels. If insulin can sustain its ability to uptake glucose then T2DM may never develop. The development of T2DM and presence of hyperglycemia is often dependent on the presence of a  $\beta$ -cell defect. In such a case, insulin stimulation via  $\beta$ -cells becomes less glucose sensitive and hepatic glucose production is increased, while peripheral uptake is decreased resulting in hyperglycemia. Hyperglycemia leads to many complications such as; high blood pressure, coagulation problems, vision and other eye

problems, impotence, lower-limb amputations, kidney disturbances, decreased nerve function as well as many cardiovascular conditions (CDC). A genetic predisposition to T2DM exists but there is also a powerful link to obesity (Wannamethee and Shaper, 1999) and physical inactivity (Hays and Clark, 1999).

The main focus of T2DM treatment is to decrease blood glucose levels as well as target underlying causes such as obesity. The recommended initial treatment during the early stages of the disease is a combination of diet and exercise, as exercise (Tanner et al., 2002) and fat loss (Hickey et al., 1998) will each improve insulin resistance. Hemoglobin A<sub>1c</sub> (HbA<sub>1c</sub>) is a measure of glycemic control recommended by the American Diabetes Association as the best measure of blood sugar control over time (ADA) and is often used as a marker for improvement. HbA<sub>1c</sub> is directly proportional to the concentration of glucose in the blood over the full life span of the red blood cell reflecting average blood glucose levels over the previous 2-3 months and is not subject to daily fluctuations.

The prevalence of T2DM and insulin resistance increases with aging.  $\beta$ -cell failure and subsequent decreases in insulin secretory capacities are also more pronounced in older adults (Chang and Halter, 2003) and could likely be a main cause for increased T2DM with age. However, insulin resistance has also been closely related to the increase in adiposity and decrease in physical activity that often accompany aging. It is difficult to distinguish between changes due to aging *per se* and those that are confounded by lifestyle factors over time. Regardless, it is important to establish whether separate guidelines should be outlined for older and younger T2DM individuals.

## 1.2 Specific Problem

Exercise has proven to be a valuable means in controlling T2DM (Boulé et al., 2001). The Canadian (CDA) and American Diabetes Associations (ADA) have set exercise and diet guidelines detailed for T2DM individuals. However, it is also important to determine whether there are special needs within T2DM population.

Specifically, it may be important to recognize older T2DM individuals separately in determining a practical exercise prescription. Older adults might respond differently to different modalities of exercise (ie. aerobic, resistance or the combination thereof) and therefore may merit a different approach to exercise prescription unique to the sub-population. In recent studies, older type 2 diabetic individuals (age >55 or 60 years) improved glycemic control following resistance training (Castaneda et al, 2002; Dunstan et al, 2002). Unfortunately, only one group of researchers has focused on aerobic exercise exclusive to the older T2DM patient and furthermore did not find significant HbA<sub>1C</sub> improvements following training (Tessier et al., 2000). Conversely, younger T2DM individuals primarily improve HbA<sub>1C</sub> levels in studies of aerobic training. This discrepancy perhaps lies in the relative lack of aerobic training research done in older diabetic patients, the relative lack of resistance training research done in younger diabetic patients as well as possible differences in compliance and intensity of training.

It is becoming clearer that older adults (not specific to T2DM) are capable of responding to exercise in a similar manner as younger adults following similar programs, intensities and durations (Mazzeo et al, 1998). However, fitness levels are generally the prime focus and there is still a lack of data supporting this claim with regard to insulin and glucose sensitivity following exercise. The finding of Tessier et al. (2000) suggest

that older T2DM individuals may not respond with improved HbA<sub>1c</sub> levels following aerobic training, common to their younger counterparts. However, this study did not provide an age comparison and was relatively short in duration and therefore further research is warranted.

In summary, there is a lack of research on effects of aerobic exercise in older diabetic subjects, and a similar lack of research on effects of resistance exercise in younger diabetic subjects. There are reasons to believe that optimal exercise prescriptions might differ according to age group. Therefore, we propose to undertake a study of the impact of aerobic exercise, resistance exercise, and their combination in older versus younger diabetic subjects in a randomized trial.

### **1.3 Objectives**

The main focus of this study is to determine whether or not a difference in glycemic control, body composition, V0<sub>2</sub>peak and strength changes following aerobic, resistance or combined aerobic and resistance exercise exist between older (55-70 years) and younger (40-54 years) previously inactive T2DM individuals following a 6-month intervention.

### **1.4 Hypotheses**

We expect that the older T2DM group will respond in a similar manner to that of the younger T2DM groups concerning body weight, glycemic control, visceral adipose tissue and subcutaneous adipose tissue following combined aerobic/resistance exercise, resistance exercise only or aerobic exercise. It is expected that the younger group has the greatest absolute muscle mass and strength improvements. However, it is hypothesized that the older group will have comparable relative improvements.

## 1.5 Significance

The worldwide presence of T2DM will increase as the general population ages. Ten percent of Canadians > 65 years have T2DM versus only 3% of those between 35-64 years (Health Canada (a), 2003). Average health care costs for individuals with diabetes are generally 2-5 times higher than non-diabetic individuals of the same age (CDA). Furthermore, sixty-three percent of costs spent on T2DM in the US are being spent on those > 65 years (Huse, Oster, Kellen, et al, 1989), resulting in a massive financial burden. Much of the increased costs are due to medications. Therefore, there is much potential both in terms of health and economics from successful nonpharmacological interventions for diabetics. Finding the most effective exercise regimes for the growing older population with T2DM is imperative.

## 1.6 Limitations

- The DARE study does not include individuals aged over 70 years, therefore we are not learning about the responses of the very old T2DM population.
- It was not feasible for all exercise programs to have equivalent caloric expenditure and therefore they will not be directly compared.
- Statistical power will be limited for some of the proposed comparisons.

## 1.7 Definitions

**Insulin Resistance:** A state in which a given concentration of insulin is associated with a subnormal glucose response.

**HemoglobinA<sub>1c</sub>:** The proportion (percent) of hemoglobin that is glycated. HbA<sub>1c</sub> reflects the average concentration of glucose in the blood during the previous 2-3 months, as it is directly proportional to the concentration of glucose in the blood over the full life

span of the red blood cells and is thus a good measure of glycemic control. Normal HbA<sub>1C</sub> is 4-6%, and diabetes is considered to be well controlled when HbA<sub>1C</sub> is <7%.

**Glycemic Control:** the body's ability to control the level of glucose in the blood.

**Type 2 Diabetes Mellitus (T2DM)** – Diabetes mellitus is diagnosed according to Canadian Diabetes Association criteria when fasting plasma glucose is  $\geq 7$  mmol/L, or 2-hour plasma glucose is  $\geq 11.1$  mmol/L after a 75 g oral glucose load, on at least two occasions. Type 2 diabetes is characterized by varying degrees of insulin resistance and *relative* insulin deficiency. In contrast, type 1 (insulin dependent) diabetes is characterized by an *absolute* insulin deficiency and consequent susceptibility to ketosis.

**Older vs. Younger adults:** For the purposes of this study, older adults are considered to be between the ages of 55-70 years and the younger population between 40-54 years.

**Resistance Training:** Exercises in which muscles generate force against a resistance that is progressively increased over time (Mazzeo et al, 1998).

**Aerobic Training:** Continuous movement of large muscle groups, stimulating the cardiorespiratory system.

**Subcutaneous Adipose Tissue:** Adipose tissue directly beneath the dermis.

**Visceral Adipose Tissue:** Adipose tissue deep to the subcutaneous adipose tissue, surrounds vital organs within the thoracic cavity.

**Homeostatic model assessment (HOMA):** Used to assess  $\beta$ -cell function and insulin resistance.

## CHAPTER II

### 2.1 Introduction

With increasing health care costs, avoiding increases in medication use would be beneficial, and is thought to be possible, at least in part, through exercise. There is ample literature concerning many aspects of exercise, although little is known about specific amounts of exercise, and which forms would be most beneficial for specific categories of people. For example, as previously outlined above, there are gaps with regard to T2DM individuals in different age groups. It is difficult to establish one ideal exercise regime for any population or disease. However, evidence-based standards and guidelines for specific populations, such as elder T2DM individuals, would provide valuable information and may help to promote wide spread participation.

### 2.2 Body Composition and Aging

Many age-related changes in body composition occur. It is common for older adults to have decreased muscle mass (Porter, Vandervoot and Lexell, 1995), increased fat mass (Cox, Cortright, Dohm and Houmard, 1999) and more specifically increased visceral fat mass (Enzi et al., 1986). These changes affect such parameters as muscle strength and insulin resistance. However, these changes do not occur solely due to the aging process. There is much debate as to the effects of aging *per se*. It is difficult to isolate age-related changes from those related to a decrease in physical activity and/or the presence of disease. The decrease in physical activity that tends to occur as an individual ages (Westerterp and Meijer, 2001) further complicates the picture and consequently is a major factor in analysis of the aging process.

Although more predominant in women than men, changes in body fat placement, along with increased body fat also occurs with age. After the age of 60 years both men and women increase visceral adipose deposits (Enzi et al, 1986). Middle-aged men are typically prone to carrying excess fat in the abdominal region, known as the android or male-type body shape (Vague, 1956). Middle-aged women, on the other hand are more likely to carry excess weight in a pear-shaped fashion known as the gynoid body shape. However, older women (often post-menopausal) have a tendency to accumulate adipose tissue in the central region, similar to men (Hunter et al, 1997; Ley, Lees and Stevenson, 1992). Janssen, Heymsfield, Allison, Kotler and Ross (2002) found that men had significantly higher VAT than women, but with age this difference becomes less significant. The female metamorphosis leading to increased central body fat (Tremollieres, Pouilles and Ribot, 1996) and VAT accumulation (Evans et al., 1983) has been linked to hormonal changes that occur during the menopause transition. However, more recently, Douchi et al. (2002) found that upper body fat distribution as well as increased adiposity is more so related to age than menopause. These changes are harmful because of the close relationship between abdominal and visceral adipose tissue with metabolic disturbances (Björntorp, 1989). Increased visceral adiposity is also more pronounced in obese individuals versus non-obese individuals (Enzi et al, 1986).

Furthermore, both fat free mass (FFM) and fat mass (FM) undergo unfavourable changes in the elderly (Kyle et al., 2001). Total body potassium and body cell mass have been found to be significantly lower in older adults, suggesting that FFM of older individuals has a different composition than younger individuals. Such differences in

FFM composition may lead to greater incidences of insulin resistance and metabolic complications.

Increases in body fat in old age have been documented between 2.2% (Going et al., 1994) and 3% (Flynn et al., 1989) per decade for men and between 3.6% (Going et al., 1994) and 5.2% (Flynn et al., 1989) per decade for women. Because fat placement is a factor and those with lower waist circumferences also have lower health risks than those with higher waist circumferences (abdominal subcutaneous and visceral adiposity), it is plausible that many health complications could be prevented if optimal body mass and/or composition was preserved over the years.

### **2.3 The Effects of Exercise on Body Composition and Fat Free Mass**

Decreased level of physical activity in the elder population plays a key role in fat accumulation (Dipietro, Casperson, Ostfeld, and Nadel, 1993) as well as muscle mass reduction for both men and women. It may be more conceivable that adults who have never been involved in regular activity decrease physical activity levels over time, but it is interesting to add that even lifetime athletes progressively decrease activity levels as they age. Katzel, Sorkin and Fleg (2001) retested 42 athletes a mean of 8.2 years post baseline testing and found exercise levels decreased. Athletes were considered those who engaged in vigorous activity a minimum of 4x/wk, with a  $VO_{2max} > 2.5$  standard deviations higher than the age-adjusted norm and whose BMI was  $< 26 \text{ kg/m}^2$  furthermore the average years of training was  $> 20$  years at baseline. Seven of the 42 men continued to train at high intensities (the runners averaged 31 miles/wk at 8.5min/mile at baseline testing and when retested averaged 27 miles/wk at 8.75 min/mile), 21 men maintained "moderate training" (averaging 33 miles/wk at 8.5

min/mile at baseline, 6 changed to race walking or cycling, for those who continued to run the average was 23 miles/wk at 10.2 min/mile), finally 12 men continued "low training" (none of these men continued to train long distances). Interestingly, even with declines in the "moderate training" group, the men were still competitive in their age category suggesting most men their age had similar declines. Unfortunately the focus of this study was aerobic fitness as measured by  $VO_{2max}$ , body fat percentages and muscle mass were not taken into account. Although, the activity dimensions of the Yale Physical Activity Survey (YPAS) has shown a significant relationship between physical activity levels and body fat percentage ( $P=0.03$ ) in older adults (Dipietro, Casperson, Ostfeld, and Nadel, 1993). Muscles, which are not only necessary for locomotion, are also actively involved in metabolic functions. Aging muscle, known to decrease in mass (Hughes et al., 2001) also have decreased contractile proteins and endure changes in metabolic function (Proctor, Balagopal and Nair, 1998).

### ***2.3.1 Aerobic Training***

Aerobic training is often implemented with the intent to increase total energy expenditure and induce a negative energy balance. Ultimately, a chronic negative energy balance will lead to weight loss. However, increased total daily energy expenditure following aerobic training is not necessarily the case, at least in the older population as pointed out by Goran and Poehlman (1992). Goran and Poehlman (1992) concluded that aerobic training is a fair method to improve cardiovascular fitness in the elderly (56-78 years) although it does not increase total energy expenditure. It was found that with aerobic training total energy expenditure actually decreased as the population had a tendency to reduce the amount of energy spent during the remainder of the day.

Regardless, aerobic exercise has been shown to decrease body fat, especially in conjunction with diet (Ross et al., 1996). Although reducing overall adiposity is beneficial for glycemic improvements, VAT decreases are the often a primary concern. Fortunately, VAT stores are mobilized first regardless of weight loss treatment (diet, combined diet/ aerobic or diet/resistance training) (Ross Rissanen, Pedwell, Clifford and Shragge, 1996).

Mourier et al (1997) found impressive results when studying the effect of exercise on abdominal obesity. A 2-month program including progressive aerobic exercise 2x/wk as well as non-progressive training 1x/wk was implemented. Twenty-four, middle-aged T2DM patients participated (although only 4 were women), 12 participants made-up the training group while the other 12 served as controls. The progressive aerobic portion was performed for 45 minutes using a mechanically braked ergocycle at 75%  $VO_{2peak}$ , while the non-progressive intermittent portion involved 5 exercise bouts on the ergocycle at 85%  $VO_2$  peak at 2 minutes each with 3 minutes at 50%  $VO_2$  peak active recovery between bouts. Significant decreases were found in both SAT and VAT masses however, the latter was more substantial. They offer the suggestion that the repeated approach of acute exercise encourages lipolysis in deep abdominal fat possibly due to an increase in catecholamine activity, however this theory was not tested. They further found great increases in thigh muscle tissue areas ( $23 \pm 4.6\%$ ) in the exercise trained group. Such increases have not been reported in many studies involving T2DM. However, this particular program did differ slightly from standard aerobic programs, as intermittent exercise was included.

### ***2.3.2 Resistance training***

Resistance exercise on the other hand, has shown to stimulate both muscular hypertrophy and decreasing body fat, cumulatively improving body composition (Dolezal and Potteiger, 1998), while total body weight generally remains relatively stable. Resistance training induced fat losses commonly occur in concert with increased muscle mass maintaining total body weight.

Miller et al. (1994) found a 1.6% decrease in body fat and a mean increase of 1.2kg in fat free mass in middle-aged men following a 4-month resistance training program, with no significant change in total body weight. Waist to hip ratio did not change. Decreased truncal fat mass has been seen following a 16-week intensive progressive resistance training program in older T2DM Latino adults and was negatively correlated with glycemic control (Castaneda et al., 2002). Unfortunately, VAT was not measured directly and therefore the use of intensive resistance training to decrease high-lipolytic VAT in older adults (>55 years) with T2DM can only be suggested on the basis of decreased central obesity and not VAT directly.

Hunter, Bryan, Wetzstein, Zuckerman and Bamman (2002) are one of few groups of researchers to examine the effect of resistance training on intra-abdominal adipose tissue in older adults. One other study, done by Treuth et al. (1995), previously found 16-weeks of resistance training in older women decreased intra-abdominal adipose tissue ( $143.9 \pm 13.3$  vs.  $130.0 \pm 12.4$  cm<sup>2</sup>) with a positive change in mid-thigh muscle mass ( $52.9 \pm 2.6$  vs.  $58.0 \pm 2.0$  cm<sup>2</sup>) but no change in total body weight, total body fat or total fat-free mass. Concurrent strength improvements were also seen. Hunter et al. (2002), however, also included men. Fifteen women and 15 men between the ages of 61-

77 years completed a 25-week resistance training program. Results seen in the women were less striking than the men. Both sexes significantly decreased body fat percentages by greater than 2% (from  $40.1 \pm 8.7\%$  to  $38 \pm 8.7\%$  in women and  $24.4 \pm 6.3\%$  to  $21.7 \pm 6.8\%$  in men), while the women were the only ones to significantly decrease both intra-abdominal adipose tissue (from  $131.2 \pm 52.3\text{cm}^2$  to  $115.8 \pm 45.8\text{cm}^2$ ) and SAT (from  $253.6 \pm 85.6\text{cm}^2$  to  $238.8 \pm 97.8\text{cm}^2$ ). It is important to note however, that the men had much less body fat than the women to begin with. Furthermore, those women with greater visceral adiposity had the greatest positive change in fat distribution. An average total loss of body fat of 6% in the women was seen, notably nearly 12% was lost from the intra-abdominal mass.

