Effects of exercise and/or diet on plasma lipid and lipoprotein levels in obese women

by

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Abstract

Rationale: Reductions in obesity, upper-body obesity and visceral adiposity are associated with improvements in metabolic complications including disturbances in the plasma lipid and lipoprotein profile. It is unclear whether exercise in addition to caloric restriction has beneficial effects on the plasma lipid and lipoprotein profile that are greater than diet alone.

Objective: This study was designed to test the hypothesis that the combination of diet and either aerobic (DA; n=8) or resistance (DR; n=13) exercise has beneficial effects on plasma lipid and lipoprotein levels that are greater than diet alone (DO; n=12) in obese women.

Research Design and Methods: Plasma lipids and lipoproteins were measured following an overnight fast. Whole body VAT, subcutaneous adipose tissue (SAT) and skeletal muscle were measured by magnetic resonance imaging at baseline and following a 16 week intervention.

Results: The daily energy deficit induced by diet (~1300 calories) was not different between groups ($p > .05$). The reductions in weight (~12%), VAT (~31%) and SAT (~21%) were not different between treatments ($p > .05$). Maximal aerobic capacity increased (~9%) within the DA group ($p < .01$). There were significant gains in strength within the DR group ($p < .01$). However, without exception, treatment effects were not different between groups for any lipid or lipoprotein variable ($p > .05$). Collapsed across group there were significant improvements in total cholesterol, low density lipoprotein cholesterol (LDL-C) and Apolipoprotein B (Apo-B) ($p < .05$) as well as significant reductions in high density lipoprotein cholesterol (HDL-C) and Apolipoprotein A

(Apo A) ($p < .05$). There was a significant decrease in the prevalence of subjects with elevated (as specified by the Canadian Consensus Conference on Cholesterol) total cholesterol and LDL-C levels post treatment ($p < .05$).

Conclusion: These findings do not support the hypothesis that the combination of diet and either aerobic or resistance exercise has effects on plasma lipid and lipoprotein levels that are greater than diet alone in obese women. Improvements in cardiovascular fitness and muscular strength were not related to improvements in plasma lipid and lipoprotein levels. As treatment differences were not observed for reductions in VAT, SAT or total adipose tissue, favorable changes in plasma lipid and lipoprotein levels may be related to reductions in total and regional adiposity.

Key words: lipids, lipoproteins, diet, exercise, weight loss, magnetic resonance imaging

Co-Authorship

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List of Abbreviations

AHA	American Heart Association
Apo A	Apolipoprotein A
Apo B	Apolipoprotein B
AT	Adipose tissue
BMI	Body mass index
CCCC	Canadian Consensus Conference on Cholesterol
CE	Cholesteryl ester
CT	Computed axial tomography
DA	Diet in combination with aerobic exercise
DO	Diet only
DR	Diet in combination with resistance exercise
F	Female
FFA	Free fatty acid
HDL-C	High density lipoprotein cholesterol
HL	Hepatic lipase
LDL-C	Low density lipoprotein cholesterol
LPL	Lipoprotein lipase
M	Male
MRI	Magnetic resonance imaging
NCEP	National Cholesterol Education Program
SAT	Subcutaneous adipose tissue
SD	Standard deviation
SM	Skeletal muscle
TC	Total cholesterol
TG	Triglyceride
VAT	Visceral adipose tissue
VLDL	Very low density lipoprotein
$\dot{V}O_{2MAX}$	Maximal oxygen consumption
WCLR	Waist circumference at the last rib
WCUM	Waist circumference at the umbilicus
WHR	Waist-to-hip ratio

1.0.0 INTRODUCTION

That obesity is associated with numerous metabolic complications including abnormalities of the plasma lipid and lipoprotein profile and other risk factors for cardiovascular disease is well documented (Després, 1988). This association has been known for sixty years or more (Newburgh & Conn, 1939). Based on clinical observations, Vague (1956) reported that the prevalence of cardiovascular disease was greater in upper-body obese individuals than in lower-body obese individuals. Indeed, that the distribution of body fat is an independent determinant of cardiovascular disease has been more recently established through epidemiological (Larsson et al., 1984; Lapidus et al., 1984) and cross-sectional (Kissebah et al., 1982; Després et al., 1985) studies.

The advent of imaging techniques such as magnetic resonance imaging (MRI) and computed axial tomography (CT) enabled researchers to separate upper-body or abdominal adipose tissue into visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT). VAT due to its proximity to the portal circulation and its metabolic characteristics is thought to be associated with significant health risks (Björntorp, 1990). Upper-body obese subjects with VAT accumulation more frequently demonstrated impaired lipid metabolism than those with SAT accumulation (Matsuzawa et al., 1995). A large amount of VAT has been shown to predict high plasma triglyceride (Albu et al., 1997) and reduced high density lipoprotein cholesterol (HDL-C) (Després et al., 1989) levels in obese premenopausal women.

Disturbances in the plasma lipid and lipoprotein profile, including elevated triglyceride, total cholesterol, low density lipoprotein cholesterol (LDL-C), and reduced

HDL-C levels, are major risk factors for cardiovascular disease (Stamler, 1992). Modification of these risk factors has been shown to predict gains in life expectancy (Tsevat et al., 1991). Using a sample from the Canadian Heart Health Survey database, Maclean et al. (1999b) demonstrated that one half of Canadian adults are at an increased risk for cardiovascular disease based on dyslipidemia of one or more of the lipid and lipoprotein plasma fractions. The high prevalence of Canadians at risk for cardiovascular disease due to disturbances in their plasma lipid and lipoprotein profiles convincingly indicates the need for research and public education in this area.

Since obesity, in particular upper-body obesity, and specifically VAT accumulation are associated metabolic disturbances, it follows that reductions in VAT and/or body weight may lead to improvements in the plasma lipid and lipoprotein profile. Indeed, a study by Fujioka et al. (1991) demonstrated that following diet-induced weight loss, metabolic improvements, including decreased triglyceride levels, were significantly associated with changes in VAT in obese women.

Discrepant findings are reported with respect to improvements in plasma lipid and lipoprotein levels in diet and/or exercise intervention studies. Whereas some studies suggested that weight loss was related to improvements in plasma lipid and lipoprotein levels (Katzel et al., 1997; Katzel et al., 1995; Stefanick et al., 1998), others did not (Kraemer et al., 1997; Reid et al., 1994). Similarly, whereas some studies suggested that in the absence of weight loss, aerobic (Katzel et al., 1995; Thompson et al., 1997) and resistance (Hurley et al., 1988) exercise were associated with improvements in plasma lipid and lipoprotein levels, again, others did not (Coon et al., 1989; Fonong et al., 1996) and (Manning et al., 1991; Smutok et al., 1993) respectively. However, few studies used

imaging techniques to determine changes in the various adipose tissue depots. The inconsistencies reported in previous diet/exercise studies may reflect differences in the nutritional composition of the diet, severity of the dietary energy restriction, dietary compliance, exercise compliance, duration of the study, and randomization, as well as differences in the mode, intensity and duration of exercise. Absent from the literature are studies that simultaneously examine whether the combination of diet and aerobic exercise, and the combination of diet and resistance exercise have effects on plasma lipid and lipoprotein levels that are different from each other, or from diet alone, in obese men and women.

In the present study, subjects were randomly assigned to one of three treatment groups: diet only, diet plus aerobic exercise or diet plus resistance exercise. We tested the hypothesis that the combination of diet and either aerobic or resistance exercise is associated with greater improvements in plasma lipid and lipoprotein levels compared to diet alone in obese women. A whole body, multislice MRI protocol was employed to determine the associations between concurrent changes in SAT, VAT, skeletal muscle and lipid metabolism.

2.0.0 REVIEW OF LITERATURE

The purpose of this literature review is twofold. The first half will introduce risk factors for cardiovascular disease including dyslipidemia, obesity, physical inactivity and genetics. As well, this section will explore the proposed mechanisms by which these risk factors promote the development of cardiovascular disease. The second half will examine the effects of intervention studies involving weight loss, diet and/or exercise on plasma lipid and lipoprotein levels.