As previously mentioned resistance training, commonly used in young adults to increase muscle mass and strength, provides the same results for older adults and inadvertently improves muscle function (Fiatarone et al., 1990). Early high-resistance training research actually revealed greater improvements in older ( $62.8 \pm 0.7$  years) compared to younger ( $23.3 \pm 1.5$  years) adults without T2DM in lean body mass increases. Given that both groups significantly altered lean body mass and body fat, but that the older group revealed a change in total body weight, greater lean body mass improvements were speculated (Craig, Everhart and Brown, 1989). Comparable improvements have been seen in protein synthesis in old adults (up to 90 years) and young adults following resistance training (Shulte and Yarasheski, 2001). This suggests resistance training as a means of reducing the age-related decrease in muscle protein synthesis, which is partially responsible for muscle protein mass reductions. Many researchers support resistance training as a means to improve lean body mass components

consequently decreasing skeletal muscle loss in older persons (Trappe, 2001; Janssen et al., 2002). Further, improvements in lean muscle mass as well as strength have been positively correlated with improved glycemic control (Castaneda et al., 2002).

### ***2.3.3 Combined Aerobic and Resistance Training***

Maiorana, O'Driscoll, Goodman, Taylor and Green (2001) developed a program that incorporated both resistance and aerobic training in a circuit fashion. Following an 8-week program with 1-hour sessions consisting of seven resistance exercises and alternating eight different aerobic stations, promising results were found for T2DM individuals ( $52 \pm 2$  years). The program was set up for the participants to maintain their heart rate within a specified target zone. Each resistance exercise was only done once and each set of 15 took 45 seconds to complete at 55% of pre-training MVC and worked up to 65% by the fourth week. Body weight did not change. Decreases in the sum of skinfolds ( $148.7 \pm 11.5$  versus  $141.1 \pm 10.7$  mm) and body fat percentages ( $29.5 \pm 1.0\%$  versus  $28.7 \pm 1.1\%$ ) were seen, although negligible. In addition, glycated hemoglobin ( $8.5 \pm 0.4$  vs.  $7.9 \pm 0.3\%$ ) and fasting blood glucose levels ( $12 \pm 0.5$  vs.  $9.8 \pm 0.5$  mmol·l<sup>-1</sup>) decreased as well. Although Maiorana et al.'s (2001) study provided positive results some single mode studies have provided superior results (Dunstan et al., 2002; Castaneda et al., 2002; Mourier et al., 1997). However, the design of the study makes it impossible to differentiate between the effects of resistance versus aerobic training or the combination of the two. It would be valuable to look at each modality and the absolute combination of the two in order to distinguish results from either modality or the combination thereof.

As previously mentioned, it is common to incorporate dietary restrictions with exercise when attempting weight loss. However, Ross et al. (2000) found that exercise alone can produce significant weight reduction provided a sufficient amount is performed. Similar body weight decreases were found following both a 12-week dietary intervention (dietary intake was decreased by 700 kcal daily) and a 12-week aerobic exercise intervention (increased energy expenditure through exercise by 700 kcal daily) (Ross et al., 1996). Ross and colleagues suggest that muscle mass content may have decreased as well and thus propose that the inclusion of exercise to induce weight loss adds the benefit of lean muscle tissue preservation. Notably however, the amount of exercise performed for this study is not realistic for the general population and was accomplished with supervision beyond that generally achieved in real life.

#### **2.4 Age Differences in Lean Body Mass and Strength**

The decline in muscle mass and consequent strength with age, now known as sarcopenia, has been debated in the past. It is now understood to be independent of physical activity and has become so well accepted that a workshop in 1994 was hosted by National Institute on Aging (NIA) in order to address related issues. Recently, Roubenoff and Castaneda (2001) confirmed that sarcopenia indeed exists in the entire elder population.

Hughes et al. (2001) found a  $12.9 \pm 15.5\%$  decrease in muscle mass in men and a  $5.3 \pm 18.2\%$  decrease in women per decade estimating muscle mass using 24-hour urine samples to assess creatinine content. These findings were concurrent with decreases in muscle strength. Whether individuals increased, decreased or maintained activity levels there was no significant difference in strength changes or muscle mass. However,

Hughes and colleagues (2001) do assert that their cohort might have been above average levels of physical activity, which could have directly confounded strength change data.

Muscle strength helps to perform daily activities, thus enabling the individual to maintain a high level of independence. Muscle mass also plays a key factor in preventing falls that are often fatal in older adults. Dutta and Hadley (1995) note the importance of age-related muscle changes such as decreased mass and metabolic function, in maintaining quality of life in the growing elder population. Vincent, Braith, Feldman, Kallas and Lownthal (2002a) following an investigation of endurance training and resistance exercise in older adults concurred that their findings imply strength gains by resistance training to improve aerobic capacity. Likewise Vincent et al. (2002b) also supports the importance of muscle strength improvement and physical performance in older adults. In a longitudinal study of adults between the ages of 45 years and 78 years, strength declines were found at follow-up testing (follow-up average was  $9.7 \pm 1.1$  years) in all muscle groups tested (knee and elbow extensor and flexor muscles) (Hughes et al., 2001). Strength is an important factor for performance in older adults (Cress, Conley, Balding, Hansen-Smith and Konczak, 1996). An age-related decrease in GLUT4 concentrations has also been established, which would further hinder metabolic function (Hughes et al., 1993).

## **2.5 The Effects of Exercise on Strength**

Muscle mass and strength are most commonly improved by implementing a resistance training program. However, aerobic exercise programs have also been credited with strength and muscle mass improvements, but generally to a lesser degree. Some may be hesitant to incorporate resistance training, specifically intensive resistance

training in the elder population for fear of injury or other potential complications. However, it has been established that the elder (Fiatarone et al., 1990) population are capable of participating in, and responding to, resistance training in a similar fashion to that of younger men (Miller et al., 1994). Furthermore, resistance training has been strongly recommended by many health advocates suggesting abundant benefits (Winett and Carpnelli, 2001; Fiatarone Singh, 2002; Deschenes and Kraemer, 2002). With that noted best results are seen following individualized programs, incorporating specific needs and varying approaches (Deschenes and Kraemer, 2002).

### ***2.5.1 Resistance Training***

Overall increases of in combined upper and lower body strength were synchronized with increased lean body mass (mean 1.2kg increase) after 4-months of resistance training in middle-aged men (Miller et al., 1994). More recently, Castaneda et al. (2002) achieved great results with an intense progressive resistance training program involving older (>55 years) Latino adults with T2DM (n=62). Following a 16-week intensive progressive resistance program including 5 pneumatic resistance machines (3 sets of 8 repetitions) conducted 3 times a week, both muscle mass and strength improved, with the latter increasing  $33 \pm 7\%$  (whole-body).

Craig, Everhart and Brown (1989) were unable to establish comparable absolute strength increases in older ( $62.8 \pm 0.7$  years, n=9) to that of the younger ( $23.3 \pm 1.5$  years, n=6) participants, where both groups followed similar programs, except that the older group did not complete biceps and triceps exercises because the researchers felt they might be too intense for this age group. When strength was expressed in percent increases however, the two groups were similar. Thus, early research by Craig et al.

(1989) supports that the elder population has the ability to respond as well to resistance training as younger individuals.

Hughes et al. (2001) collected follow-up measures for strength, muscle mass, physical activity and health and function status approximately  $9.7 \pm 1.1$  years (range: 7.9-12.6 years) after baseline assessment. These researchers found that those who reported being involved in resistance training achieved greater levels of spontaneous physical activity than those counterparts who did not. Thus contradicting results in older adults following aerobic training (Goran and Poehlman, 1992). Although greater physical activity was achieved, no differences in strength between the two groups were seen and the authors attributed the inability to stimulate strength improvements to age factors (Hughes et al., 2001). However, it seems more conceivable that the reported resistance training and increased exercise levels were not performed with sufficient intensity, frequency and/or duration to produce strength gains. The lack of structure or detailed records of exercise leaves this point unclear. However, many articles support strength gains in response to resistance training in older adults and should be weighted more heavily because intensity, frequency and/or duration were well recorded to account for actual physical activity performed.

### ***2.5.2 Aerobic Training***

Aerobic training is often prescribed for T2DM as a means to improve blood glucose levels and insulin resistance and can do so despite little evidence of any great beneficial effect on body weight (Boulé et al., 2001). Improvements in strength and muscle mass are less pronounced. Early research by Meredith et al. (1989) has found no muscle mass improvements after endurance training in either the old ( $65.1 \pm 2.9$  years) or

the young ( $23.6 \pm 1.8$  years) individuals. Although, Meredith and colleagues (1989) were able to demonstrate improved oxidative capacity as well as increased glycogen stores in the muscle in the older group. Such promising data substantiates beneficial muscle adaptation following aerobic training in older adults. Other researchers have been able to find increased and/or maintained muscle mass with aerobic training (Ross et al., 1996). Furthermore, Ross et al. (2000) found their exercise group (12 weeks of treadmill walking for one hour per day, 7 days a week at 70% maximal heart rate reserve) preserved skeletal muscle after weight loss. Meredith et al (1987) found previously aerobically active (a minimum of 2 years prior to testing) young ( $26.8 \pm 1.2$  years) and older ( $52.0 \pm 1.9$  years) men showed no difference in lean body mass, an encouraging result. The older group also showed greater fat mass.

### ***2.5.3 Combination Resistance/Aerobic Training***

It would seem reasonable to hypothesize that the combination of resistance and aerobic training would produce additive results. Unfortunately, there is a lack of research on the combination of the two modalities and results are inconclusive. There is a further lack of such research in the T2DM and elder population in this regard.

Maiorana et al. (2001), found significant improvements in muscular strength ( $403 \pm 30$  kg to  $456 \pm 31$  kg, sum of 7 maximal contractions) following an 8-week combined aerobic and resistance program in a circuit training design involving T2DM participants ( $52 \pm 2$  years). Glycemic control and functional capacity also improved leading Maiorana et al. to strongly advocate this method of training for individuals with T2DM.

Cress et al. (1996) implemented a combined aerobic and resistance training program for older women. The program consisted of weighted stair climbing (10% of

body weight was carried on the participants back while ascending and descending stairs), upper body resistance exercises done with elastic tubing, half an hour of endurance dancing and a 10-minute warm-up/cool-down and stretching period (3/wk for 50 wks). Strength and stair climbing performances did improve although the study lacks statistical power as there were only 13 participants involved and strength gains were only seen in isokinetic knee extensions at 180°/sec ( $7.8 \pm 1.5$  Nm). However, the authors also indicated the need for exercises to develop knee extension strength due to its involvement in stair climbing.

## **2.6 Age Differences in Glycemic Control**

Age-related decreases in basal insulin secretion (Iozzo et al., 1999) and glucose tolerance (Broughton, James, Alberti and Taylor, 1991) have been established in the elder population, however there is much debate as to the cause of such changes. Many of the potential causes have been previously discussed, such as; increased abdominal obesity (specifically VAT), decreased activity levels, decreases in lean tissue mass leading to decreased glucose transporters etcetera. Therefore, it is difficult to distinguish declines in glycemic control due to aging *per se*, or those due to other confounding factors. Regardless of whether decreased glycemic control is due to decreased physical activity, increased body fat or exclusively aging, each element claims some portion of liability.

## **2.7 Adipose Tissue and Glycemic Control**

Weight loss, more specifically, fat loss, has been a cornerstone treatment for those with glucose impairments for decades, generally by prescribing aerobic exercise and a dietary intervention, although weight loss by any means, has been proven beneficial in glycemic control. To illustrate this point, great improvements in fasting insulin (84%),

insulin sensitivity (360%) and insulin action following vast fat losses by surgical procedures ( $142.3 \pm 6.8$  to  $79.6 \pm 4.1$  kg) in morbidly obese participants have been seen (Houmard et al., 2002).

Combining aerobic training and dietary treatment is common and is often recommended for weight loss. Nonetheless, aerobic training by itself can provide beneficial weight loss results. Walker, Piers, Putt, Jones and O'Dea (1999) included 11 T2DM women who followed a 12-week walking program (a minimum of 1hr walk, 5x/wk) and examined cardiovascular risk factors and body composition. They found significant decreases in body weight ( $77.9 \pm 13$  to  $76.4 \pm 12.3$  kg), upper body fat ( $18.3 \pm 5.5$  to  $17.2 \pm 5.1$  kg) and waist fat ( $4.45 \pm 1.27$  to  $4.15 \pm 1.23$  kg). However, total energy expenditure and the intensity of exercise were not recorded. Therefore, difficulty remains in establishing detailed weight loss guidelines through walking. However, it was not reported if absolute improvements were clinically significant. Further research has also shown the value of resistance training (with dietary intervention) to induce weight (specifically VAT) loss (Ross et al., 1996) and found VAT mobilization in both men and women in weight loss induced by diet alone, or in concert with either aerobic or resistance training. Fat losses were comparable following dietary intervention with or without exercise. However, SAT reductions with exercise were more central than following dietary intervention only, where the loss was relatively uniform.

FFAs released from highly lipolytic VAT contribute to insulin resistance. Hickner, Racette, Binder, Fisher and Kohrt (2000) studied the antilipolytic response of 10 obese premenopausal women. Following 10 days of endurance exercise (1hr/day for 10 out of 14 consecutive days, working at 70%  $\text{VO}_{2\text{max}}$  for 25min followed by five 5min

intervals at 90%  $VO_{2max}$  ) improved insulin mediated antilipolytic action was seen. Specifically, it was suggested that the main sites for such improvements were VAT or skeletal muscle because SAT did not show improvements.

## 2.8 Exercise and Glycemic Control

Low levels of physical activity have been associated with decreased insulin sensitivity and those who engage in physical activity are less likely to develop metabolic complications, such as hyperglycemia and T2DM. Glucose disposal in athletes, per kg of muscle mass is much greater (32% higher) than sedentary individuals. Ebeling et al, (1993) found improved glucose disposal rates which he and his colleagues correlated with improved forearm blood flow (64% improvement compared to control group), although improved blood flow compared to a sedentary population had only a small impact on improved glycemic control. Other factors that improve glycemic control in athletes include increased muscle mass and muscle contraction, with subsequent increases in glucose transporter action, decreased body fat, specifically lower VAT masses, thereby decreasing the propensity of FFA release and the consequent insulin resistance.

Since skeletal muscle is a primary target tissue for glucose transport and glucose utilization, strategies targeting changes in skeletal muscle could play key roles in treating insulin resistance. Insulin stimulates the translocation of GLUT4 to the surface of the cell, an essential step for glucose entry into skeletal muscle (Abel, Shepherd and Kahn, 1996). The decreased function of insulin may be related to an increase in TNF- $\alpha$  expressed in obese T2DM individuals (Katsuki et al., 1998). The release of TNF- $\alpha$  is increased with increased mass of fat cells and slows GLUT-4 translocation. It has also

been suggested that the TNF- $\alpha$  inhibits further adipocyte hypertrophy and is possibly linked to insulin resistance in obesity (Skolnik and Marcusohm, 1996). Prevention of TNF- $\alpha$  induced insulin resistance may be possible by blocking TNF- $\alpha$  function, as elucidated by Ruan, Miles, Ladd, Ross, Golub, Olefsky and Lodish (2002) who found reduced sensitivity to insulin and subsequent increase in FFA (70%) plasma concentrations following a 1 day TNF- $\alpha$  exposure treatment. Consequently both decreased GLUT4 translocation and increased TNF- $\alpha$  reduced glucose uptake via skeletal muscle and promoted increased blood glucose levels. Fortunately for obese individuals, including many with T2DM, it is now understood that there are two separate GLUT4 pools that are activated by different stimuli, one dependent upon insulin and the other on exercise (Coderre, Kandror, Vallega and Pilch, 1995). Therefore, although glucose uptake via insulin is decreased, obese individuals can continue to stimulate GLUT4 translocation with exercise, thereby decreasing blood glucose levels. This theory is a powerful argument to support exercise for those with insulin resistance.