2.1.0 Dyslipidemia as a risk factor for cardiovascular disease

Disturbances in the plasma lipid and lipoprotein profile, including elevated triglyceride, total cholesterol, low density lipoprotein cholesterol (LDL-C), and reduced high density lipoprotein cholesterol (HDL-C) levels, are major risk factors for cardiovascular disease (Stamler, 1992). Modification of these risk factors has been shown to predict gains in life expectancy (Tsevat et al., 1991). The Canadian Heart Health Survey Database included the results from 10 provincial heart health surveys carried out between 1986 and 1992. With this database, Maclean et al. (1999b) demonstrated that one half of Canadian adults are at increased risk for cardiovascular disease because of dyslipidemia from one or more of the lipid and lipoprotein plasma fractions. Specifically the report indicated that approximately one in two Canadian adults are at an increased risk due to elevated cholesterol levels, nearly one third due to elevated triglyceride levels, over one third due to elevated LDL-C levels and eight per cent due to low HDL-C levels (Maclean et al., 1999b). The high prevalence of Canadians at risk for

cardiovascular disease due to disturbances in their plasma lipid and lipoprotein profiles convincingly indicates the need for research and public education in this area.

2.1.1 Brief summary of the physiology of plasma lipids and lipoproteins

Cholesterol is required by the body as a component of cell membranes and for the manufacture of steroid hormones such as progesterone, estrogen and testosterone (Thibodeau, 1992). It is formed by the liver and circulates in lipoproteins. Excessive dietary cholesterol may increase plasma cholesterol slightly, however, by a negative feedback mechanism, a substantial increase in plasma cholesterol is prevented (Brown & Goldstein, 1986). Excessive dietary fat increases plasma cholesterol which results in increased fat deposition in the liver which leads to increased acetyl-CoA in the liver cells for production of cholesterol (Brown & Goldstein, 1986). A diet high in unsaturated fat decreases plasma cholesterol, although the mechanism is unknown (Brown & Goldstein, 1986). Hypercholesterolemia increases the risk for coronary heart disease. However, angiographic studies show that even advanced coronary atherosclerosis responds to cholesterol lowering treatment (NCEP, 1993).

Triglycerides are useful in storing energy in cells for later use (Thibodeau, 1992). The link between triglycerides and cardiovascular disease appears to be complex. However, it may be partially explained by the association between high triglycerides, low HDL-C levels, and unusually atherogenic forms of LDL (NCEP, 1993). High levels of plasma triglycerides may be an indirect risk factor for cardiovascular disease. They reflect disturbances in lipid transport such as a decrease in the catabolism of triglyceride-rich lipoproteins and an increase in lipid exchange among lipoproteins (Grundy, 1982).

This results in triglyceride enrichment of LDL-C and decreases in the plasma concentration of HDL-C.

For the purpose of transportation in the blood, the hydrophobic lipid molecules must combine with protein molecules. These combined structures are referred to as lipoproteins. According to their gravitational densities, lipoproteins are classified as very low density (VLDL), intermediate density (IDL), low density (LDL) and high density (HDL) lipoproteins.

LDL-C is recognized as the major atherogenic lipoprotein fraction (MacLean, 1999b). Low density lipoproteins deliver cholesterol to the cells, which use it for their structural and metabolic requirements. LDL-C enhances the deposition of cholesterol in the arterial wall, effectively contributing to the process of atherosclerosis (Campos et al., 1992). Drexel et al., (1996) determined that increased levels of LDL-C could predict the presence of cardiovascular disease, although they could not be used to estimate the extent of the associated health risk.

Several subspecies of LDL exist and are categorized by size and density. A high proportion of small dense LDL particles is known as the dense LDL phenotype. It is well accepted that the dense LDL phenotype is associated with cardiovascular disease (Tchernof et al., 1996). However, the mechanisms governing this association remain unclear. Austin et al. (1994) proposed two explanations. First, the relationship may be mediated by concurrent modifications in other plasma lipid and lipoprotein levels for example increased triglyceride and decreased HDL-C levels. Alternatively, these authors suggested that the relationship may be explained by an increased sensitivity to oxidation

of the small dense LDL particles and a reduced attraction of these particles to the LDL receptor.

Apolioprotein B (Apo B) is a protein that facilitates the catabolism of LDL particles by receptor-mediated endocytosis (Brown & Goldstein, 1986). Apo B rich LDL particles have been associated with cardiovascular disease, even in subjects with normal lipid levels (Sniderman et al., 1982). In these individuals, the LDL particles were smaller and denser than LDL in normal subjects. As such, the concentration of LDL-C was normal, although the number of LDL particles was elevated (Sniderman et al., 1982).

HDL-C has been found to be inversely associated with cardiovascular disease (MacLean et al., 1999b). High density lipoproteins serve as acceptors of cholesterol from various tissues. They promote the removal of cholesterol from the periphery and its return to the liver. As such, HDL-C protects against the development of atherosclerosis. High levels of HDL-C (>1.6 mmol/L) are reported to be a negative risk factor for cardiovascular disease (NCEP, 1993).

2.1.2 Guidelines commonly used for the classification of dyslipidemia

In Canada, four sets of guidelines are commonly used for the identification and management of dyslipidemia (MacLean et al., 1999a). These guidelines include *The Canadian Consensus Conference on Cholesterol* (CCCC), *The Second Report of the United States National Cholesterol Education Program* (NCEP), *The Toronto Working Group on Cholesterol Policy*, and *The Canadian Task Force on the Periodic Health Examination*. Following a comprehensive review of the impact of different blood lipid evaluation and treatment guidelines, major differences were observed in the impact of the

various guidelines with respect to the percentage of subjects who were tested, provided with a lipid profile, and eligible for diet and/or drug therapy. Maclean et al., (1999a) suggested that the guidelines of the CCCC and the NCEP are most effective in identifying Canadians with dyslipidemia. The criteria of the CCCC and the NCEP are outlined in Table 1.

TABLE 1: Lipid and lipoprotein criteria of the CCCC and the NCEP

The Canadian Consensus Conference on Cholesterol (CCCC)

Lipid or Lipoprotein	Desirable	Moderate Risk	High Risk
Plasma Cholesterol	< 5.2 mmol/L	5.2-6.2 mmol/L	> 6.2 mmol/L
Plasma Triglyceride	< 1.7 mmol/L	1.7-2.3 mmol/L	> 2.3 mmol/L
LDL-Cholesterol	< 3.4 mmol/L	3.4-4.1 mmol/L	> 4.1 mmol/L
HDL-Cholesterol	≥ 0.9 mmol/L	N/A	< 0.9 mmol/L

The Second Report of the United States National Cholesterol Education Program (NCEP)

Lipid or Lipoprotein	Desirable	Moderate Risk	High Risk
Plasma Cholesterol	< 5.2 mmol/L	5.2-6.2 mmol/L	> 6.2 mmol/L
Plasma Triglyceride	< 2.3 mmol/L	2.3-4.5 mmol/L	> 4.5 mmol/L
LDL-Cholesterol	< 3.4 mmol/L	3.4-4.1 mmol/L	> 4.1 mmol/L
HDL-Cholesterol[a]	≥ 0.9 mmol/L	N/A	< 0.9 mmol/L

[a] HDL-Cholesterol in excess of 1.6 mmol/L is recognized by the NCEP as a negative risk factor for cardiovascular disease

In summary, a plasma lipid and lipoprotein profile exhibiting elevated levels of total cholesterol, triglycerides, and low density lipoproteins in addition to reduced levels of high density lipoproteins is associated with the greatest risk of cardiovascular disease.

2.2.0 Obesity as a risk factor for cardiovascular disease

Obesity is associated with numerous metabolic complications such as glucose intolerance, hyperinsulinemia, diabetes, hypertension, hyperlipidemia and changes in the concentration and/or composition of plasma lipoproteins (Després, 1988). These metabolic complications are known risk factors for cardiovascular disease. As such, there is an increased prevalence of cardiovascular disease in obese individuals (Vermeulen, 1990). Canada's Health Promotion Survey completed in 1990 indicated that weight-related problems may pose a risk to nearly 50 percent of Canadians (Canadian Society for Exercise Physiology, 1995). The risk of cardiovascular disease increases with the level of obesity (Executive Summary, 1998).

2.2.1 Classification of obesity

Current classification of overweight and obesity considers body mass index (BMI) which is an indication of total body weight with respect to height and waist circumference which is an indication of body fat distribution to predict risk for cardiovascular disease. The relevance of body fat distribution will be discussed further in a later section. For women, a BMI of 25 to 29.9 and a waist circumference $\leq$ 88 cm is associated with an *increased* risk of cardiovascular disease whereas a similar BMI and a waist circumference in excess of 88 cm is associated with a ***high*** risk of cardiovascular disease. A BMI of 30 to 34.9 and a waist circumference $\leq$ 88 cm is associated with a ***high*** risk of cardiovascular disease, whereas a similar BMI and a waist circumference in excess of 88 cm is associated with a ***very high*** risk of cardiovascular disease (Executive Summary, 1998).