Hughes et al. (1993) were the first to determine that exercise increases GLUT4 protein in human muscle using a longitudinal approach. As previously mentioned GLUT4 can be activated by two separate stimuli leading to decreased blood glucose levels (either via exercise or insulin). Cox et al. (1999) studied the effect of exercise on GLUT4 concentrations and insulin sensitivity. They found significantly increased GLUT4 protein concentrations following one week of cycle ergometry at 70-75%  $VO_{2max}$  in young (18-30 years) men and women as well as older (50-70 years) men and women. No age effect on training response was found, concluding that increasing GLUT4 concentrations by aerobic exercise at similar intensities, both old and young will respond

in a similar fashion. Moreover, increased glucose transporter concentrations should have a great positive impact on improving insulin action, although with such a short training period Cox et al. (1999) did not find such results. However, Ebeling et al. (1993) found GLUT4 protein concentrations in the muscle of athletes were 93% higher than non-active control participants and associated this finding with improvements in total body glucose disposal (Ebeling et al., 1993).

Hughes et al. (1993), found older adults with impaired glucose tolerance were able to improve glucose disposal through improved insulin response in the peripheral tissues, while maintaining a stable body weight with aerobic activity. However, Tessier et al. (2000), who focused exclusively on elder (>65 years) T2DM patients, found no significant changes in HbA<sub>1C</sub>, fasting glycemia, BMI or total body weight in the exercise (n=19) group. The study implemented a 16-week aerobic/endurance exercise training that consisted of 20 minutes of rapid walking 3x/wk, starting at 35-59% HR<sub>max</sub> and working towards 60-79% HR<sub>max</sub> by the fourth week which was maintained for the remaining 12 weeks. Strength/endurance exercises were also included comprised of 2 sets of 20 repetitions taxing major muscle groups. Some beneficial results were seen however; improved treadmill time at follow-up testing and a reduced area under the curve for glycemia during the oral glucose tolerance test in the exercise group were seen.

Both normoglycemic women and women with T2DM who participated in a 12-week walking program for 1-hour walks/5 days a week, improved BMI and central fat masses and produced subsequent improvements in fasting blood glucose and HbA<sub>1c</sub> levels. Using a step-wise multiple regression analysis, the authors found glycemic improvements were related with central fat losses rather than improved fitness parameters

( $VO_{2max}$  , in this case) (Walker et al., 1999). Castaneda et al. (2002) also found promising results in older T2DM following exercise training. This was seen following a 16-week randomized controlled trial implementing progressive resistance training program. Improvements in glycemic control of  $12.6 \pm 2\%$  versus a negative change of  $1.2 \pm 1\%$  was seen in the exercise group, compared with the control group.

Healthy men, between the ages of 50 and 63 years, showed improved insulin action following a 16-week resistance training program. Concurrently, improvements in overall strength (47%), fat free mass (from  $62.4 \pm 2.1$  kg to  $63.6 \pm 2.1$  kg) and decreased body fat percentage ( $27.2 \pm 1.8\%$  to  $25.6 \pm 1.9\%$ ), were exhibited with improved fasting plasma insulin albeit no significant change was seen in fasting plasma glucose levels (Miller et al., 1994). Postmenopausal women also displayed improved insulin action after a 16-week resistance training program and positive strength changes were also noted (Ryan, Pratley, Elahi and Goldberg, 2000).

The more practical “side effects” of exercise are also of clinical importance. An impressive reduction in glucose lowering medication occurred in 72% of T2DM patients randomized to resistance training, compared to 3% of participants in the T2DM control group (Castaneda et al., 2002). In the same study, 42% of participants in the control group had their glucose-lowering medications increased versus only 7% in the resistance exercise group. Overall, it is clear that exercise can decrease HbA1c levels great enough to reduce diabetic risks (Boulé et al., 2001)

## **2.9 Conclusion**

Ten percent of the older Canadian population has T2DM according to the latest survey, and this number will rise as the general population ages (Health Canada (a),

2003). Trends of decreased activity levels, decreased muscle mass and increased adiposity are well documented in this population. With age, it is common for even elite athletes to decrease physical activity, if not in duration, generally in intensity (Katzel et al., 2001). Decreases in physical activity are linked to both decreased muscle mass and increased body fat, however, they are also present independent of physical activity, and are in part due directly to aging. Moreover, increased adiposity with age is generally focused in the metabolically dangerous central and visceral regions (Hunter et al., 1997). Both aerobic and resistance (Miller et al., 1994) exercise have lead to significant fat loss, especially in concert with dietary intervention (Ross et al., 1996). Resistance training increases muscle mass, while both resistance and aerobic training will preserve muscle mass and defend against the effects of sarcopenia. Furthermore, both modalities have also shown strength improvements. Older participants are able to respond in a similar manner than their younger counterparts to both aerobic and resistance training for the aforementioned parameters (Mazzeo et al., 1998). However, when focusing on glucose control adaptations, the exercise response between the two age groups is less understood.  $\beta$ -cell failure and decreased insulin secretory capacities are common in older adults (Chang and Halter, 2003). Exercise has been shown to improve glucose control, even without weight loss (Boulé et al., 2001), and both young and old have shown similar improvements. Nevertheless, there is a present lack of research to establish whether older T2DM participants improve glycemic control in the same manner as their younger counterparts following the same exercise modality or between aerobic and resistance training. Collectively, such data could provide useful insight into the most efficient treatment approach for each specific age group within the T2DM population.

### **CHAPTER III: ARTICLE**

**OLDER AND YOUNGER T2DM PARTICIPANTS RESPOND SIMILARLY  
IN BODY COMPOSTION, METABOLIC PROFILE AND FITNESS TO 6-MONTHS  
OF AEROBIC, RESISTANCE AND COMBINED AEROBIC AND RESISTANCE  
EXERCISE**

## ABSTRACT

In previous research, resistance exercise reduced HbA1c primarily in studies of older type 2 diabetic (T2DM) subjects (age>55), while aerobic exercise reduced HbA1c primarily in studies of relatively younger subjects. We compared changes in HbA1c, fitness and body composition in response to 6 months of exercise training in older (55-70 yrs: n= 53) vs. younger (40-54 yrs: n=44) T2DM participants in a randomized trial.

Previously inactive T2DM subjects were randomized to aerobic exercise (**A**; progressing to 45min at 75% HR max, n=24), resistance exercise (**R**; 2-3 sets of 8-12 RM, n=23), combination aerobic and resistance training (**AR**; n=25) or a waiting control-list group (**C**; n=25). Each exercise group trained 3x/wk for 6 months. Strength testing was done using an 8 repetition maximum (RM) protocol for seated row, leg press and bench press. VO<sub>2</sub>peak was assessed using graded treadmill protocols to volitional fatigue. A single cut CT scan was used to quantitate abdominal visceral and subcutaneous fat and mid-thigh muscle cross-section. All tests were performed at baseline and 6-months.

The responses of older and younger subjects did not differ significantly on any measure. A1c decreased from 8.0 % to 7.1% in younger **A**, and from 7.4% to 6.7% in older **A**. In **AR** decreases were similar: 7.9% to 6.8% in younger **AR**, 7.8% to 6.8% in older **AR**. A1c changed little in **R**: 7.8% to 7.7% in younger **R**, 7.7 to 7.3% in older **R**. No significant change in HbA1c occurred in either older or younger subjects in **C**. Mean increases in VO<sub>2</sub>peak for **A** were 6.9% in old and 7.4% in young and for **AR** were 7.6% in old and 4.9% in young. Strength increased in **AR** by 47.5%, 51.0% and 37.9% in young and 41.1%, 46.0% and 30.4% in young for bench press, leg press and seated row respectively. The **R** young group improved by 68.6%, 86.2% and 47.6% and the old by

44.3%, 72.3% and 31.9% for bench press, leg press and seated row respectively. The aerobic only group also improved in strength. Neither  $VO_2$ peak nor strength changed significantly in C. Therefore, older (55-70 years old) and younger (40-54 year old) T2DM subjects responded similarly to aerobic, resistance or combined exercise in terms of glycemic control, strength, and aerobic fitness.

## INTRODUCTION

The worldwide presence of T2DM will increase as the general population ages. Ten percent of Canadians > 65 years have T2DM versus only 3% of those between 35-64 years (Health Canada (a), 2003). Average health care costs for individuals with diabetes are generally 2-5 times higher than non-diabetic individuals of the same age (CDA). Furthermore, sixty-three percent of costs spent on T2DM in the US are being spent on those > 65 years (Huse, Oster, Kellen, et al, 1989), resulting in a massive financial burden. Much of the increased costs are due to medications. Therefore, there is much potential both in terms of health and economics from successful nonpharmacological interventions for diabetics. Finding the most effective exercise regimes for the growing older population with T2DM is imperative.

Trends of decreased activity levels, decreased muscle mass and increased adiposity are well documented in elderly. With age, it is common for even elite athletes to decrease physical activity, if not in duration, generally in intensity (Katzel et al., 2001). Decreases in physical activity are linked to both decreased muscle mass and increased body fat, however, these body composition change are also present independent of physical activity, and are in part due directly to aging. Moreover, increased adiposity with age is generally focused in the central and visceral regions posing a metabolic threat (Hunter et al., 1997). Both aerobic (ACSM, 2001) and resistance (Miller et al., 1994) exercise have lead to significant fat loss, especially in concert with dietary intervention (Ross et al., 1996). Resistance training is preferred to increase muscle mass, while both resistance and aerobic training will preserve muscle mass and defend against the effects of sarcopenia. Furthermore, both modalities have also shown strength improvements.

Older participants are able to respond in a similar manner than their younger counterparts to both aerobic and resistance training for the aforementioned parameters (Mazzeo et al., 1998). However, when focusing on glucose control adaptations, the exercise response between the two age groups is less understood.

Exercise has been shown to improve glucose control, even without weight loss (Boulé et al., 2001), and both young and old have shown similar improvements. Nevertheless, there is a present lack of research to establish whether older T2DM participants improve glycemic control to the same extent as their younger counterparts following the same exercise modality or between aerobic and resistance training. Specifically, it may be important to recognize older T2DM individuals separately in determining a practical exercise prescription. Older adults might respond differently to different modalities of exercise (ie. aerobic, resistance or the combination thereof) and therefore may merit a different approach to exercise prescription unique to the sub-population. Collectively, such data could provide useful insight into the most effective treatment approach for each specific age group within the T2DM population.

In recent studies, older type 2 diabetic individuals (age >55 or 60 years) improved glycemic control through resistance training (Castaneda et al, 2002; Dunstan et al, 2002). Unfortunately, only one group of researchers has focused on aerobic exercise exclusive to the older T2DM patient and it did not find significant HbA<sub>1c</sub> improvements following training (Tessier et al., 2000). Conversely, the studies showing improvement in HbA<sub>1c</sub> through exercise have involved relatively younger subjects. There is a relative lack of aerobic training research done in older diabetic patients, and a relative lack of resistance training research done in younger diabetic patients.

In summary, there is a lack of research on effects of aerobic exercise in older diabetic subjects, and a similar lack of research on effects of resistance exercise in younger diabetic subjects. There are reasons to believe that optimal exercise prescriptions might differ according to age group. Therefore, the focus of the current study is determine whether or not a difference in glycemic control, body composition, V02peak and strength changes following aerobic, resistance or combined aerobic and resistance exercise exist between older (55-70 years) and younger (40-54 years) previously inactive T2DM individuals following a 6-month intervention.

## METHODS

Ninety-Six previously sedentary individuals with Type 2 Diabetes Mellitus (68 men, and 28 women) not taking insulin with HbA1c levels between 0.066 and 0.099 took part in this study. Participants were categorized into two age groups, 40-54 years (n=44) and 55-70 years (n=53) (see Table 1). Table 4 depicts baseline and follow-up characteristics. Recruitment was done through local radio, physicians and newspaper advertisements. Exclusion criteria included 1) participation in regular physical activity ( $\geq 2$  times per week for at least 20 minutes per session) during the previous 6-month 2) insulin therapy 3) change in medication for diabetes, blood pressure or lipids in the 2 months prior to enrolment 4) significant weight change (increase or decrease of  $\geq 5\%$  of body weight) during the 2 months prior to enrolment 5) significant renal disease (serum creatinine  $\geq 200$  mEq/l. or proteinuria  $> 1$  g/24 hours) 6) uncontrolled hypertension (blood pressure  $> 160$  mm Hg systolic or  $> 95$  mm Hg diastolic blood pressure in a sitting position) 7) restriction in physical activity due to disease (ie. intermittent claudication, severe peripheral neuropathy or active proliferative retinopathy, unstable cardiac or pulmonary disease, disabling stroke or severe arthritis) 8) significant cognitive deficit resulting in the inability to understand or comply with instructions 9) unwillingness to sign informed consent. The Ottawa Hospital Research Ethics Board approved the study protocol.

*Experimental Design* Baseline testing included: anthropometric measurements, blood sampling, V02peak testing, strength (8RM) testing and a CT scan. Once baseline testing was completed and the subject fit all inclusion criteria, they began the one month run-in

period. During the run-in period it was mandatory for the subject to attend and complete a minimum of 10 or the 12 possible sessions in order to remain in the study. If the minimum sessions were not completed the subject was not randomized. For those who were able to attend the required sessions, they were randomized at this time. Following randomization each subject followed the protocol for their respective group (discussed in more detail below) for the following 26 weeks. Follow-up testing was completed at 6-months. A schematic representation of the experimental design can be seen in figure 1.

*Anthropometric Measurements* included body weight, height and waist circumference. Body weight was taken using a standard beam scale measured to the nearest .0 of a kilogram. Height was measured to the nearest millimetre. Waist circumference was measured at the midpoint between the top of the iliac crest and the inferior aspect of the ribcage at the mid-axillary line.

*Blood Sampling* was used to acquire HbA1c levels as a measure of glycemic control, fasting plasma glucose and insulin were also measured in order to use the HOMA model to assess insulin sensitivity. Blood samples were taken in the morning following a 12 hour fast, both at baseline and 6-months. Hemoglobin A1c analysis was done using an ion exchange chromatography (BioRAD Diastat®) and reflects an approximate 3-month average of blood glucose concentrations and is considered the best test of blood sugar control over time by the American Diabetes Association.

Fasting plasma glucose and insulin were used as an estimate of insulin sensitivity as well as  $\beta$ -cell function. The Homeostasis (HOMA) model was used where the formulas are:

Insulin Resistance Index =  $FI \times G/22.5$ , where FI represents fasting insulin levels (U/ml) and G represents fasting glucose (mmol/l) (Sakane et al., 1997).

*V<sub>O2</sub>peak* testing was performed on a separate testing day at the University of Ottawa Heart Institute both at baseline and 6-months. Participants arrived in a non-fasted state. A treadmill ramp protocol was used with continuous breath-by-breath analysis to determine *V<sub>O2</sub>peak*. A continuous 12-lead electrocardiogram monitoring (v.4.03, GE Marquette Medical Systems Inc.) was also performed to screen for ischemic heart disease. A physician was present throughout testing and testing was terminated if a clinically significant ST depression or elevation, arrhythmia, chest discomfort or lightheadedness occurred. Such subjects were eliminated from continuing participation with the study unless cleared by the consulting cardiologist after full assessment.

*Strength Testing* was done using an 8RM protocol for seated row, bench press and leg press at the University of Ottawa. A universal gym (EXM-2000S, Body Solid, USA) was used. Strength testing was done at baseline and 6-months, the tester was blind to baseline results when 6-month testing was in progress. 8-RM strength values were converted to a predicted 1-RM using the Wathan et al. (1994) prediction equation:

$$1\text{-RM} = 100 \cdot \text{rep wt} / (48.8 + 53.8 \cdot \exp [-0.075 \cdot \text{reps}]) \quad \text{Eq. 1.0}$$

The equation suggested by Wathan et al. was found to be the best suited prediction equation as it was validated in a mixed population that resembled middle-aged and older men and women more than the typical young fit college students that other equations have been validated in. Those who completed more than 10 repetitions during testing

were not included in analysis as the prediction equation loses accuracy after 10 repetitions (LeSuer et al., 1997)

*Computed Tomography* was used to quantitate abdominal, visceral and subcutaneous fat as well as mid-thigh muscle cross-sectional area. A GE scanner was used (General Electric, Milwaukee, WI) and analysis was done using Tomovision "Slice-O-Matic" (V.4.2, 2001) body composition software (Tomovision, Montreal, QC). This method has been validated for this purpose (Matsuzawa, 1997). All scans were single cut CT scans. The abdominal scan was taken at the level of the L4-L5 vertebral disk space, the mid-thigh cross-section was taken mid-way between the base of the patella and iliac crest. Visceral adipose quantities were subtracted from the total tissue area in the abdomen to establish subcutaneous adipose tissue area. Both high and low density muscle were used to calculate changes in the mid-thigh cross sectional area, representative of muscular changes (ie. hypertrophy, atrophy)

*Diet* A standard diet following the recommendations of the Canadian Diabetes Association (50-55% CHO, 15-20% protein and <30% fat) was outlined for participants. Participants met with a dietician at baseline, 3-months and 6-months. It should be noted that this was not intended as a weight loss program. A minimum of 90% of requirements for weight maintenance according to the Harris-Benedict formula (BMR for men =  $[66 + (13.7 \times \text{body weight in kg}) + (5 \times \text{height in cm}) - (6.8 \times \text{age in years})] \times 1.2$  and BMR for Women =  $[665 + (9.6 \times \text{body weight in kg}) + (5 \times \text{height in cm}) - (6.8 \times \text{age in years})] \times 1.2$ ) (Harris and Benedict, 1919) was prescribed. This strategy was chosen in order to

highlight the influence of exercise by minimizing the impact of diet on weight change, and in order to keep diet similar among groups. A three-day food log was completed prior to the visit, reviewed with the patient and dietician and used to assess dietary intake at each visit. Computer software (NUTRIBASE) (v.3.05, Cybersoft Inc., USA) was used to analyze the results.

***Exercise Intervention*** After completing initial screening and all baseline tests participants began a 4-week run-in period to assess compliance and familiarize participants with the exercise protocol. Training was done at Ottawa-area YMCAs. Participants trained 3x/wk during the run-in period completing both aerobic and resistance training 2x/wk and aerobic training at the third weekly session. Supervision was provided twice a week during this time. Attendance of 10 of the 12 possible sessions was mandatory to continue in the study. Once the run-in period was complete participants were randomized into one of four groups: aerobic exercise only (A), resistance exercise only (R), combined aerobic and resistance exercise (A+R) or the (waiting list) control group (C).

Randomization was stratified by gender and age (40-54 and 55-70 years). Supervision was provided 1x/wk for weeks 5-8 (the 4-weeks following randomization and once every two weeks for the remainder of the study). Each exercise group completed a 5-10 minute warm-up prior to training and 5-10 minute cool-down including stretching following training. The A group progressed to 45 minutes at 75% heart rate maximum on the treadmill or cycle ergometer. Polar<sup>TM</sup> Heart Rate monitors (Polar Electro A1, U.S.A) were provided. The R group progressed to 3 sets of 8 repetition maximum (8RM) by the

end of the run-in period and continued for the duration of the program progressively increasing resistance. The resistance program was made up of two alternating work-outs which are outlined in Table 2. The A+R group performed both the aerobic and resistance protocols (see Table 3). Those randomized to the waiting control list returned to their sedentary lifestyles prior to enrolment but were offered to return to exercising with the same benefits as if they had been placed in an exercise group initially upon completion of follow-up testing. A schematic representation can be seen in figure 1.

*Statistical Analysis* Means are represented  $\pm$  standard error (SE). As previously mentioned, data of those who did not complete the study post randomization was carried forward from baseline or 3 month data. The current research was a randomized controlled trial and a substudy of a larger randomized controlled project. A 4x2x2 factorial repeated measures design was used (group x age group x time). Further, a 4x2 (group x age group) multivariate analysis of variance (ANOVA) was used to establish if there were any group or age group differences at baseline for dependent variables. Change from baseline to 6-months was analyzed with a 4x2 (group x age group) repeated measures ANOVA. Main effects and interactions of treatment for absolute and relative (%) changes were analyzed using a multivariate ANOVA. Tukey's B *post hoc* was used when  $P < 0.05$  for the multifactorial repeated measures ANOVA comparison tests was found to isolate baseline differences as well as main treatment effects. Bonferonni adjustments were used when interpreting ANOVA results ( $P < 0.05/\text{number of groups}$ ).

## RESULTS

Ninety-seven participants were randomized for the pilot group, one was excluded from the present analysis due to hyperthyroidism that developed during the study. The present analysis is therefore on the remaining 96 subjects. Overall compliance throughout the program was high. There were no significant differences in post-randomization compliance between exercise groups (A=75.9%; R=81.8% and AR=76.9% respectively). There was an age difference in compliance within the AR group where the 55-70 year old group was significantly more compliant (ARO= 89% vs. ARY=69% compliant,  $p=0.038$ ). However, the lack of compliance in the younger AR group was driven primarily by two drop-outs who attended zero sessions. Compliance without those two participants was 79.4%. Eighty-seven percent of the pilot group successfully completed the study. The most common reason for drop-outs was for a medical reason. In such instances, baseline or 3-month data, whenever possible, was carried forward. All 96 participants were included for analysis of body weight, hemoglobin A1c and  $V_{O2peak}$ , as baseline measures were available to carry forward when necessary. Six participants were not included in the analysis of abdominal subcutaneous and visceral adipose because they were too large for the CT scanner and baseline measures were not taken. Thus, the number of participants included in abdominal adipose analysis per group was as follows: ARY=13, ARO=10, RY=11, RO=11, AY=11, AO=11, CY=7, CO=16. For the same reasons mentioned above eleven participants were excluded from the leg scan analysis. Three HOMA baseline values were not calculated due to missing baseline values and those participants were excluded from the HOMA model analysis. Also,

thirteen participants were excluded from the bench press analysis, 8 from the leg press analysis and 20 from the seated row analysis due to missing baseline data or too many repetitions performed. When greater than 10 repetitions were performed the accuracy of the prediction equation is reduced (LeSuer et al., 1997) and was not used for analysis.

**Body Composition** Participant characteristics at baseline and 6-months are given in Table 4. Baseline values for body weight, abdominal SAT, abdominal VAT and mid-thigh cross-sectional muscle area were not significantly different between the 40-54 year old group and the 55-70 year old group.

When age groups were pooled, improvements were significant following AR ( $p=0.039$ ) and A ( $p=0.012$ ). No age or group effect was found when comparing 0-6 month data. When considering % change however, the older A group decreased body weight significantly more than the younger A group. The older A group decreased body weight from  $101.5\pm 6$  to  $95.8\pm 4.7$  kg vs.  $99.7\pm 5.3$  to  $99.4\pm 5.3$  kg in the younger A group, a decrease of  $4.25\pm 2.4\%$  vs.  $0.53\pm 0.9\%$ , respectively. The older participants tended to have a lower baseline body weight. Further, all older exercise groups had a slightly greater tendency to lose weight than their younger counterparts.

In all exercise groups, both abdominal SAT and abdominal VAT decreased, with the exception of the younger R group who had a mean increase of  $8.61\pm 6.9\%$ . However, this increase was primarily driven by two participants, one who was extremely non-compliant and when removed from analysis the difference was negligible ( $0.28\pm 3.6\%$  change). Pooled data shows that AR groups had a significant improvement in both abdominal SAT ( $p=0.004$ ) and VAT ( $p=0.001$ ): The pooled R group had significant

decreases in SAT only ( $p=0.025$ ) and the pooled A group had significant decreases in VAT only ( $p=0.047$ ). No age effect was seen. The younger AR group improved SAT and VAT significantly ( $-5.76\pm 3.7\%$  and  $-7.56\pm 7.8\%$ ) while the older AR group had significant improvements in VAT only ( $-1.97\pm 1.44\%$ ). The older group responded with the greatest abdominal SAT decline following the R program with a  $6.1\pm 3.2\%$  decrease compared to  $3.07\pm 3.3$  and  $0.67\pm 2.6\%$  decrease in the A or AR groups respectively. The younger group responded with the greatest reduction in abdominal SAT, to the AR training, a  $5.76\pm 3.7\%$  reduction versus the  $3.30\pm 2.0$  and  $2.96\pm 2.2\%$  reductions following the R and A programs respectively. Older A and R groups had a slightly greater tendency to decrease abdominal SAT and VAT compared to the younger A and R groups. All exercise groups had slight increases in mid-thigh muscle cross-sectional area (CSA) at follow-up testing, while both control groups had a significant decline over the 6-month period (younger C group,  $-3.3\pm 1.5\%$ ; older C group,  $-0.23\pm 0.6\%$ ). When all exercise groups were pooled together, the older participants had a statistically significant increase where the younger group did not. Both younger and older age groups had the significant increases in muscle CSA following the R training program ( $2.9\pm 0.8\%$  and  $3.4\pm 1.1\%$  respectively) as well as following the AR training program ( $2.3\pm 1.0\%$  and  $2.1\pm 0.5\%$  respectively).

**Strength** Baseline and 6-month strength data are presented in Table 5. Baseline values were not significantly different between groups. Both AR and R groups significantly improved each strength measure for both age groups. The A group significantly improved leg press in both age groups and bench press for the younger A group. The

younger participants had a tendency to have greater improvements. Percent change data for bench press, seated row and leg press can be found in figures 7, 8 and 9 respectively.

***V<sub>O2peak</sub>*** No baseline differences existed between groups. Baseline and 6-month values are presented in Table 4. The older group showed greatest improvements following the combined program (24.3±1.6 to 26.0±1.4 ml/kg/min), followed by the aerobic program (23.2±1.5 to 25.0±1.8 ml/kg/min), with little to no change after resistance only training. The younger group responded best to the aerobic only training (23.9±1.6 to 23.2±1.5 ml/kg/min) followed by the combined program (23.3±1.2 to 23.7±2.2 ml/kg/min), with little to no improvement following the resistance only program. Although such changes may be due to body weight changes. Percentage change is represented in Figure 10.

***Glycemic Control*** No baseline differences between groups existed. Baseline and 6-month values are presented in Table 4. The combination group provided the best results for the younger participants (-13.17±3.2% change), followed by the aerobic only group (-7.35±3.9% change). The older adults showed similar improvements following either the aerobic only (-8.73±3.1% change) or the combination (-8.69±3.9% change) programs. The older group responded better to resistance only training than their younger counterparts where the older group improved glycemic control by 4.74±2.6% and the younger group worsened slightly. HOMA results showed significant improvement in the both the younger and older aerobic only group (p=0.002 and p=0.059 in young and old A respectively). There were no baseline HOMA differences. Further, overall both younger and older groups as a whole improved significantly (p=0.002 and p=0.059 respectively).

*Dietary Intake* No baseline differences were seen between groups for total calorie intake. However, baseline values for the aerobic only group demonstrated a significant difference in percentage of carbohydrate intake between the older and younger group. The resistance only group showed significant differences percentage of fat and the combined group had a significant difference in percent of protein intake between the two age groups at baseline. All groups started below the recommended values for carbohydrate intake (50-55% total calories). All groups were within the recommended range for protein, with the exception of the younger resistance only group who was only slightly higher ( $20.2 \pm 1.2\%$  of total caloric intake) and all groups had slightly higher % fat intakes at baseline than recommended. The younger aerobic only group increased % carbohydrate intake significantly, increasing it to within the recommended percentage. The younger resistance only group also had a significant increase in % total calories for carbohydrates, but failed to elevate intake to the recommended % intake. Younger and older participants had a significantly different change in % total caloric intake for carbohydrates within the aerobic only group they also had significantly different baseline values. Percent total caloric fat intake changed significantly differently between older and younger resistance only participants ( $2.3 \pm 8.8\%$  change vs.  $-9.3\%$  change, respectively). No significant changes were made to total caloric intake in any group.

## DISCUSSION

The goal of the present study was to examine whether or not there was a difference in response to different exercise modalities between younger (40-54 years) and older (55-70 years) T2DM individuals. An important goal for clinicians is to improve glycemic control in T2DM patients of all ages. Attaining this goal would decrease the chances of micro- and macro-vascular complications which are often the most serious consequences of T2DM. Decreasing central obesity leads to greater insulin sensitivity, while increased muscle mass and contraction increase blood glucose uptake into the muscles with and without the presence of insulin and are major contributors to the T2DM treatment. The abovementioned variables can be altered through exercise. However, the question remains as to which mode of exercise will promote the greatest benefit for older and younger T2DM, and whether the preferred mode is the same for each age classification.

### *Aerobic Exercise*

Aerobic exercise, a means of expending energy, decreasing body fat, often maintaining muscle mass and improving glycemic control, is a common recommendation for T2DM patients. Meredith et al (1987) found previously aerobically active older ( $52.0 \pm 1.9$  years) adults showed greater fat mass than younger adults ( $26.8 \pm 1.2$  years). Present data showed slightly higher VAT values for the younger, rather than the older aerobic only group (SAT values were similar, though neither was significantly different). Increased body fat, specifically VAT is in part related to the early presence of T2DM in younger adults. In T2DM participants, Mourier et al. (1997) found decreases in both abdominal SAT and VAT of -17.9% and 40.5% respectively, after aerobic training 3x/wk

at >75% of VO<sub>2</sub>peak for 55 minutes for 10 weeks. This decrease was associated with a great improvement in HbA1c (from 8.5% to 6.2%). Others have also found decreased central obesity with aerobic training, while some find little to no change. Duration and intensity are key factors in fat loss and aerobic training.

The present study did not find significant improvements in muscle mass as represented by mid-thigh CSA in either the younger aerobic only ( $1.2 \pm 0.7\%$  change) or the older aerobic only group ( $1.4 \pm 0.7\%$  change). Similarly, no muscle mass improvements after endurance training in either the old ( $65.1 \pm 2.9$  years) or the young ( $23.6 \pm 1.8$  years) individuals was seen in early research by Meredith et al. (1989). However, Meredith and colleagues were also able to demonstrate improved oxidative capacity as well as increased glycogen stores in the muscle of the older group. Such promising data substantiates beneficial muscle adaptation following aerobic training in older adults. The present study was able to find muscle mass maintenance following aerobic training, contrary to the control groups where each age group had modest declines (younger  $-3.3 \pm 1.5\%$  change; older  $-0.2 \pm 7.2\%$  change). Other researchers have also been able to find increased and/or maintained muscle mass with aerobic training (Ross et al., 1996; Ross et al., 2000). Muscle mass maintenance in Ross et al.'s trial (2000) was found in concert with significant weight loss. Weight loss was significant in the older aerobic only group of the present study but not the younger aerobic only group. Accordingly Ross and colleagues strongly encourage the use of exercise as a means of weight loss and lean body mass maintenance rather than diet alone, or in concert with dietary interventions.

It is clear that aerobic training can improve cardiovascular fitness even in very old (>80 years) adults (Vaitkevicius et al., 2002). Within our study the increases of  $VO_{2peak}$  on the aerobic only group were  $7.4 \pm 1.7\%$  in the younger group and  $6.8 \pm 4.0\%$  in the older group. However, improved cardiovascular fitness does not necessarily enhance total energy expenditure in older adults. It is suggested that older adults compensate by decreasing daily physical activity while involved in regular aerobic training (Goran and Poehlman, 1992). Further, there were also concurrent improvements in body weight which could account for improved  $VO_2$  values. Other benefits however, are brought about by aerobic training such as the effect of exercise on FFA release. FFAs released from highly lipolytic VAT contribute to insulin resistance. Hickner, Racette, Binder, Fisher and Kohrt (2000) studied the antilipolytic response of 10 obese premenopausal women. Following 10 days of endurance exercise (1hr/day for 10 out of 14 consecutive days, working at  $70\% VO_{2max}$  for 25min followed by five 5min intervals at  $90\% VO_{2max}$ ) improved insulin mediated antilipolytic action was seen. Specifically, it was suggested that the main sites for such improvements were VAT or skeletal muscle because SAT did not show improvements. This was seen in basal state without change in body composition. Aerobic exercise can improve glycemic control even with a lack of body composition changes (Boulé et al., 2001). Improved glucose transport via GLUT4 (Dela et al., 1994) and increased muscle glycogen stores (Hickner et al., 1997) contribute to improved glycemic control.

Glycemic control improved significantly in both age groups following aerobic exercise. The younger group improved HbA1c from  $0.080 \pm 0.003$  to  $0.071 \pm 0.002$  and the older group from  $0.074 \pm 0.003$  to  $0.067 \pm 0.003$ . Contrary to these findings, the one study

to date that focused primarily on older (>65 years) T2DM adults and aerobic exercise (Tessier et al., 2000) failed to find improvement in HbA1c, leaving the impression that older T2DM may not respond well to aerobic only training. No studies to our knowledge have compared such a response with younger T2DM adults. Present results show older T2DM adults are able to respond in a similar fashion to younger T2DM adults to aerobic training in body weight, abdominal VAT and SAT, mid-thigh muscle CSA, HbA1c and  $\dot{V}O_{2peak}$ . Further, results showed a significant improvement in HbA1c and  $\dot{V}O_{2peak}$  for the older and younger group. The older group even showed mildly greater HbA1c improvements than the younger group (AY=-7.3±3.9% change and AO=-8.7±3.1% change). The relatively short duration of Tessier et al.'s study (16-weeks) may be a contributing factor to the lack of significant improvement. Clearly more randomized controlled trials of greater duration are still necessary for conclusive generalizations regarding aerobic training in the older T2DM population.

### *Resistance Exercise*

Resistance training as a treatment for T2DM has been overlooked until the recent past. Fiatarone Singh (2002) however seems to be a present vocal enthusiast for resistance training as a part of collaborative treatment for T2DM. In a recent publication Willey and Fiatarone Singh (2003) proclaim progressive resistance training (PRT) as a "new strategy for fighting insulin resistance". PRT improves muscular strength, but also improves body composition by improving muscle size concurrent with decreased VAT and total body fat (Treuth et al., 1995). The present study supports this statement, with the exception of VAT in the younger resistance only group who had a mean increase of 8.6±6.9%, although primarily driven by two participants who were extremely non-

compliant and had respective VAT increases of 57% and 41%. By removing these two participants the percent change became negligible ( $0.28 \pm 3.6\%$ ) for abdominal VAT measures.