2.2.1 Upper-body obesity as a risk factor for cardiovascular disease

Vague (1947) introduced the concept of body fat distribution as a predictor of a "tendency toward vascular accidents" more than 50 years ago. He also coined the terms *gynoid* and *android* obesity. Gynoid obesity refers to obesity that is prominent on the lower half of the body (fat accumulation in the gluteo-femoral region). In contrast, android obesity refers to obesity in the upper half of the body (fat accumulation in the abdominal region). Based on clinical observation, Vague (1947) reported that the prevalence of cardiovascular disease was greater in upper-body obese individuals than in lower-body obese individuals. That the distribution of body fat is an independent determinant of cardiovascular disease has been more recently established through epidemiological (Larsson et al., 1984; Lapidus et al., 1984) and cross-sectional (Kissebah et al., 1982; Després et al., 1985) studies.

To further dissociate the effects of obesity from those related to fat distribution, Després et al. (1990) studied the potential associations between fat distribution and plasma lipoprotein levels in a sample of 22 lean women. In this sample it was observed that a high upper-body fat accumulation was associated with increased LDL-C and decreased HDL-C levels. Lower-body fat accumulation showed no association with plasma lipoprotein levels.

2.2.3 Visceral adipose tissue as a risk factor for cardiovascular disease

The advent of imaging techniques such as magnetic resonance imaging (MRI) and computed axial tomography (CT) enabled researchers to separate abdominal adipose tissue into visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT). Due to

its proximity to the portal circulation and its metabolic characteristics, VAT is thought to be associated with significant health risks (Björntorp, 1990). Indeed, upper-body obese subjects with visceral fat accumulation more frequently demonstrated impaired carbohydrate and lipid metabolism than those with subcutaneous fat accumulation (Matsuzawa et al., 1995).

2.2.4 Associations of visceral adipose tissue with lipid and lipoprotein metabolism

Many published reports confirm that the accumulation of VAT is associated with dyslipidemia which may increase the risk of cardiovascular disease (Després & Lamarche, 1993). High VAT has been shown to predict higher plasma triglyceride levels in obese premenopausal women, independent of total adiposity (Albu et al., 1997). In normal weight men and women, VAT was determined to be significantly correlated with plasma triglyceride and total cholesterol concentrations (Matsuzawa et al., 1995). Després et al. (1989) reported that in obese premenopausal women, the absolute amount of VAT was negatively correlated with HDL-C levels. VAT accumulation has also been associated with an increased proportion of small dense LDL particles (Tchernof et al.,1996). The precise mechanisms governing these relationships continue to be debated.

Després et al. (1990) compared obese women with similar levels of total body fat who differed considerably in their level of VAT, to non-obese women. The results of this study demonstrated that although the obese women with low levels of VAT had much higher total adiposity than the non-obese controls, the only value in their plasma lipid and lipoprotein profile that indicated an increased risk of cardiovascular disease was an increase in plasma triglycerides. In contrast, the obese women with high levels of VAT

were found to have increased plasma triglycerides, increased total cholesterol, increased LDL-C, reduced HDL-C and reduced HDL-C to LDL-C ratios (Després, 1990). Therefore, despite comparable levels of adiposity in the two obese groups, obese women with low levels of VAT exhibited fewer metabolic complications than women with visceral obesity.

It has been suggested that a VAT threshold may exist with respect to metabolic complications. This threshold has been expressed as a cross-sectional area and as a ratio of VAT to SAT. Després (1997) reported that men and women with cross-sectional areas of visceral adipose tissue below 100 cm^2 exhibited relatively normal metabolic profiles, whereas men and women with a visceral adipose tissue accumulation above 130 cm^2 were generally characterized by a blood lipid profile predictive of an increased risk of cardiovascular disease. However, Williams et al. (1996) reported more conservative values for women, stating that above 110 cm^2 metabolic disturbances will be increased and that below 40 cm^2 cardiovascular disease risk will not be affected. Matsuzawa et al. (1995) used a ratio of the visceral fat area to the subcutaneous fat area obtained by CT at the umbilical region to classify the type of obesity exhibited by their subjects (male and female). Those with a ratio of 0.4 or more were defined as viscerally obese and those with a ratio below this cut-off were defined as the subcutaneous obesity group. In men and women, disorders of glucose and lipid metabolism were more common in the visceral fat group compared to the subcutaneous fat group.

Unfortunately, access to imaging techniques such as MRI and CT is limited and expensive. As well, in the case of CT, the technique exposes subjects to ionizing radiation. Consequently, these techniques are not practical for use by physicians or other

health care workers who are interested in evaluating cardiovascular disease risk in their patients. For this reason, the ability of simple anthropometric measurements to predict VAT have been studied. Measurement of the waist circumference is reported to be a good predictor of VAT (Pouliot, 1992). This measurement is fast, easy and is not associated with any risk or cost. A waist circumference measurement in excess of 100 cm is thought to represent a critical value above which the risk of major disturbances in the plasma lipid and lipoprotein profile is increased significantly (Pouliot, 1992).

2.2.5 Mechanisms associating visceral adipose tissue with cardiovascular disease

In *in vitro* studies, VAT has been shown to be metabolically active and highly sensitive to stimulation of lipolysis (Ostman et al., 1979; Efendic, 1979). As well, compared to subcutaneous adipocytes, visceral adipocytes have a lower sensitivity to the antilipolytic effects of insulin (Bolinder et al., 1983). Maysuzawa et al. (1995) further investigated the metabolic characteristics of visceral adipose tissue. These authors determined that VAT has a high lipolytic activity in response to norepinephrine. They also demonstrated increased lipogenic activity in VAT compared with SAT, by observing enhancement of the synthesis of acyl-CoA, which is one of the key enzymes of lipogenesis. These results confirmed that VAT is metabolically active and sensitive to stimulation of lipolysis.

In a 1984 editorial, Per Björntrop addressed the question, "How can an enlarged fat depot with lipolytically sensitive adipocytes cause hypertriglyceridemia?". He proposed that high lipolytic activity produces large quantities of free fatty acids (FFA) and that in the case of the VAT depot, the depot empties its FFA into the portal vein.

Excess FFA in the portal circulation increases very low density lipoprotein secretion by the liver resulting in increased plasma triglyceride concentrations.

Currently, as it is not possible to measure hepatic FFA flux in humans, this proposed mechanism has yet to be proven. However, recent research with rats has confirmed proposed mechanisms of hepatic carbohydrate metabolism in relation to VAT (Barzilai et al., 1998). It follows that similar use of the animal model will provide improved understanding of hepatic lipid metabolism.

Després & Lamarche (1993), proposed that in abdominally obese individuals, the associations between excess VAT and disturbances in plasma lipid and lipoprotein concentrations may be explained in part by alterations in the activities of lipoprotein lipase (LPL) and hepatic lipase (HL). These two enzymes hydrolyse triglycerides. In previous studies, these authors reported that levels of VAT were positively associated with HL activity (Després et al., 1989) and that total body fat was negatively correlated with plasma post heparin LPL activity (Pouliot et al., 1991).

In summary, obesity, in particular upper-body obesity, and specifically VAT accumulation are associated with metabolic disturbances. The association between VAT and dyslipidemia may be explained by decreased LPL and increased HL activity. A simplified overview of the effects of VAT on plasma lipid and lipoprotein metabolism is provided in Figure 1.