ACSM recommends PRT for older adults and obese persons as a means of preventing T2DM (ACSM, 1998). However, the American Diabetes Association (2001) clearly suggests that “high-resistance” exercise is not suitable for the elderly or those with long standing T2DM, even though Fiatarone et al. (1990) found high-intensity strength training to be beneficial in strength, muscle and mobility gains for frail nonagenarians. The ADA does however support moderate weight training, focused on high repetitions and light weights for the upper-body to “nearly all” T2DM patients. Randomized trials have examined the effects of high-intensity resistance training in T2DM adults (Dunstan et al., 2002; Castaneda et al., 2002) producing improvements in glycemic control. Dunstan et al. (2002) randomized 36 T2DM individuals to 6 months of progressive resistance training plus weight loss or flexibility exercise plus weight loss. HbA1c declined  $1.2 \pm 1.0\%$  in the resistance training plus weight loss group vs. a decline of  $0.4 \pm 0.8\%$  in the control (weight loss only) group ( $p < 0.05$ ). These studies included participants aged 55-80 years and did not include younger T2DM individuals. A shorter study of 16-weeks of progressive resistance training (Castaneda et al., 2002) with participants  $>55$  years, found HbA1c improved  $-4.3 \pm 0.2\%$  compared to control participants who showed no change. Similar resistance exercise in the present study resulted in a smaller percent change of  $-4.7 \pm 2.6\%$  in the older resistance only group from baseline to 6-months. Further, such improvements did not occur in the younger resistance only group who only improved HbA1c levels by  $0.13 \pm 3.3\%$ . It would be of

benefit to have more research available on resistance training in the younger T2DM population and as well as resistance training versus aerobic training for both ages (Willey and Fiatarone Singh, 2003).

The present study found significant increases in mid-thigh muscle cross section area for both age groups following resistance training, but not aerobic training only. The older control group decreased muscle CSA area minimally ( $-0.23 \pm 0.6\%$ ) while significant muscle CSA was lost in the younger control group ( $-3.4 \pm 1.5\%$  change after 5-months of being sedentary). Exercise is a means of hypertrophy or muscle mass maintenance. Both age groups, following all exercise programs (A, R and A+R) in the present study, had modest improvements in mid-thigh muscle CSA following resistance only training.

Decreases in muscle mass will lead to decreased strength. The resistance only group also provided the greatest strength improvements. In the present study, strength was measured using an 8RM for bench press, leg press and seated row. The older T2DM population showed greater baseline values for bench press only. The younger exercise groups (A, R and AR) showed greater strength improvements than the older exercise groups for all exercises (bench press, leg press and seated row); however the differences were not significant. The control groups, with the exception of the older group for bench press only, also had modest improvements in strength. However, this is likely a residual effect from the 1-month run-in period during which they became familiar with the resistance exercises.

Since improved glycemic control is a key goal of T2DM treatment and aerobic training (but not resistance training) provided significant improvements in HbA1c in both age groups, resistance training does not seem like the best treatment option for either age group. However, the benefits of resistance training should not be overlooked, especially for the older groups. Variables that were not looked at in the present study are also important to account for. For example, according to the American College of Sports Medicine (1998) resistance training can provide a multitude of benefits for the elder population including bone density, functional status as well as increasing physical activity. In support of this last statement Nelson et al. (1994) found daily physical activity and total energy expenditure improved with resistance training contrary to another group's finding following aerobic training (Goran and Poehlman, 1992) in older adults. Although it seems the younger T2DM group did not benefit greatly from resistance training alone (with the exception of significant improvements in strength and mid-thigh muscle CSA, which were minimal following aerobic only training), the older T2DM group had a slightly better response in all parameters with the exception of strength. It should be noted that the younger control group had a tendency to decrease mid-thigh muscle cross sectional area greater than the older control group. However, baseline values for the control group were unlike those of the exercise groups as all older exercise groups had lower baseline mid-thigh CSA values but the control group did not (younger= $412.21 \pm 84.1$  cm<sup>2</sup>; older= $433.71 \pm 34.1$  cm<sup>2</sup>). Regardless, maintaining muscle mass is also important to younger T2DM. Comparable improvements were seen following resistance training and aerobic training in the older group in abdominal VAT, strength and mid-thigh muscle CSA and a greater improvement was seen following

resistance training in abdominal SAT (older aerobic group =  $-3.1 \pm 3.3\%$  change; older resistance group =  $-6.1 \pm 3.2\%$  change). As previously documented, resistance training should play an integral role in the treatment of older adults with T2DM (Willey and Fiatarone Singh, 2003), but should likely be in concert with another form of treatment to make up the difference in improved glycemic control. It would be of benefit to have more research available on a suitable intensity for older T2DM since it seems that intensity of resistance training is a function of improved insulin sensitivity (Willey and Fiatarone Singh, 2003).

### *Combined Aerobic and Resistance Exercise*

Few researchers have examined the effect of combining aerobic and resistance training in the T2DM population and it was generally done in a circuit fashion (Honkola, Forsén and Eriksson, 1997; Maiorana et al., 2001) rather than adding an aerobic training program to a resistance training program. It was part of the goal of this study to determine the effects of combined aerobic and resistance training on older and younger T2DM individuals and if they responded differently to fitness, metabolic and body composition parameters.

Dunstan et al. (2002), Castaneda et al. (2002) and Mourier et al. (1997) have all shown greater improvements in single mode studies than the beneficial results found by Maiorana et al. (2001) following a circuit training regime. In the present study however the combined program provided a greater amount of significant improvements for both age groups than either method alone. Notably, energy expenditure was not equal in each program and the improvements following the combined program are likely related to relatively higher energy expenditure. Combined treatment provided the greatest results

for the younger participants in VAT declines by  $-7.6 \pm 7.8\%$ , SAT by  $-5.8 \pm 3.7\%$  and HbA1c by  $-13.2 \pm 3.2\%$ . Results in the older group for VAT, SAT and HbA1c and  $V_{O2peak}$  were the greatest following AR. As previously discussed, resistance training alone provided the greatest improvement in both strength and mid-thigh muscle CSA for both ages. However, the combined group did show comparable results, although more so for the older group. Aerobic training alone provided greatest improvements for the younger group in  $V_{O2peak}$ , but nothing else. Although improvement in HbA1c for the older group was equivocal following both aerobic only exercise and combined aerobic and resistance exercise.

### ***Overall***

Overall the present study demonstrated decreased body weight and abdominal SAT and an increase in mid-thigh cross-sectional area and  $V_{O2peak}$  in both age groups following all exercise interventions. HbA1c was also improved in both age groups for all exercise groups with the exception of the younger R group, as previously discussed. Some differences were noted, although they lacked statistical significance. For example, when comparing percent change of body weight in the older versus the younger participants within the aerobic only group in the present study, the older group did have a significantly greater weight loss than that of the younger aerobic only group. The older aerobic only group did however also have greater mean body weights at baseline. In support, Ballor and Keesey (1991) found the amount of weight lost post exercise is directly related to baseline obesity suggesting that the greater percent change in body weight is more likely related to initial body weight rather than age *per se*. Conversely, pooled data for the older group had a slightly greater tendency to decrease body weight

overall even though the pooled younger group had higher baseline measures. The younger T2DM participants had a mean initial body weight of  $100.4 \pm 16.8$  kg versus  $93.3 \pm 19.2$  kg in the older T2DM group. Unfortunately, the actual size of the adipocytes was not measured but may play a role in amount of fat lost.

More importantly, and of greater clinical significance, is central adiposity. In the present study pooled results showed no significant difference in baseline values between age groups. Although the younger T2DM group did have slightly greater initial values (younger T2DM;  $411 \pm 23$  cm<sup>2</sup> SAT and  $214 \pm 16$  cm<sup>2</sup> VAT versus  $333 \pm 19$  cm<sup>2</sup> SAT and  $208 \pm 12$  cm<sup>2</sup> VAT for the older T2DM group) than the older group. One study comparing healthy older (50-70 year old) and younger (18-30 year old) adults showed that the older group had significantly more body fat (calculated using skin folds) at baseline. It is possible that the lack of significant difference in baseline values in the present group is due to the relative proximity of the two age groups. However, it is also conceivable that the similarity of abdominal adipose measures between the younger and older T2DM groups may be more closely related to T2DM itself. The older T2DM group had a slightly greater tendency to decrease abdominal VAT in all exercise groups and abdominal SAT in all but the combined exercise group. Again, baseline abdominal SAT measures were higher in all of the younger groups (aerobic, resistance, combined and control).

Physical activity is commonly known to reduce the deterioration of aerobic capacity in older adults (ADA, 2002). Although the present study found little change following resistance exercise alone, Vincent et al. (2002) propose that strength gains from resistance training could lead to improved aerobic capacity in elderly men and women.

The combined aerobic and resistance program and the aerobic only program provided the best results, where the older group responded slightly better to the combined program than the younger group. Ross et al. (1996) showed improvements of 14% in 33 obese men following 16 weeks of diet and aerobic training. Our findings were slightly less impressive, but significant nonetheless following either the aerobic (young group improved  $7.4 \pm 1.8\%$  and the older group improved  $6.8 \pm 4.0\%$ ) or the combined (young group improved  $4.9 \pm 2.6\%$  and the older group improved  $7.6 \pm 3.5\%$ ) programs. Improvements were only slightly greater when drop-out participants, where data was carried forward were removed (the younger A group improved  $10.2 \pm 1.6\%$ , the older A group improved  $8.7 \pm 4.9\%$  and the younger AR group improved  $5.8 \pm 3.3\%$  while the older AR group improved  $8.8 \pm 4.4\%$ ).

Present study participants were relatively well-controlled T2DM with HbA1c levels ranging between 0.066 and 0.099. There were no significant baseline differences between the age groups. Further, there was no significant difference between the age groups following exercise with the exception of the resistance only group, where the younger T2DM had a negative response. Both older and younger participants improved glycemic control best following the combined exercise program, especially the younger group with  $13.2 \pm 3.2\%$  decline in HbA1c. To our knowledge there are no similar studies to date to compare these results. Although the negative change in the younger resistance only group is negligible, the older T2DM responded slightly better to resistance only training.

This is the first study to examine if older and younger T2DM responded differently to aerobic, resistance or combined exercise. Studies of individuals with T2DM in the past have focused on the effects of resistance training, primarily in the older T2DM population (Miller et al., 1994; Casteneda et al., 2002; Dunstan et al, 2002), and the effects of aerobic training, primarily on the younger T2DM population (Mourier et al., 1997), with the exception of Tessier et al. (2000), who found discouraging results for older T2DM adults following aerobic training. Our findings demonstrated no significant difference in change of body weight, abdominal VAT, abdominal SAT, mid-thigh muscle CSA, strength, VO<sub>2</sub>peak, or glycemic control between the older and younger T2DM participants following a 6-month exercise intervention. Furthermore, contrary to past literature (Tessier et al., 2000), The present study demonstrated significant improvement in glycemic control in the older T2DM aerobic only group where results were similar to their younger counterparts on this and other measures. Resistance training however, did not provide significant improvement in glycemic control in either group. Thus each age group responded similarly, even in strength gains following 6-months of aerobic only and resistance only training.

The main goal for improvement in any patient with T2DM is to maintain proper glycemic control, however, there are added benefits for both T2DM and the older population to maintain and/or increase muscle mass and strength and decrease abdominal adiposity. Therefore, it is strongly suggested that there are benefits to both exercise modalities and that the combination of the two provides the greatest improvements in older T2DM. Further, our data suggest that resistance training alone does not provide

adequate change in younger T2DM individuals. The addition of aerobic training and resistance training seems to provide the greatest overall benefit for this group.

## STATEMENT OF CONTRIBUTION OF COLLABORATORS

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Table 1. Number of participants in each group, also showing the number of men and women in each group.

NUMBER OF PARTICIPANTS PER GROUP		
	40-54 yrs	55-70 yrs
<b>AEROBIC</b>	11 (M=7;W=4)	12 (M=10;W=2)
<b>RESISTANCE</b>	11 (M=9;W=2)	12 (M=8;W=4)
<b>COMBINED</b>	15 (M=8;W=7)	10 (M=9;W=1)
<b>CONTROL</b>	7 (M=5;W=2)	18 (M=12;W=6)
<b>TOTAL</b>	<b>44</b>	<b>52</b>

Table 2. List of exercises completed during resistance training focusing on major muscle groups. Group A and group B exercises are done on alternating days.

GROUP A EXERCISES	GROUP B EXERCISES
Abdominal Crunches	Abdominal Crunches
Seated Row	Lateral Pulldowns
Seated Bicep Curls	Seated Chest Press (Fly)
Bench Press	Leg Press
Leg Press	Upright Rows
Shoulder Press	Triceps Pushdown
Leg Extension	Leg Curls

Table 3. Exercise protocol outline from week 1 to week 26 for both the aerobic only group as well as the resistance only group. The combination group follows both the aerobic only protocol as well as the resistance only protocol.

Week	Aerobic Training			Resistance Training			
	Duration (min/day)	Intensity (%HR max)	Frequency (days/wk)	Sets	Reps	Weight (RM)	Frequency (days/wk)
1-2	15	60	3	1	15	15	2
3-4	20	60	3	2	12	12	2
5-6	25	70	3	3	8	8	3
7-8	30	70	3	3	8	8	3
9-10	35	70	3	3	8	8	3
11-12	40	70	3	3	8	8	3
13-16	45	70	3	3	8	8	3
17-19	40	75	3	3	8	8	3
20-26	45	75	3	3	8	8	3

Table 4. Participant characteristics at baseline and 6-months for each randomized group. Means are represented  $\pm$  SE and \* indicates a significant difference from baseline to 6-months ( $p < 0.05$ ).

Dependent Variable	Aerobic Only	Resistance Only	Combination (A+R)	Control	Aerobic	Resistance	A+R	Control
<b>N</b>								
40-54yr	11	11	15	7				
55-70yr	12	12	10	18				
<b>Age (yrs)</b>								
40-54yr	49 $\pm$ 1	47 $\pm$ 1	49 $\pm$ 1	46 $\pm$ 2				
55-70yr	61 $\pm$ 1	61 $\pm$ 1	60 $\pm$ 1	59 $\pm$ 0.8				
<b>BMI (kg/m<sup>2</sup>)</b>								
40-54yr	34.7 $\pm$ 1.3	35.1 $\pm$ 1.9	34.5 $\pm$ 1.5	33.9 $\pm$ 1.8	-1.4 $\pm$ .93	-0.3 $\pm$ .82	-2.1 $\pm$ 1.2	-3.7 $\pm$ 1.96
55-70yr	33.6 $\pm$ 7.0	30.7 $\pm$ 1.5	30.0 $\pm$ 4.8	32.1 $\pm$ 1.3	-4.3 $\pm$ 2.5	-8.2 $\pm$ .75	-1.5 $\pm$ 1.5	-6.9 $\pm$ 0.81
<b>Weight (kg)</b>								
40-54yr	99.7 $\pm$ 5.3	100.6 $\pm$ 4.6	100.4 $\pm$ 4.7	101.5 $\pm$ 7.3	-5.3 $\pm$ 0.86	-1.4 $\pm$ .76	-1.85 $\pm$ 1.0	-4.0 $\pm$ 1.86
55-70yr	101.5 $\pm$ 6.0	90.6 $\pm$ 7.3	86.6 $\pm$ 4.5	93.3 $\pm$ 3.5	-4.25 $\pm$ 2.4*	-8.2 $\pm$ .72	-1.97 $\pm$ 1.4	-6.9 $\pm$ 0.78
<b>Ab. SAT (cm<sup>2</sup>)</b>								
40-54yr	419.79 $\pm$ 38.5	431.6 $\pm$ 49.8	391.84 $\pm$ 40.4	405.07 $\pm$ 51.5	-2.96 $\pm$ 2.2	-3.3 $\pm$ 2.0	-5.76 $\pm$ 3.7*	-3.35 $\pm$ 2.9
55-70yr	387.18 $\pm$ 44.6	333.44 $\pm$ 50.1	287.15 $\pm$ 43.4	324.04 $\pm$ 23.7	-3.07 $\pm$ 3.3	-6.1 $\pm$ 3.2*	-0.67 $\pm$ 2.6	1.25 $\pm$ 1.84
<b>VAT (cm<sup>2</sup>)</b>								
40-54yr	222.92 $\pm$ 42.5	190.30 $\pm$ 21.9	207.01 $\pm$ 25.8	248.63 $\pm$ 35.9	-4.72 $\pm$ 5.3	8.61 $\pm$ 6.9	-7.56 $\pm$ 7.8*	-5.9 $\pm$ 4.5
55-70yr	226.23 $\pm$ 25.3	219.6 $\pm$ 28.7	194.33 $\pm$ 28.0	196.32 $\pm$ 17.2	-9.47 $\pm$ 5.9	-7.7 $\pm$ 3.9	-12.9 $\pm$ 6.9*	0.25 $\pm$ 7.2
<b>Muscle CSA</b>								
40-54yr	461.1 $\pm$ 32.9	468.5 $\pm$ 17.7	471.54 $\pm$ 43.1	412.21 $\pm$ 84.1	1.18 $\pm$ 0.7	2.90 $\pm$ 0.8*	2.28 $\pm$ 1.0*	-3.35 $\pm$ 1.5*
55-70yr	399.7 $\pm$ 53.3	377.4 $\pm$ 29.1	432.23 $\pm$ 17.6	433.72 $\pm$ 34.1	1.43 $\pm$ 0.7	3.38 $\pm$ 1.1*	2.06 $\pm$ 0.5*	-0.23 $\pm$ 0.6

Table 5. Baseline and 6-month values for strength, V<sub>O2</sub> and HbA<sub>1c</sub> for each randomized group. Means are represented ± SE and \* indicates a significant difference from baseline to 6-months (p<0.05).

Dependent Variable	Aerobic Only	Resistance Only	Combination (A+R)	Control	Aerobic	Resistance	A+R	Control
<b>Strength</b>								
<b>Bench Press</b>								
40-54yr	62.7±8.4	66.2±8.1	66.3±9.1	73.0±12.7	20.9±12.7*	68.6±23.0*	47.6±10.2*	3.93±6.0
55-70yr	82.5±6.6	68.4±9.7	69.2±8.5	72.8±9.4	-2.5±5.0	44.4±18.2*	41.1±7.6*	-5.3±6.8
<b>Leg Press</b>								
40-54yr	264.3±35.1	253.3±41.4	254.2±32.2	279.5±41.5	53.9±13.5*	86.2±33.7*	51.0±16.0*	22.6±7.3
55-70yr	229.7±51.2	203.8±29.1	324.1±39.1	239.4±30.7	45.4±15.5*	72.3±17.0*	46.0±10.5*	36.6±25.0*
<b>Seated Row</b>								
40-54yr	100.4±7.6	107.9±10.2	99.8±8.5	109.0±10.2	9.01±5.6	47.6±12.1*	37.9±7.9*	2.7±8.3
55-70yr	103.3±11.3	93.7±11.3	107.6±7.2	101.1±8.1	9.3±9.0	31.9±9.6*	30.4±5.5*	9.5±4.7
<b>V<sub>O2peak</sub></b>								
(ml/kg/min)								
40-54yr	23.9±1.6	24.8±1.4	23.3±1.2	25.3±1.9	7.4±1.75*	0.88±2.61	4.93±2.65*	-2.4±3.1
55-70yr	23.2±1.5	21.6±1.1	24.3±1.6	23.4±1.2	6.85±4.0*	1.13±3.3	7.61±3.54*	.87±1.7
<b>HbA<sub>1c</sub> (%)</b>								
40-54yr	0.08±.003	0.078±.003	0.079±.003	0.077±.003	-7.3±3.9*	0.13±3.3	-13.2±3.2*	-.78±4.6
55-70yr	0.074±.002	0.077±.002	0.078±.003	0.078±.002	-8.7±3.1*	-4.74±2.6	-8.69±3.9*	-3.7±3.0

Table 6. Baseline and 6-month values for nutritional intake for each exercise group and the control group. Represented as mean  $\pm$  SE, \* significant effect of time, § younger and older groups changed significantly differently, □ significant baseline difference between younger and older groups ( $p < 0.05$ ). Three participants were not included because of missing data.

	40-54 years				55-70 years			
	Baseline	6-months	% Change	Sign.	Baseline	6-months	% Change	Sign.
<b>AEROBIC</b>								
N	11				12			
CHO (% Total Calories)	44.6 $\pm$ 2.2	52.6 $\pm$ 1.9	20.0 $\pm$ 5.9	* § □	47.9 $\pm$ 2.2	48.7 $\pm$ 2.2	4.3 $\pm$ 7.2	§
Protein (% Total Calories)	19.6 $\pm$ 0.9	18.9 $\pm$ 1.1	-0.7 $\pm$ 8.4		20.1 $\pm$ 1.0	20.7 $\pm$ 2.1	2.4 $\pm$ 7.3	
Fat (% Total Calories)	34.5 $\pm$ 1.8	29.4 $\pm$ 2.1	-13.7 $\pm$ 5.6		31.3 $\pm$ 2.1	31.1 $\pm$ 2.4	4.5 $\pm$ 9.7	
Total Calories	1914.5 $\pm$ 112.1	1763.0 $\pm$ 78.7	-5.95 $\pm$ 5.2		2057.0 $\pm$ 105.8	1886.7 $\pm$ 168.4	-6.6 $\pm$ 8.4	
<b>RESISTANCE</b>								
N	11				12			
CHO (% Total Calories)	42.1 $\pm$ 2.1	47.4 $\pm$ 1.9	14.0 $\pm$ 4.5	*	52.4 $\pm$ 3.1	51.7 $\pm$ 2.4	1.2 $\pm$ 6.0	
Protein (% Total Calories)	20.2 $\pm$ 1.2	21.4 $\pm$ 1.1	8.1 $\pm$ 6.9		18.1 $\pm$ 0.9	19.5 $\pm$ 1.1	8.1 $\pm$ 4.4	
Fat (% Total Calories)	36.8 $\pm$ 2.2	33.6 $\pm$ 5.0	-9.3 $\pm$ 9.3	§ □	30.0 $\pm$ 2.3	29.3 $\pm$ 1.9	2.3 $\pm$ 8.8	§
Total Calories	2436.1 $\pm$ 138.5	1915.4 $\pm$ 166.2	-19.7 $\pm$ 7.0		2179.8 $\pm$ 105.8	1911.0 $\pm$ 120.7	-11.0 $\pm$ 6.1	
<b>COMBINED</b>								
N	13				9			
CHO (% Total Calories)	49.1 $\pm$ 2.7	48.5 $\pm$ 2.6	0.2 $\pm$ 5.1		48.4 $\pm$ 2.2	48.1 $\pm$ 1.3	1.1 $\pm$ 5.3	
Protein (% Total Calories)	15.8 $\pm$ 1.4	19.2 $\pm$ 1.5	53.4 $\pm$ 43.3	* □	19.2 $\pm$ 1.7	19.6 $\pm$ 1.2	8.2 $\pm$ 12.0	
Fat (% Total Calories)	33.0 $\pm$ 2.3	32.0 $\pm$ 2.6	0.1 $\pm$ 8.2		31.2 $\pm$ 1.9	31.1 $\pm$ 1.5	4.9 $\pm$ 11.4	
Total Calories	2187.0 $\pm$ 288.8	2144.1 $\pm$ 275.7	-0.5 $\pm$ 3.6		1912.7 $\pm$ 91.8	1818.6 $\pm$ 109.1	-4.9 $\pm$ 4.7	
<b>CONTROL</b>								
N	7				18			
CHO (% Total Calories)	45.1 $\pm$ 2.8	46.5 $\pm$ 2.0	4.8 $\pm$ 5.7		49.1 $\pm$ 2.1	50.6 $\pm$ 2.1	4.2 $\pm$ 3.7	
Protein (% Total Calories)	16.9 $\pm$ 1.4	18.9 $\pm$ 1.3	14.8 $\pm$ 9.0		18.6 $\pm$ 0.7	19.6 $\pm$ 1.0	6.4 $\pm$ 5.5	
Fat (% Total Calories)	35.6 $\pm$ 3.1	32.4 $\pm$ 2.2	-4.1 $\pm$ 10.8		30.8 $\pm$ 1.8	30.5 $\pm$ 1.6	4.0 $\pm$ 8.4	
Total Calories	2529.0 $\pm$ 228.7	2155.1 $\pm$ 244.9	-13.9 $\pm$ 7.0		2144.0 $\pm$ 159.4	1888.8 $\pm$ 118.0	-8.4 $\pm$ 5.5	

Figure 1. Schematic representation of experimental protocol. Baseline testing includes anthropometric measures, blood sampling,  $V_{O2peak}$ , strength testing (8RM) and a CT scan. Once baseline testing is complete and the participant fits all inclusion criteria the run-in period begins. If at minimum 10 of the 12 required sessions during run-in are completed the participant is then randomized and will continue in the study. The participant will remain in the group they were randomized in for a total of 26 weeks. If less than 10 sessions are completed during the run-in period the participant does not continue in the study and is not randomized. Baseline testing is completed again at 6-months.

**BASELINE TESTING**

- anthropometric measures
- blood sampling
- V02peak
- Strength testing (8RM)
- CT scan

**RUN-IN**  
wk 1-4

**INTERVENTION** wks 5-26

Attendance >10 of 12

NO → DNQ

**Randomization**

- Aerobic Only
- Resistance Only
- Combined
- Control Waiting -List

**FOLLOW-UP TESTING**

- anthropometric measures
- blood sampling
- V02peak
- Strength testing (8RM)
- CT scan



Figure 2. Percent of sessions attended out of those required  $\pm$  SE.

# Compliance

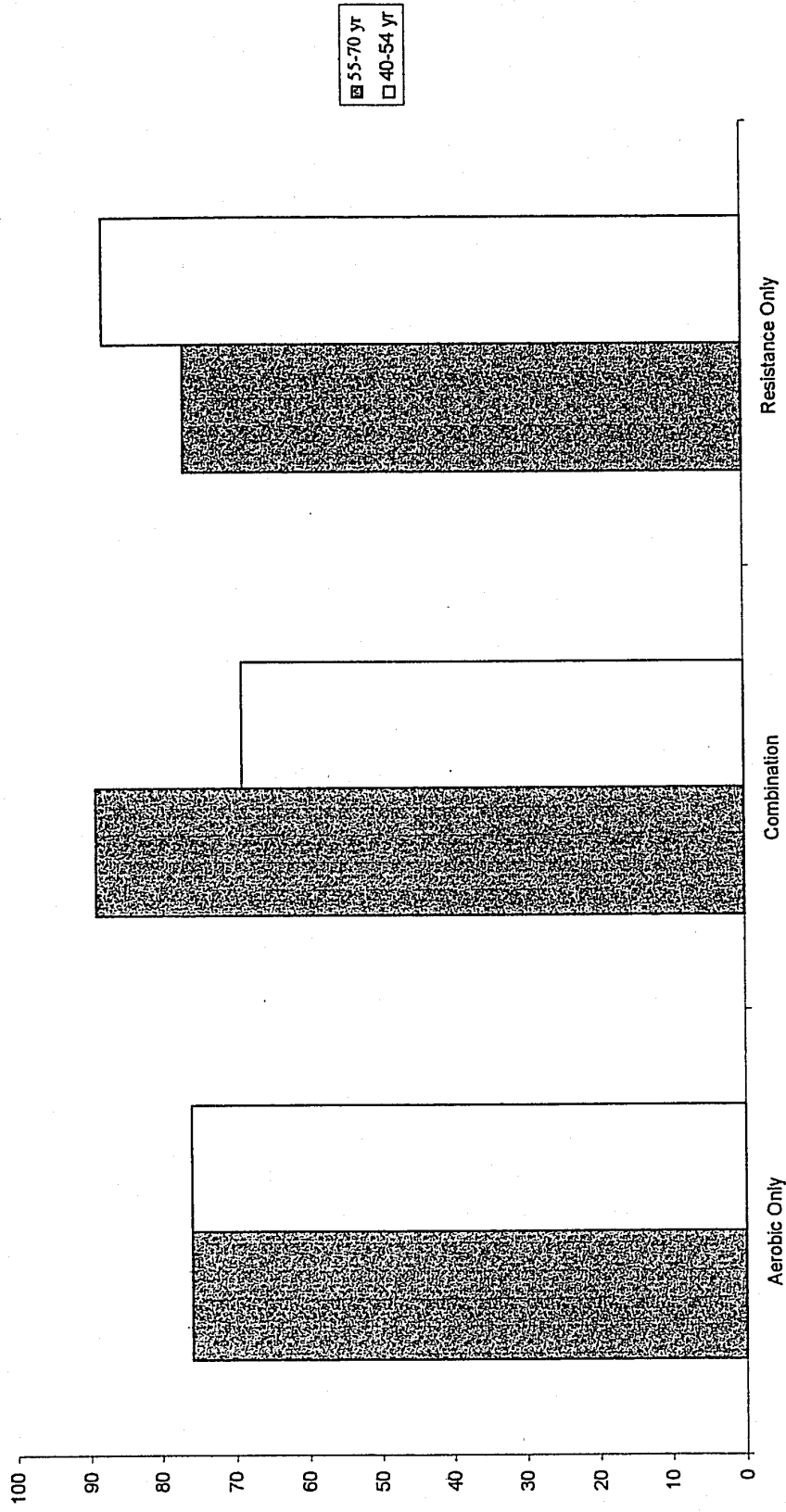


Figure 3. Mean percent change from 0-6 months in body weight for each exercise group and the control group where grey represents the 55-70 year old group and white represents the 40-54 year old group ( $p < 0.05$ ). Significant changes were seen in the older aerobic only group only (N=96).

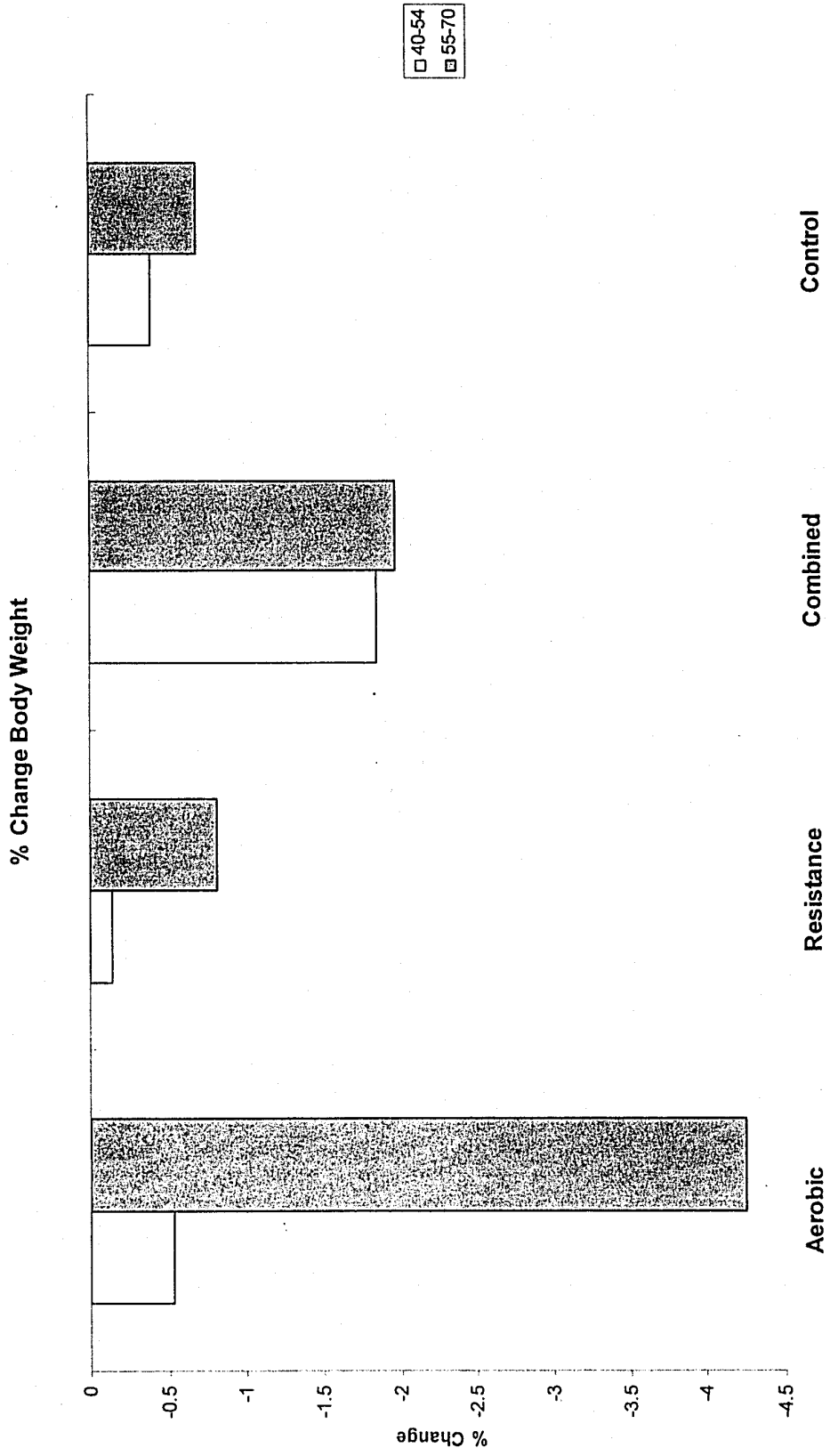


Figure 4. Mean percent change from 0-6 months in mid-thigh muscle CSA for each exercise group and the control group where grey represents the 55-70 year old group and white represents the 40-54 year old group ( $p < 0.05$ ). Significant positive changes were seen in both age groups following resistance only exercise and combined exercise groups. A significant decline was seen in the younger control group. Eleven participants were excluded from analysis because they either dropped out or were too large for the scanner ( $N=85$ ).