2.3.0 Physical inactivity as a risk factor for cardiovascular disease

Physical inactivity increases the relative risk of cardiovascular disease up to 2.4 times (American Heart Association, 1998). This increase in risk is comparable to that

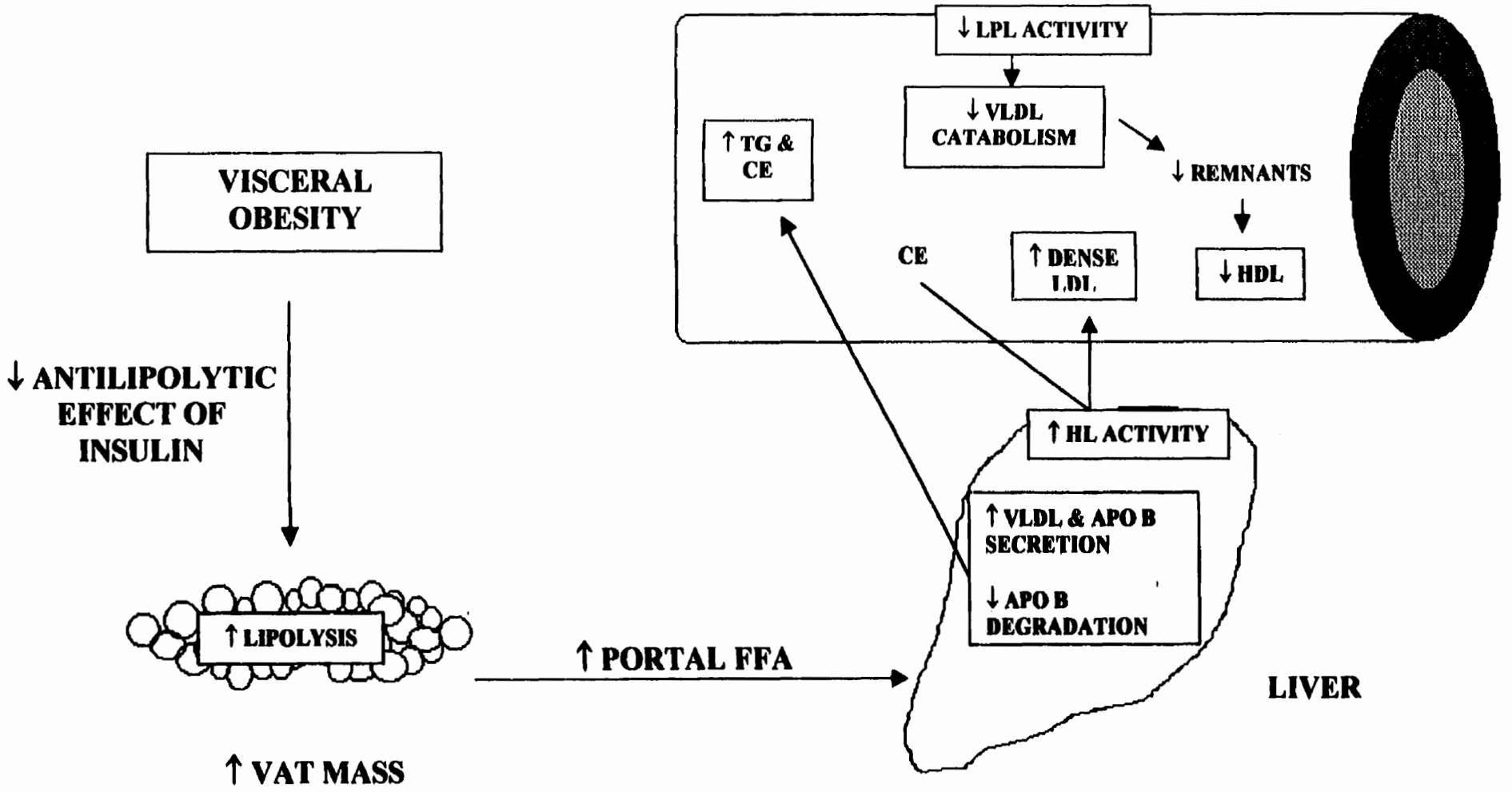

Figure 1: Simplified overview of the effects of VAT on lipid and lipoprotein metabolism (adapted from Després, 1997)

↑, increase; ↓, decrease; VAT, visceral adipose tissue; FFA, free fatty acid; Apo B, Apolipoprotein B; VLDL, very low density lipoprotein; HL, hepatic lipase; TG, triglyceride; CE, cholesteryl ester; LPL, lipoprotein lipase; LDL, low density lipoprotein; HDL, high density lipoprotein

associated with high blood pressure or cigarette smoking (AHA, 1998). Physically active individuals tend to experience fewer clinical manifestations of cardiovascular disease and their clinical episodes appear to be less severe and occur later in life (Haskell, 1986). Very active middle-aged men and women (compared to sedentary controls) have higher plasma concentrations of HDL-C, lower levels of VLDL-C and triglyceride, and often moderately lower levels of LDL-C (Wood, 1994). Very active people are also leaner and smoke less (Wood, 1994). However, it is not clear as to whether the reduction in risk factors is a result of enhanced cardiovascular fitness, reduced body fat, or other factors.

The American College of Sports Medicine (ACSM) has defined the minimum amount of exercise required to improve physical fitness as "20 minutes of continuous exercise performed at a minimum of 50% of maximal oxygen consumption ($\dot{V}O_{2MAX}$), three days per week for several weeks" (ACSM, 1991). However, the ACSM also reported that a different minimum exercise stimulus may be required to improve health related fitness, including plasma lipid and lipoprotein levels. Deprés and Lamarche (1994) suggested that the risk of cardiovascular disease may be altered to a greater extent by the volume of exercise rather than by its intensity. This was based on the premise that any substantial increase in daily energy expenditure will eventually lead to weight loss that will result in improvements in lipid metabolism, independent of cardiovascular fitness. They recommended prolonged endurance exercise of low intensity (approximately 50% of $\dot{V}O_{2MAX}$) to significantly improve metabolic variables and the resulting risk of cardiovascular disease.

Haskell (1984) suggested that a threshold of approximately 1000 calories of energy expenditure per week exists to elicit plasma lipid or lipoprotein changes. Above

this level a dose-response exists, with greater changes occurring up to an expenditure of 4,500 calories per week. However, it may be more difficult to change the plasma lipid and lipoprotein concentrations in women by exercise training than in men. Modification of the activity of the enzymes involved in the synthesis, transport and catabolism of the various lipoproteins (specifically LPL, HL) are considered to mostly likely mediate these exercise-induced changes. This mechanism is illustrated in Figure 2.

2.4.0 The role of genetics in determining lipid and lipoprotein metabolism

Severe metabolic complications are not observed in all viscerally obese individuals (Després et al., 1992). This suggests that genetic predisposition may be a factor in determining the susceptibility of viscerally obese individuals to metabolic disorders. Vohl et al. (1995) proposed that visceral obesity may exacerbate the genetic susceptibility of dyslipidemia. Visceral obesity may be associated with elevated triglyceride levels and low HDL-C concentrations in individuals who are homozygous for the + allele of the *hind*III restriction site in intron 8 of the LPL gene (Vohl et al., 1995). These authors determined that in viscerally obese individuals, the +/+ genotype of the LPL gene was associated with increased triglycerides and decreased HDL-C. Other genotypes have also been shown to be associated with increased susceptibility of viscerally obese individuals to metabolic disorders. However, as genetic predisposition is not a major focus of this review, they will not be discussed in detail.

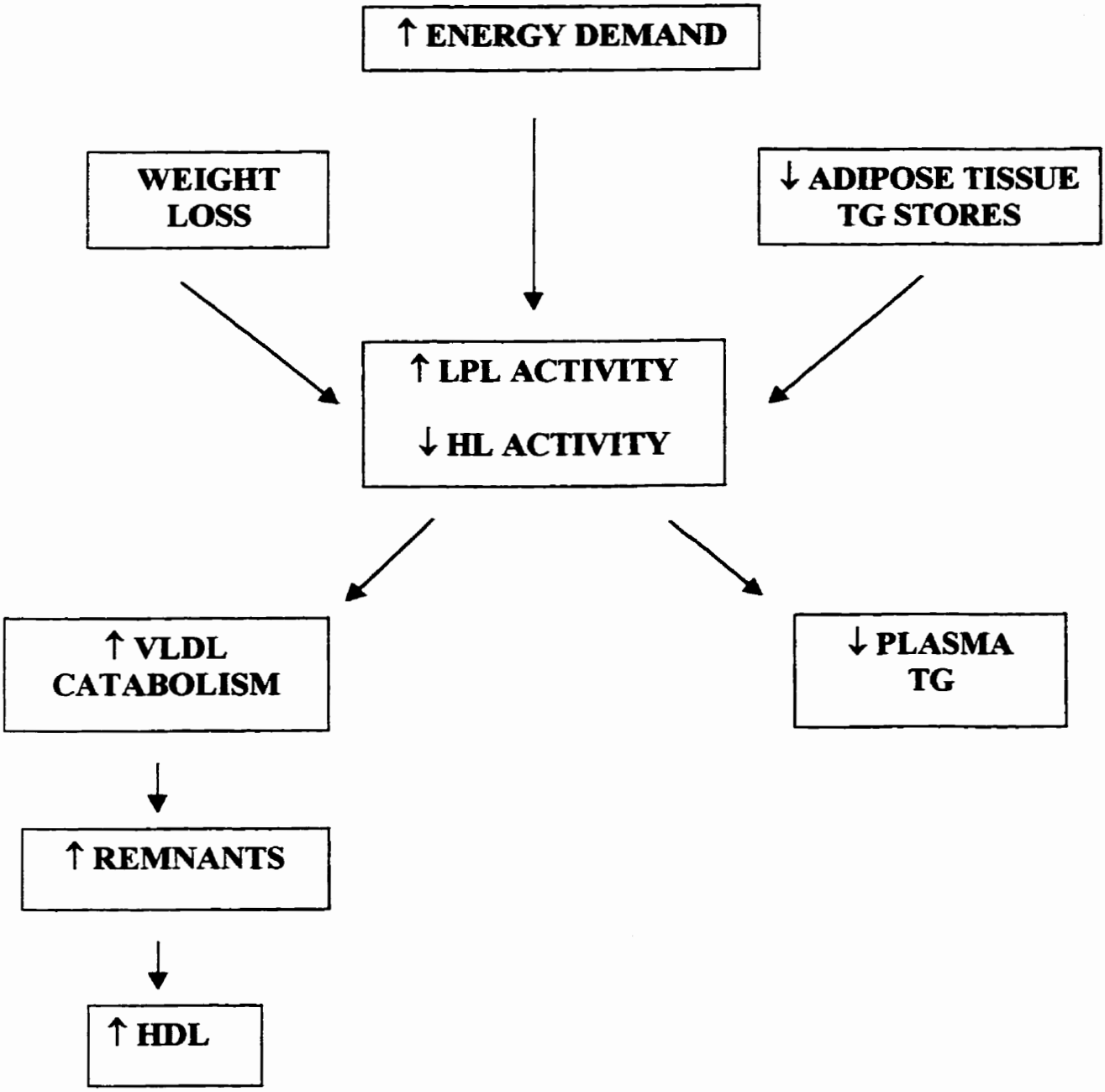

Figure 2: Effect of exercise on plasma lipid and lipoprotein levels

↑, increase; ↓, decrease; LPL, lipoprotein lipase; HL, hepatic lipase; TG, triglyceride; VLDL, very low density lipoprotein; HDL, high density lipoprotein

2.5.0 Summary of risk factors that may contribute to disturbances in the plasma lipid and lipoprotein profile

Obesity, visceral adiposity, genetics and physical inactivity may contribute to disturbances in the plasma lipid and lipoprotein profile. Intervention studies have examined the independent and combined effects of weight loss, fat loss, increased physical activity and changes in diet composition on plasma lipid and lipoprotein levels. The remainder of this review will focus on the findings of these studies.

2.6.0 Effect of weight loss on lipid and lipoprotein metabolism

There is increasing evidence that in obese individuals, moderate weight loss (5-10% of initial body weight) has beneficial effects on cardiovascular risk factors such as dyslipidemia (Van Gaal, 1997). These improvements in the plasma lipid and lipoprotein profile have been demonstrated whether weight loss is induced by caloric restriction or increased energy expenditure (NCEP, 1993). Table 2 summarizes the results of eleven studies that examined the effect of diet-induced weight loss on plasma lipid and lipoprotein levels. The effect of exercise-induced weight loss will be discussed in a later section.

Of the eleven studies summarized in Table 2, two (Katzel et al., 1995; Wood et al., 1991) observed significant reductions in total cholesterol with weight loss. Similarly, LDL-C was seen to decrease in two (Katzel et al., 1995; Wood et al., 1991) of the eleven weight loss intervention studies. The reason for the discrepancy is not clear. Studies with very low initial triglyceride levels (<1.0 mmol/L) (Hagan et al., 1986(♀); Kraemer et al., 1997; Wood et al., 1991) or small weight loss (<3 kg) (Stefanick et al., 1998) did not show significant changes in plasma triglycerides following the intervention. Studies

Table 2: Effect of weight loss achieved by caloric restriction on plasma lipids and lipoproteins

Study	Subject Characteristics	Duration of Intervention	Weight Change (kg)	Baseline Lipids (mmol/L)				% Change (%)			
				TC	LDL-C	HDL-C	TG	TC	LDL-C	HDL-C	TG
Coon et al. (1989)	M=10 obese	9 weeks	-11.4*	4.37	2.92	0.78	1.47	-4.8	-6.2	+14.1*	-19.7
Dengel et al. (1994)	M=15 obese	43 weeks	-8.0*	4.68	3.18	0.89	1.51	-3.8	-5.7	+14.6*	-21.8
Hagan et al. (1986)	F=12 M=12 overweight	12 weeks	F -5.5† M -8.4†	5.12 5.22	3.31 3.41	1.39 1.05	0.94 1.67	-6.0 -5.4	-4.8 0.0	-7.9 -2.9	-7.4 -33.5*
Katzel et al. (1995)	M=44 obese	39 weeks	-9.5*	4.71	3.10	0.90	1.49	-4.2†	-7.0†	+13.3†	-18.0†
Kraemer et al. (1997)	F=8 obese	12 weeks	-6.2*	N/R	N/R	N/R	0.74	-13.3	-14.0	-17.8*	+13.5
Reid et al. (1994)	F+M=9 obese	12 weeks	-5.6*	5.96	N/R	1.16	2.44	-4.2	N/R	-17.2*	-22.1
Schwartz (1987)	M=12 obese	13 weeks	-13.1*	4.70	N/R	0.86	1.77	-16.0	N/R	+12.8*	-34.5*
Sopko et al. (1985)	M=10 obese	12 weeks	-6.2*	4.22	2.76	0.97	1.19	+1.4	+1.8	+2.4*	+2.25
Stefanick et al. (1998)	F=46 M=49 obese	52 weeks	F -2.7† M -2.8†	6.19 5.84	4.15 4.02	1.23 0.94	1.80 1.94	-3.4 -5.8	-4.6 -6.7	+0.8 -3.2	-2.8 -3.6

Study	Subject Characteristics	Duration of Intervention	Weight Change (kg)	Baseline Lipids (mmol/L)				% Change (%)			
				TC	LDL-C	HDL-C	TG	TC	LDL-C	HDL-C	TG
Wood et al. (1991)	F=31 M=40 obese	52 weeks	F –4.1† M –5.1†	4.98 5.41	3.09 3.63	1.50 1.10	0.85 1.44	-7.8† -7.8	-9.1† -10.7	-10.0 +1.8	+10.6 -8.3
Wood et al. (1988)	M=42 obese	39 weeks	-7.2†	5.71	3.84	1.10	1.59	-6.3	-8.1	+10.9†	-17.0†

M, male; F, female; N/R, not reported; TC, total cholesterol; LDL-C low density lipoprotein cholesterol; HDL-C high density lipoprotein cholesterol; TG, triglyceride.

* $p < .05$, pre vs. post
† $p < .05$, vs. control group

with high initial triglyceride levels in combination with substantial weight loss were associated with the greatest improvement in plasma triglycerides (Hagan et al., 1986(♂); Katzel et al., 1995; Schwartz, 1987; Wood et al., 1988). Of the studies presented in Table 2, approximately half reported significant increases in HDL-C with weight loss (Coon et al., 1989; Dengel et al., 1994; Katzel et al., 1995; Schwartz, 1987; Sopko et al., 1985; Wood et al., 1988). Two studies reported significant decreases in HDL-C with weight loss (Kraemer et al., 1997; Reid et al., 1994). Again, the reason for the discrepancy is not clear.

The effect of gender on improvements in plasma lipid and lipoprotein levels with weight loss is unclear. Of the four studies in Table 2 reporting data on female subjects, only Wood et al. (1991) showed a significant improvement in the plasma lipid and lipoprotein profile with weight loss. In contrast, of the nine studies in Table 2 reporting data on male subjects, only two (Stefanick et al., 1998; Wood et al., 1991) did not show a significant improvement in the plasma lipid and lipoprotein profile with weight loss. Three studies reported data on male and female subjects. Of these studies, one showed significant improvements in the plasma lipid and lipoprotein profile in men but not women (Hagan et al., 1986), one showed significant improvements in the plasma lipid and lipoprotein profile in women but not men (Wood et al., 1991), and one did not show significant improvements in the plasma lipid and lipoprotein profile (Stefanick et al., 1998).