% Change Mid-Thigh Muscle CSA

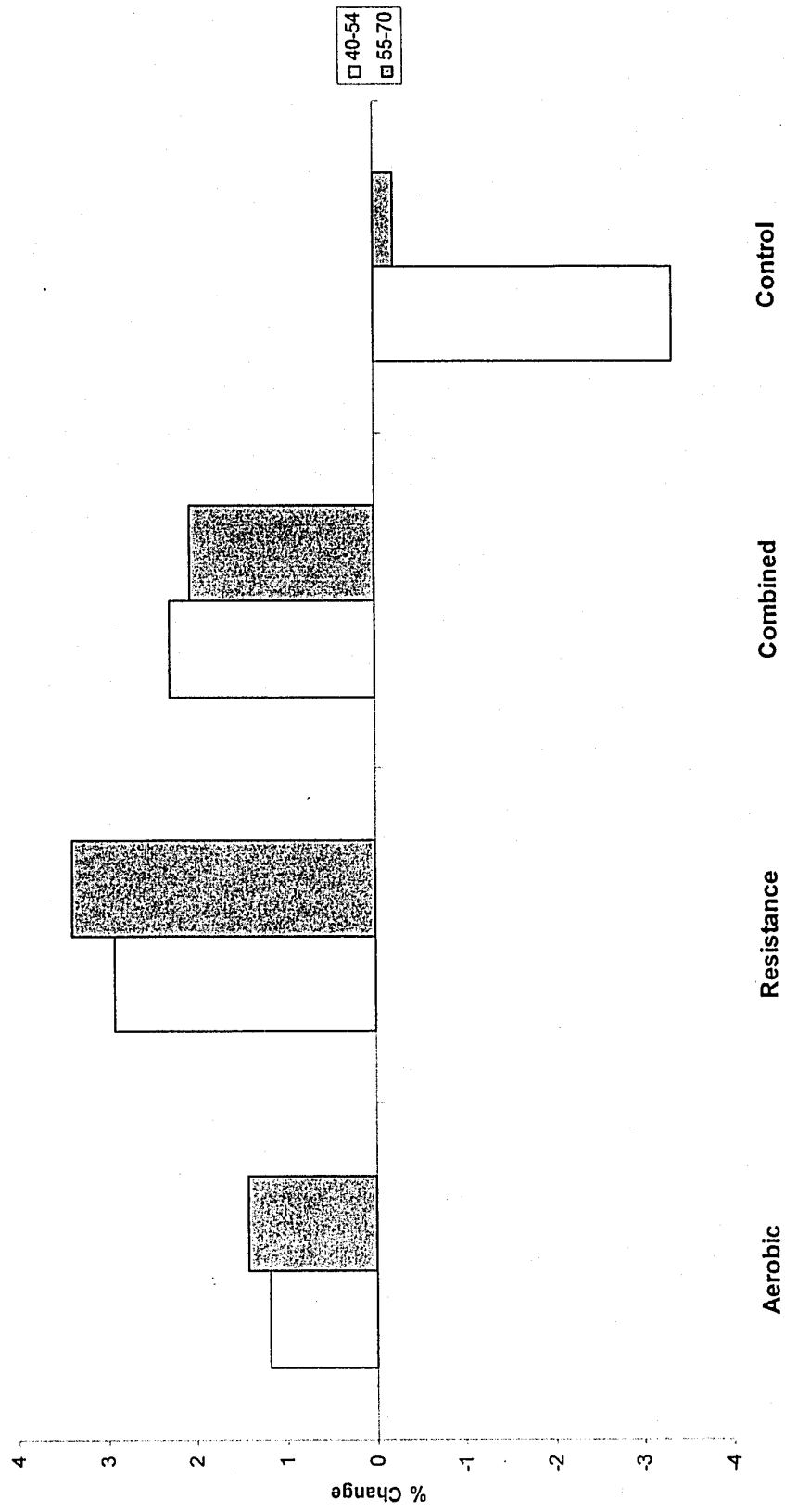


Figure 5. Mean percent change in abdominal SAT from 0-6 months for each exercise group and the control group where grey represents the 55-70 year old group and white represents the 40-54 year old group ( $p < 0.05$ ). Significant changes were seen in both age groups following the combined exercise program and in the older group following aerobic only training. Six participants were excluded from analysis because they either dropped out or were too large for the scanner (ARY=13, ARO=10, RY=11, RO=11, AY=11, AO=11, CY=7, CO=16).

% Change Abdominal SAT

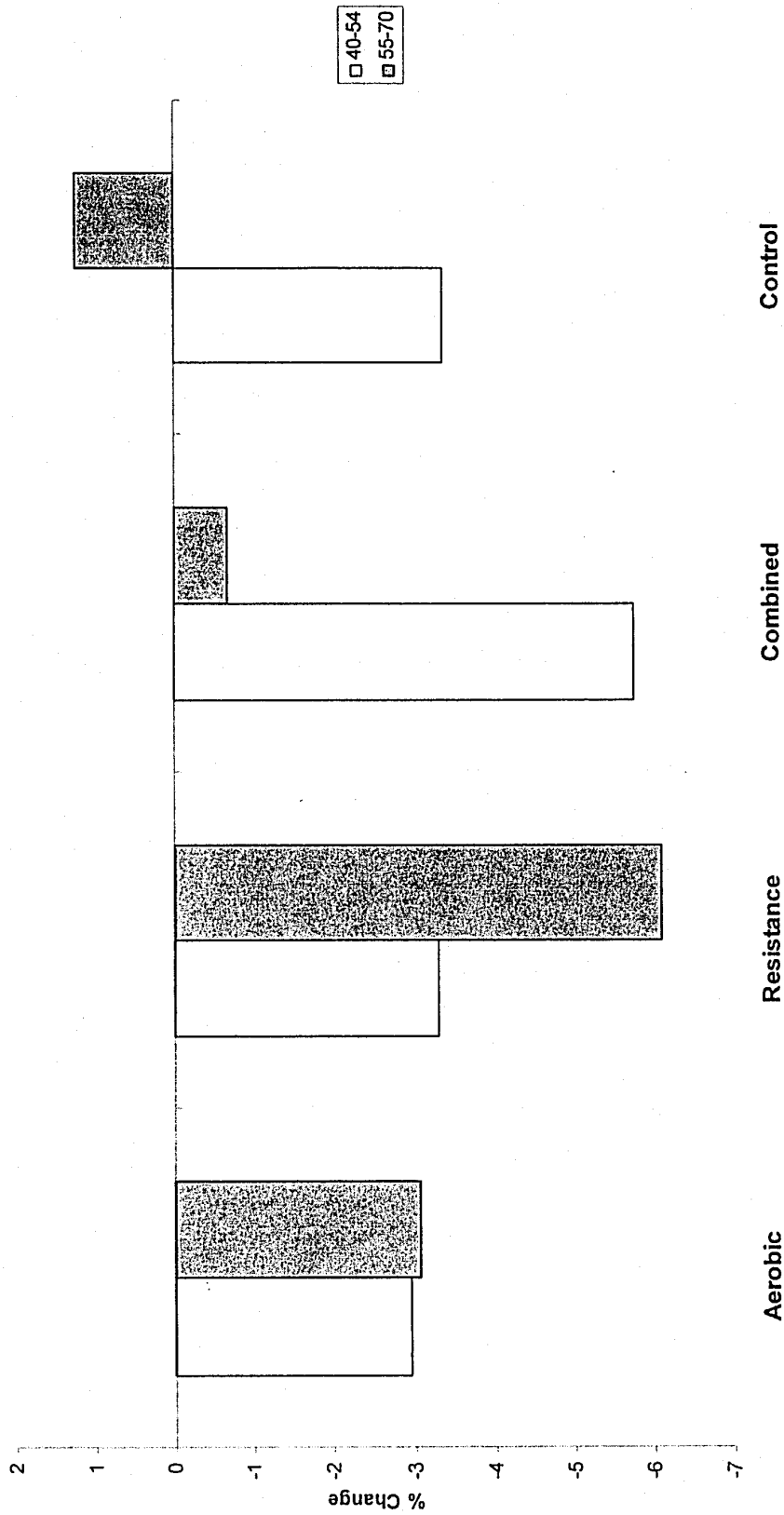


Figure 6. Mean percent change in abdominal VAT from 0-6 months for each exercise group and the control group where grey represents the 55-70 year old group and white represents the 40-54 year old group ( $p < 0.05$ ). Significant improvements were seen in both age groups following the combined program. Six participants were excluded from analysis because they either dropped out or were too large for the scanner (ARY=13, ARO=10, RY=11, RO=11, AY=11, AO=11, CY=7, CO=16).

% Change Abdominal VAT

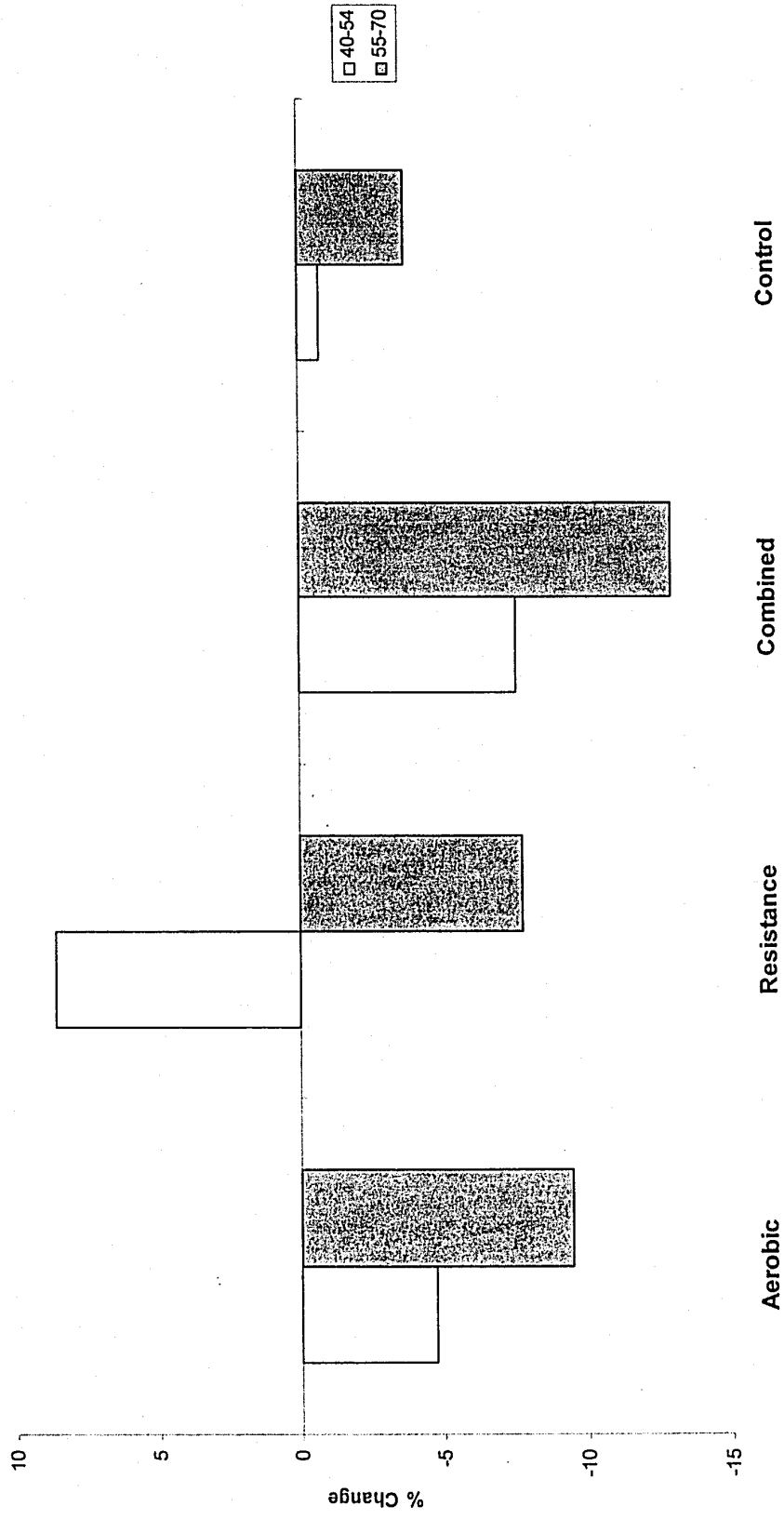


Figure 7. Mean percent strength change for the bench press from 0-6 months for each exercise group and the control group where grey represents the 55-70 year old group and white represents the 40-54 year old group ( $p < 0.05$ ). Thirteen participants were excluded from analysis because they either dropped out or performed too many repetitions to use the prediction equation ( $N=83$ ).

% Strength Change: Bench Press

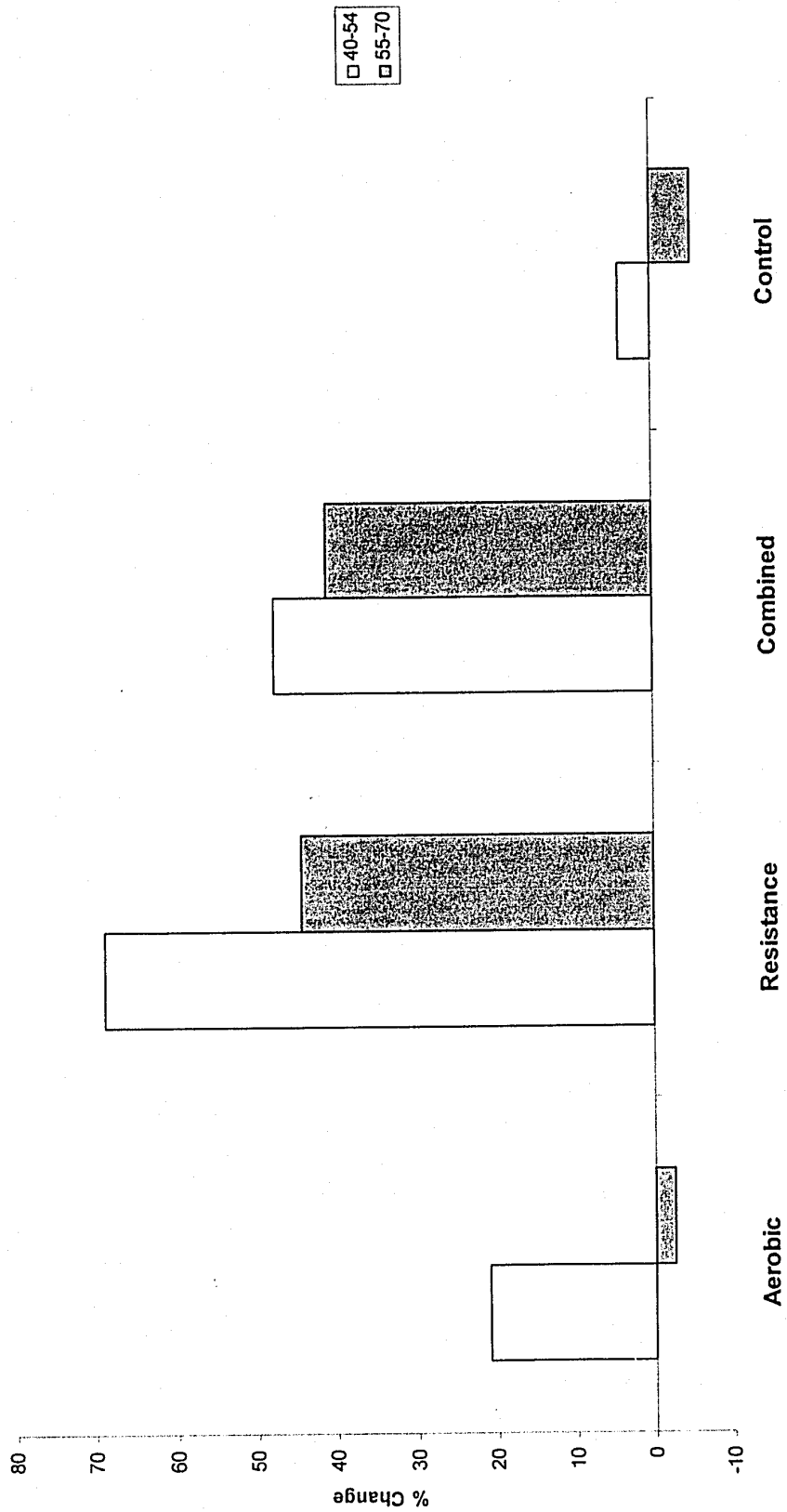


Figure 8. Mean percent strength change for the seated row from 0-6 months for each exercise group and the control group where grey represents the 55-70 year old group and white represents the 40-54 year old group ( $p < 0.05$ ). Twenty participants were excluded from analysis because they either dropped out or performed too many repetitions to use the prediction equation ( $N=76$ ).