A meta-analysis by Dattilo and Kris-Etherton (1992) examined the effects of weight reduction on blood lipids and lipoproteins in studies published between 1966 and 1989. Principal findings of this statistical analysis were that weight reductions were

accompanied by decreases in total cholesterol, triglycerides and LDL-C. Active weight loss (a period of negative energy balance) was associated with a decrease in HDL-C, whereas a reduced, stabilized weight was associated with an increase in HDL-C. With the exception of LDL-C, initial lipids and lipoproteins were highly correlated with expected change; a greater initial concentration predicted a greater decrease with weight loss. These authors reported that the observed decreases in total cholesterol with weight loss may be explained in part by various mechanisms. First, the mobilization of adipose tissue cholesterol stores may inhibit hepatic cholesterol synthesis (Vaswani, 1983). Second, cholesterol excretion with bile may be enhanced with weight loss (Bennion & Grundy, 1975).

It has been suggested that the changes in HDL-C concentrations during (Taskinen & Nikkila, 1979) and following (Schwartz & Brunzell, 1981) weight loss may be explained by changes in LPL activity. LPL activity increases after weight has stabilized at a reduced weight. However, during active weight loss or negative energy balance, tissue LPL activity is reduced. During active weight loss, decreased LPL activity impairs VLDL-C hydrolysis, resulting in decreased in lipid remnants available for transfer to HDL-C. When weight is stabilized at a reduced level, increased LPL activity increases the catabolism of VLDL-C, which increases the lipid available for transfer to HDL-C and results in increased concentrations of HDL-C (Dattilo & Kris-Etherton, 1992).

2.7.0 Effect of diet composition on lipid and lipoprotein metabolism

Diet composition has been reported to be the most significant factor influencing the plasma lipid and lipoprotein profile (NCEP, 1993). Specifically a diet high in total

fat, saturated fat, and cholesterol, and low in water soluble dietary fiber is thought to promote the greatest risk of cardiovascular disease (Stone, 1996). A variety of dietary strategies can be implemented to lower total cholesterol and LDL-C levels. The extent to which dietary strategies are successful in achieving this goal depends on several factors including the initial total cholesterol level (individuals with the highest levels will observe the greatest change), the acceptance and compliance with the diet, and the associated changes in body weight.

Dietary therapy should be directed at modifying dietary factors known to adversely influence blood cholesterol such as saturated fats, cholesterol and obesity (Stone, 1996). The rationale to reduce total fat in the diet is based on the concept that it will decrease saturated fat intake, decrease the total calorie intake and promote weight reduction.

In a meta-analysis of 37 dietary intervention studies, the NCEP's Step I diet (≤ 30% of total energy as fat, ≤ 10% of energy as saturated fat and ≤ 300mg dietary cholesterol/d) and Step II diet (≤ 7% of energy as saturated fat and ≤ 200mg dietary cholesterol/d) were found to significantly decrease plasma lipids and lipoproteins (Yu-Poth et al., 1999). The Step II dietary intervention resulted in greater decreases in plasma total cholesterol, triglycerides, LDL-C and HDL-C (Yu-Poth et al., 1999). The Step I diet did not decrease HDL-C. Significant correlations were reported between decreases in dietary total and saturated fatty acids and decreases in total cholesterol, LDL-C and HDL-C (Yu-Poth et al., 1999).

Excessive reduction of fat intake can increase triglyceride levels and lower HDL-C (Grundy et al., 1989). Hudgins et al. (1996) determined that after a ten day eucaloric,

low fat, high carbohydrate diet (10% of calories as fat and 75% as glucose polymers) fatty acid synthesis was increased. In contrast, fatty acid synthesis was minimal following high fat diet (40% of calories as fat and 45% as glucose polymers) of the same duration. However, based on the results of their previous research, these authors caution that fatty acid synthesis was increased to a lesser extent when half of the carbohydrate was starch or a mixture of complex carbohydrates (Hudgins et al., 1995; Hudgins et al., 1993).

The biosynthesis of fatty acids (de novo lipogensis or DNL) occurs via two metabolic pathways. With the exception of the presence of the VLDL secretory pathway in the liver cell, the pathways are similar in hepatocytes and adipocytes. The major pathway is illustrated in Figure 3. Thus, increased fatty acid synthesis due to the extreme substitution of dietary fat with sugar can promote cardiovascular disease.

A diet high in monosaturated fatty acids may promote a decrease in total cholesterol similar to that associated with a low fat diet, while maintaining HDL-C and triglyceride levels. Mensink & Katan (1987) compared the effects of a carbohydrate rich diet (62% carbohydrate, 22% fat) and a monosaturated fatty acid (olive oil) rich diet (46% carbohydrate, 40% fat) on plasma lipid and lipoprotein levels in healthy men and women. Both diets were associated with similar reductions in total cholesterol compared to a Western diet. However, the high carbohydrate diet was associated with decreased HDL-C and increased triglyceride levels. The diet high in monosaturated fatty acids was shown to promote a decrease in non-HDL cholesterol without altering HDL-C or triglyceride levels.

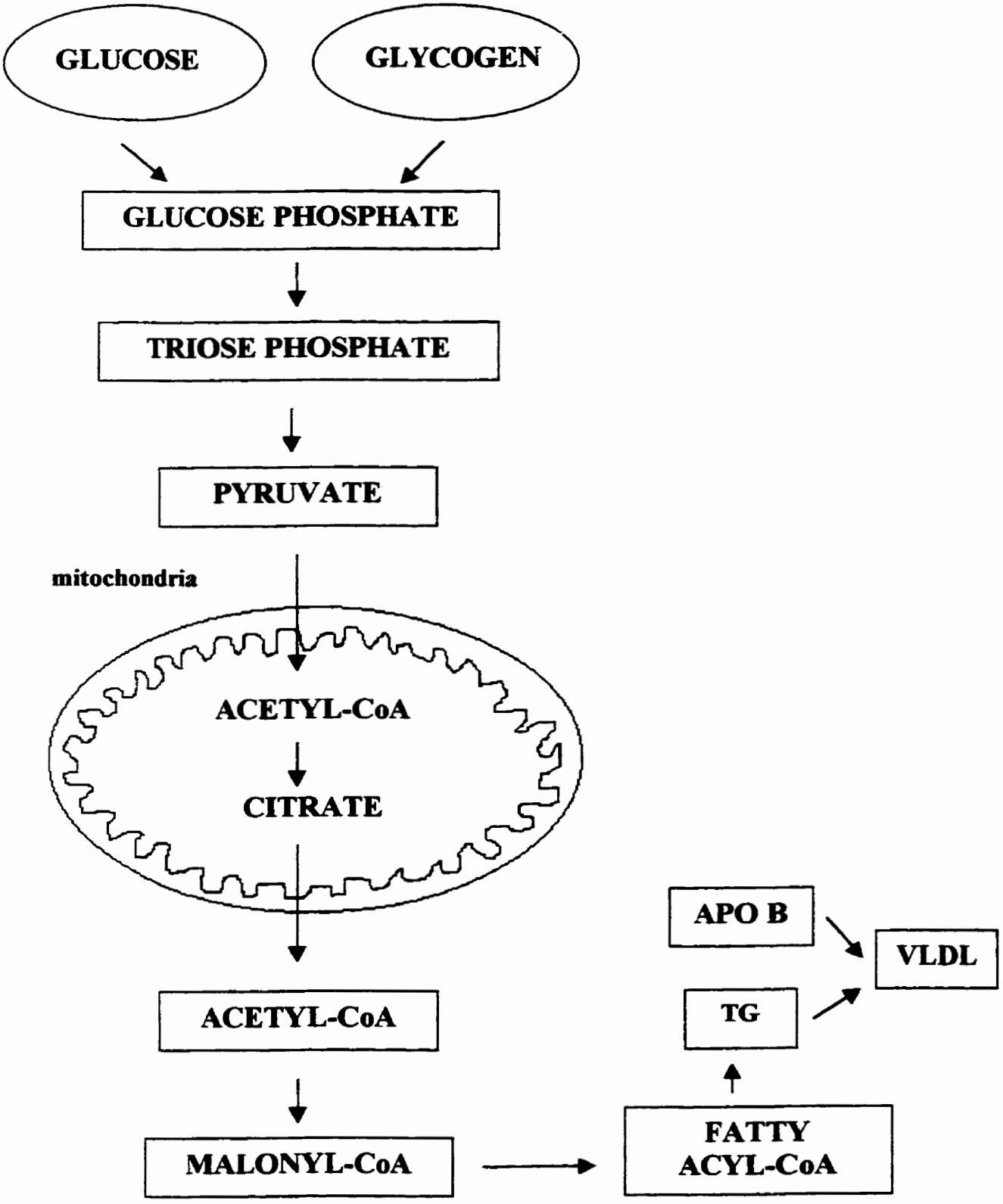

Figure 3: De novo lipogenesis in hepatocytes (adapted from Hellerstein et al., 1996)