% Strength Change: Seated Row

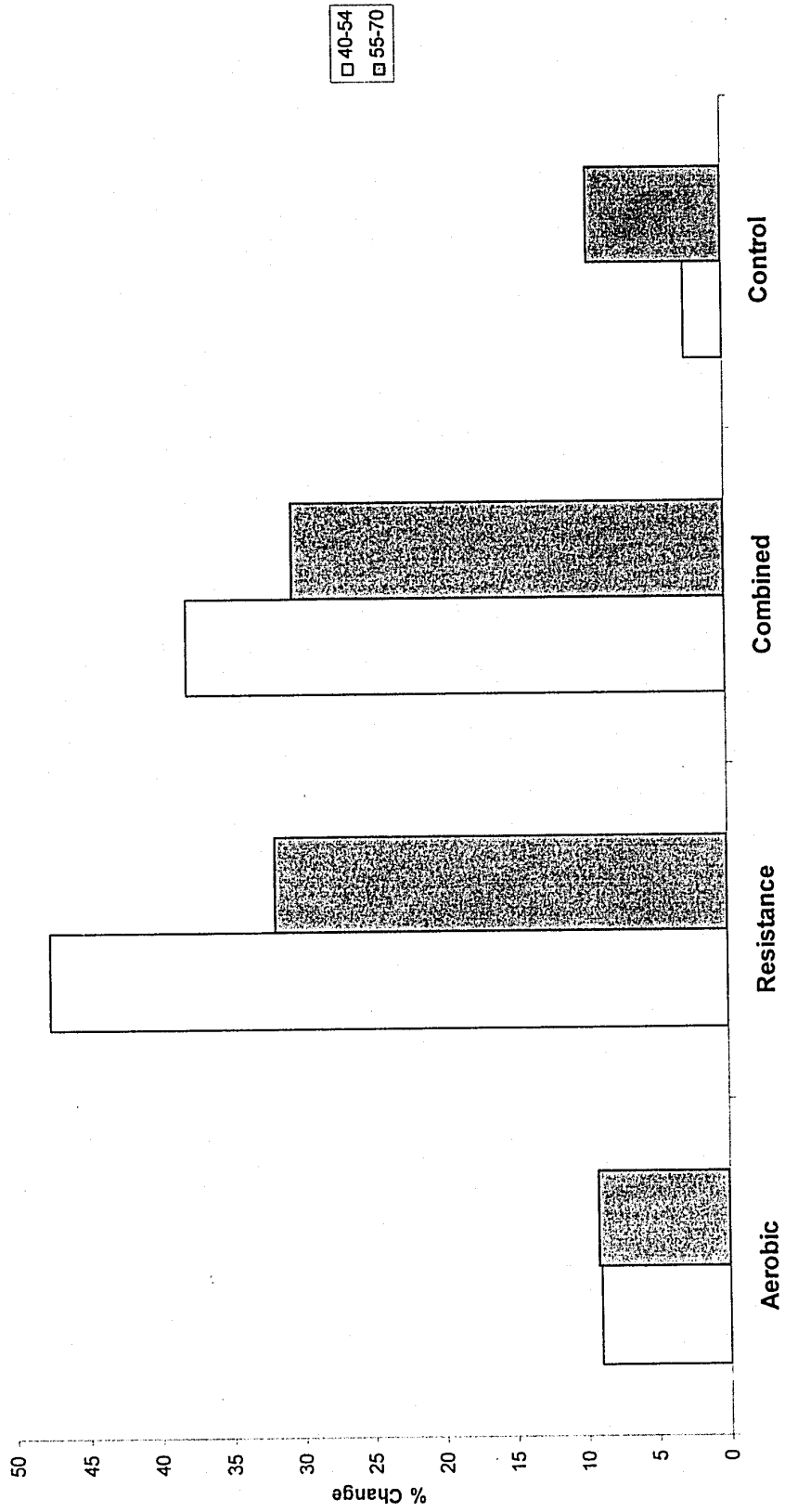


Figure 9. Mean percent strength change for the leg press from 0-6 months for each exercise group and the control group where grey represents the 55-70 year old group and white represents the 40-54 year old group ( $p < 0.05$ ). Eight participants were excluded from analysis because they either dropped out or performed too many repetitions to use the prediction equation ( $N=88$ ).

% Strength Change: Leg Press

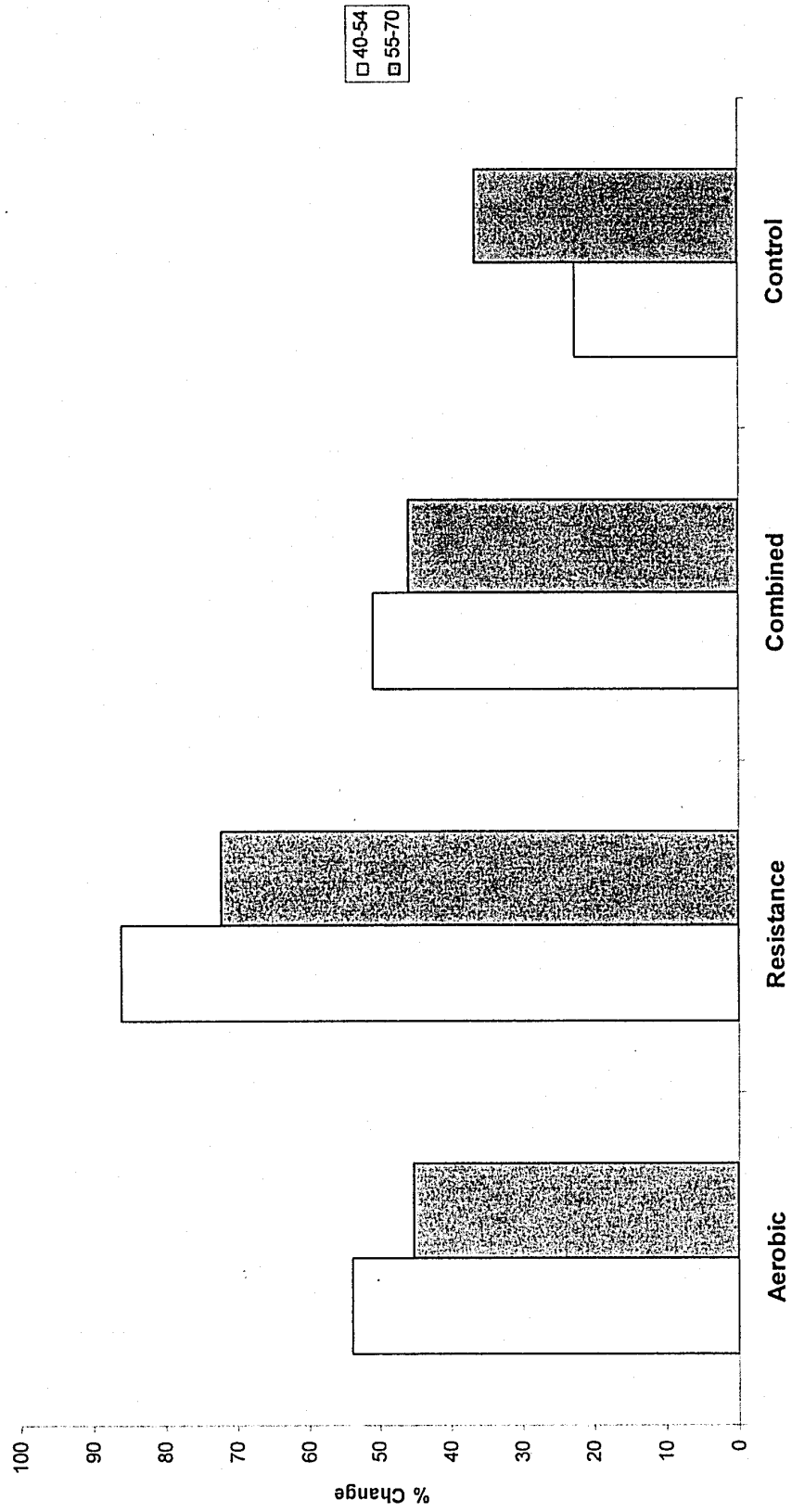


Figure 10. Mean percent change from 0-6 months for each exercise group and the control group for V02 peak, where grey represents the 55-70 year old group and white represents the 40-54 year old group ( $p < 0.05$ ). Significant improvements were seen in both age groups following aerobic only training and combined training (N=96).

% Change V02peak

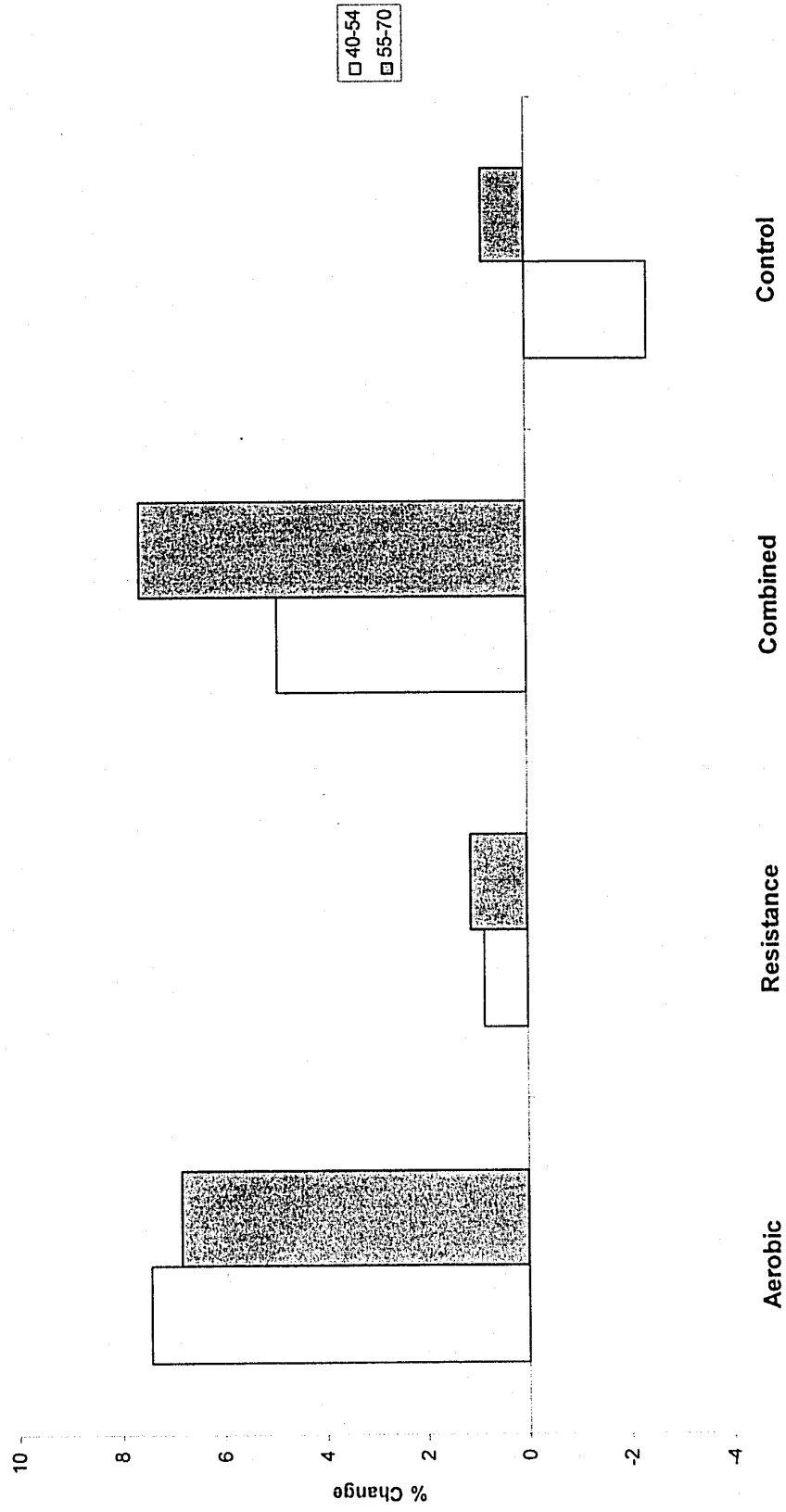


Figure 11. Mean percent change from 0-6 months for each exercise group and the control group for HOMA, where grey represents the 55-70 year old group and white represents the 40-54 year old group ( $p < 0.05$ ). Significant improvements were seen in both age groups following aerobic only training ( $N=93$ ).

% Change HOMA

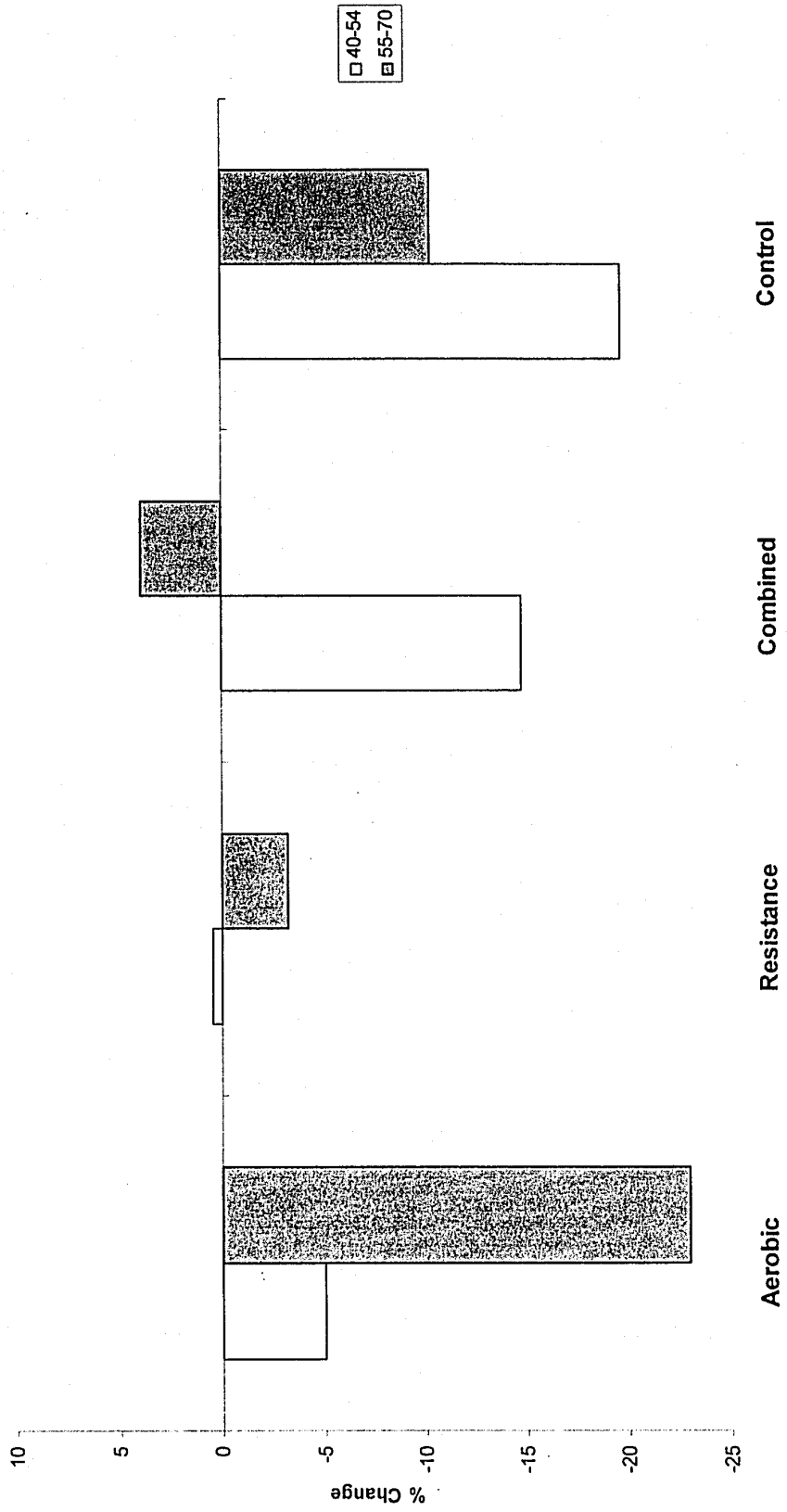


Figure 12. Mean percent change from 0-6 months for each exercise group and the control group for HbA1c, where grey represents the 55-70 year old group and blue represents the 40-54 year old group ( $p < 0.05$ ). Significant improvements were seen in both age groups following aerobic only training and combined training (N=96).

% Change HbA1c