TG, triglyceride; Apo B, Apolipoprotein B; VLDL, very low density lipoprotein

2.8.0 Effect of exercise on lipid and lipoprotein metabolism

It is thought that regular exercise may have favorable effects on plasma lipid and lipoprotein levels. Indeed, in a meta-analysis of 66 training studies by Tran et al. (1993), it was reported that the average exercising subject was found to have significant reductions in total cholesterol, triglyceride, and LDL-C levels whereas the plasma lipid and lipoprotein levels for the control subjects did not change. The mechanism by which exercise affects plasma lipid and lipoprotein variables may be mediated by weight loss (see Figure 2). It is unclear whether exercise in the absence of weight loss has a significant effect on plasma lipid and lipoprotein levels. A further limitation with regard to research examining the physiological effects of exercise is that few studies have simultaneously reported data on aerobic versus resistance exercise.

2.8.1 Aerobic exercise

The results of 23 studies that investigated the effect of aerobic exercise with or without weight loss on plasma lipid and lipoprotein variables are summarized in Table 3. Significant decreases in total cholesterol greater than 5% were noted in some (Dengel et al., 1998; Kraemer, 1997) but not other (Kanaley et al., 1993; Sopko et al., 1985) studies with concurrent weight loss. Significant decreases in total cholesterol greater than 5% were not reported in the absence of weight loss. These results suggest that aerobic exercise in the absence of weight loss does not improve total cholesterol levels.

Significant decreases in plasma triglycerides were noted in some aerobic exercise studies with (Dengel et al., 1998; Kanaley et al., 1993) and without (Katzel et al., 1995; Thompson et al., 1997) weight loss but not in other aerobic exercise studies with

Table 3: Effect of aerobic exercise or diet + aerobic exercise interventions on plasma lipids and lipoproteins

Study	Subject Characteristics	Duration of Intervention	Type of Interv.	Weight Change (kg)	Baseline Lipids (mmol/L)				% Change (%)			
					TC	LDL-C	HDL-C	TG	TC	LDL-C	HDL-C	TG
Coon et al. (1989)	M=10 obese	39-52 weeks	E	N/C	4,78	3,28	0,81	1,51	-5,9	-7,0	+3,7	-8,6
Dengel et al. (1998)	M=9 obese	26 weeks	DE	-9,1*	4,65	2,96	0,76	2,05	-14,6*	-12,0	+5,3	-39,0*
Dengel et al. (1994)	M=15 obese	43 weeks	DE	-7,6*	4,78	3,28	0,92	1,44	-7,5*	-12,5*	+5,4	-24,3*
Fonong et al. (1996)	F=14 M=23 lean	8 weeks	E	N/C	5,45	3,44	1,41	1,40	-3,7	-7,0	-1,4	-5,0
Hagan et al. (1986)	F=24 M=24 overweight	12 weeks	E	(F) N/C	4,65	2,74	1,36	1,29	+2,8	+11,3	-5,9	-23,2
			DE	(F) -9,4†	5,11	3,20	1,28	1,39	-0,4	+9,1	-10,2	-29,5
			E	(M) N/C	5,12	3,00	0,92	2,71	+6,4	+12,0	-6,5	+1,5
			DE	(M) -11,4†	5,04	3,23	0,99	1,87	-15,3†	-11,1	0,0	-49,7†
Kanaley et al. (1993)	F=19 obese	17 weeks	DE	-8*	5,12	N/R	1,01	1,22	-12,1	N/R	+4,0	-24,6*
Katzel et al. (1997)	M=21 obese	39 weeks	E	N/C	4,58	3,07	0,86	1,41	-1,3	0,0	+4,6	-9,2
		+ 39 weeks	DE	-8,1*	4,52	3,07	0,90	1,28	-5,1*	-7,5*	+11,1*	-16,4*
Katzel et al. (1995)	M=49 obese	39 weeks	E	N/C	4,71	3,12	0,87	1,50	-1,8†	-4,2†	+5,0	-9,3†
Kraemer et al. (1997)	F=31 obese	12 weeks	DE	-6,5*	N/R	N/R	N/R	1,07	-16,1*	-17,2*	-13,3	-13,1

Study	Subject Characteristics	Duration of Intervention	Type of Interv.	Weight Change (kg)	Baseline Lipids (mmol/L)				% Change (%)			
					TC	LDL-C	HDL-C	TG	TC	LDL-C	HDL-C	TG
Nicklas et al. (1987)	M=46 lean – obese	39 weeks	E	-<2*	4,65	3,15	0,85	1,38	-4,9	-6,0	+8,2*	-15,9*
Reid et al. (1994)	F+M=14 obese	12 weeks	E	N/C	6,21	N/R	1,04	2,22	+1,8	N/R	+19,2*	-4,8
			DE	-7,8*	6,28	N/R	1,05	2,78	-9,5*	N/R	+9,5	-35,0*
Schwartz (1987)	M=14 obese	13 weeks	E	-2,8*	4,52	N/R	0,94	1,42	+4,0	N/R	+7,4*	-2,1
Sopko et al. (1985)	M=13 obese	12 weeks	E	N/C	4,30	2,72	1,00	1,46	+1,4	+0,7	+2,0	+0,7
			DE	-6*	4,41	2,78	1,03	1,46	-0,7	-3,6	+5,5*	-7,5
Sopko et al. (1983)	M=10 overweight	12 weeks	DE	-3,2*	6,28	4,21	1,19	2,24	-4,3	-2,6	+11,8*	-31,7
Stefanick et al. (1998)	F=86 M=95 obese	52 weeks	E	(F) N/C	6,19	4,15	1,23	1,80	-2,4	-3,4	+4,9	-7,8
			DE	(F) -3,1†	6,19	4,15	1,23	1,80	-7,3†	-8,9†	-2,4	-6,7
			E	(M) N/C	5,84	4,02	0,94	1,94	-2,2	-2,2	+3,2	-7,7
			DE	(M) -4,2†	5,84	4,02	0,94	1,94	-9,1†	-12,7†	+1,1	-4,1
Thompson et al. (1997)	M=17 obese	52 weeks	E	N/C	5,40	3,75	1,01	1,45	-1,5	-3,5	+9,9*	-8,3*
Vermeulen (1990)	F=26 obese	4 weeks	DE	-7,7*	6,89	4,91	1,25	2,18	-22,3*	-24,4*	-3,2	-25,7*
Walberg et al. (1988)	F=12 obese	4 weeks	DE	-7,3*	4,00	N/R	1,22	0,97	-23,7*	N/R	-3,3	+25,8
Weintraub et al. (1989)	M=6 lean – obese	7 weeks	E	N/C	4,50	2,69	1,26	0,92	-3,5	-4,1	+4,0	-14,1*

Study	Subject Characteristics	Duration of Intervention	Type of Interv.	Weight Change (kg)	Baseline Lipids (mmol/L)				% Change (%)			
					TC	LDL-C	HDL-C	TG	TC	LDL-C	HDL-C	TG
Williams et al. (1990)	M=48 lean	52 weeks	E	-1.9†	5.54	3.77	1.28	1.36	-2.7	-4.0	+3.9	-9.6
Wood et al. (1991)	F=42	52 weeks	DE	(F) -5.1†	4.98	3.09	1.50	0.85	-5.6†	-9.4†	-1.3	-2.3
	M=39 obese		DE	(M) -8.7†	5.41	3.63	1.10	1.44	-7.4	-7.4	+12.7†	-33.3†
Wood et al. (1988)	M=47 obese	52 weeks	E	-4†	5.64	3.83	1.06	1.52	-4.4	-6.5	+10.4†	-10.5†
Zmuda et al. (1998)	M=17 obese	52 weeks	E	N/C	5.37	3.70	0.99	1.50	-1.3	-3.0	+9.1*	-6.0

M, male; F, female; N/R, not reported; N/C, no change; TC, total cholesterol; LDL-C low density lipoprotein cholesterol; HDL-C high density lipoprotein cholesterol; TG, triglyceride; E, exercise; DE, diet + exercise.

* $p < .05$, pre vs. post
† $p < .05$, vs. control group

(Kraemer et al., 1997; Sopko et al., 1985) and without (Stefanick et al., 1998; Williams et al., 1990) weight loss. Thus, the effect of aerobic exercise per se on plasma triglyceride levels is unclear.

Significant increases in HDL-C were noted in some aerobic exercise studies with (Katzel et al., 1997; Spoko et al, 1983) and without (Reid et al., 1994; Thompson et al., 1997) weight loss but not in other aerobic exercise studies with (Dengel et al., 1998; Kanaley et al., 1993) and without (Hagan et al., 1986; Katzel et al., 1997) weight loss. Thus, the effect of aerobic exercise per se on HDL-C levels is unclear.

The improvements in plasma lipid and lipoprotein levels with aerobic exercise in men and women do not appear to be different. Of the seven studies in Table 3 reporting data on obese female subjects, only one (Hagan et al., 1986) did not show a significant improvement in the plasma lipid and lipoprotein profile with aerobic exercise. Similarly, of the fourteen studies in Table 3 reporting data on obese male subjects, only one (Coon et al., 1989) did not show a significant improvement in the plasma lipid and lipoprotein profile with weight loss. Three studies reported data on male and female subjects. Of these studies, one showed significant improvements in the plasma lipid and lipoprotein profile in men but not women (Hagan et al., 1986), and two showed significant improvements in the plasma lipid and lipoprotein profile in men and women (Stefanick et al., 1998; Wood et al., 1991).

2.8.2 Resistance exercise

Significant improvements in plasma lipid and lipoprotein levels have been reported following some resistance exercise studies (Hurley et al., 1988) but not others (Smutok et al., 1993; Manning et al., 1991). Manning et al. (1991) suggested that a lack of body weight loss, the lack of a negative caloric balance, and the type of training that required low energy expenditure may explain why the lipid, lipoprotein and apolipoprotein levels were not altered. However, Hurley et al. (1988) reported improvements in HDL-C and LDL-C in the absence of changes in total body and percent body fat. Goldberg (1989) suggested that dynamic resistive training (e.g. circuit weight training) will promote the utilization of glucose and fat by muscles and that this effect may improve lipid and lipoprotein levels.

2.9.0 Summary

To date the independent effects of genetics, weight loss, diet and exercise modification on the plasma lipid and lipoprotein profile are presented in the literature with varying degrees of controversy. The complex interactions of these variables are also poorly understood. Genetic research suggests that a susceptibility to abnormalities in the plasma lipid and lipoprotein profile may exist in some individuals. This susceptibility may be intensified when accompanied by visceral obesity. Weight loss induced by either diet or the combination of diet plus exercise shows beneficial effects on the plasma lipid and lipoprotein profile. A decrease in visceral adipose tissue may be a key factor in determining this metabolic improvement. The effect of exercise on plasma lipid and lipoprotein variables may be mediated by weight loss. The volume of exercise is thought

to have a more significant influence on metabolic fitness than the intensity of the activity. Three dietary habits typically contribute to an unfavorable metabolic profile. These include a high intake of saturated fat, a high intake of cholesterol and a caloric intake that exceeds the requirements of the body.

From the present review, it is apparent that many issues surrounding the effects of diet and exercise on plasma lipid and lipoprotein levels remain unresolved. Specifically, it is unclear whether exercise in addition to caloric restriction will produce a greater improvement in plasma lipid and lipoprotein levels and whether the effects of aerobic and resistance exercise will be different. The present study has been designed to test the hypothesis that the combination of diet and either aerobic or resistance exercise has beneficial effects on the plasma lipid and lipoprotein profile that are greater than diet alone in obese women.

3.0.0 MANUSCRIPT

The following chapter of this thesis is presented in manuscript format. For simplicity the references for the manuscript are included in Chapter 5.0.0.

Effects of exercise and/or diet on
plasma lipid and lipoprotein levels in obese women

Introduction

Since obesity, in particular upper-body obesity, and specifically visceral adipose tissue (VAT) accumulation are associated with metabolic disturbances (Després & Lamarche, 1993), it follows that reductions in VAT and/or body weight may lead to improvements in the plasma lipid and lipoprotein profile. Indeed, a study by Fujioka et al. (1991) demonstrated that following diet-induced weight loss, metabolic improvements, including decreased triglyceride levels, were significantly associated with changes in VAT in obese premenopausal women.

Discrepant findings are reported with respect to improvements in plasma lipid and lipoprotein levels in diet and/or exercise intervention studies. Whereas some studies suggested that weight loss was related to improvements in plasma lipid and lipoprotein levels (Katzel et al., 1997; Katzel et al., 1995; Stefanick et al., 1998), evidence to the contrary was also reported (Kraemer et al., 1997; Reid et al., 1994). Similarly, whereas some studies suggested that in the absence of weight loss, aerobic (Katzel et al., 1995; Thompson et al., 1997) and resistance (Hurley et al., 1988) exercise were associated with improvements in plasma lipid and lipoprotein levels, again, there is evidence to the contrary (Coon et al., 1989; Fonong et al., 1996) and (Manning et al., 1991; Smutok et al., 1993) respectively.

The inconsistencies reported in previous diet/exercise studies may reflect differences in the nutritional composition of the diet, severity of the dietary energy restriction, dietary compliance, exercise compliance, duration of the study, and randomization, as well as differences in mode, intensity and duration of exercise. As well, few studies used imaging techniques to determine changes in the various adipose

tissue depots. Absent from the literature are studies that simultaneously examine whether the combination of diet and aerobic exercise, and the combination of diet and resistance exercise have effects on plasma lipid and lipoprotein levels that are different from each other, or from diet alone, in obese men and women.

In the present study, obese female subjects randomly assigned to one of three treatment groups: diet only, diet plus aerobic exercise or diet plus resistance exercise. We tested the hypothesis that the combination of diet and either aerobic or resistance exercise is associated with greater improvements in plasma lipid and lipoprotein levels compare to diet alone in obese women. A whole body, multislice magnetic resonance imaging (MRI) protocol was employed to determine the associations between concurrent changes in subcutaneous adipose tissue (SAT), VAT, skeletal muscle mass and lipid metabolism.

Subjects and Methods

Subjects

Thirty-six obese but otherwise healthy premenopausal women were recruited from the general public through the local media and were randomly assigned to the three treatment groups; diet only (DO), diet plus aerobic exercise (DA), and diet plus resistance exercise (DR). Inclusion criteria required that the women were upper-body obese (BMI > 27; WHR ≥ 0.85), were weight stable (±2 kg) for six months prior to the beginning of the study, were sedentary for at least three months prior to the beginning of the study, were premenopausal, did not smoke, took no medications known to affect the study variables (e.g. oral contraceptives), and consumed on average fewer than two alcoholic beverages per day.

Thirty-five subjects completed the study. One subject (from the DA group) was excluded from the data analysis in order to ensure that the groups were matched for BMI (BMI > 47). One subject (from the DA group) was excluded from the data analysis due to an extreme hyperlipidemic profile at baseline (TG = 8.5 mmol/L; total cholesterol=7.1 mmol/L). Thus, data are reported for thirty-three women: twelve in the DO group, eight in the DA group and thirteen in the DR group. With the exception of skeletal muscle, there were no differences between treatment groups for any of the anthropometric, MRI or lipid variables ($p > .05$). All subjects gave their fully informed, written consent to participate in the study. The study was conducted in accordance with the ethical guidelines of Queen's University.

Anthropometric variables

Body weight was assessed using a balance scale calibrated to 0.1 kg with the subject dressed only in a t-shirt, undergarments and a pair of shorts. Barefoot standing height was measured to the nearest 0.1 cm using a wall-mounted stadiometer. Circumference measurements were obtained at the level of the umbilicus, last rib, and hip, with the subject in a standing position according to the procedure outlined in the Anthropometric Standardization Reference Manual (Lohman (Ed.), 1988). All circumference measurements were obtained by the same investigator pre- and post-treatment. Body fat distribution by anthropometry was estimated by waist-hip-ratio (WHR) calculated using the waist circumferences of the umbilicus and the last rib.

Tissue measurements by MRI

The MRI images were obtained with a Siemens 1.5-tesla scanner (Erlangen, Germany). A T1-weighted, spin-echo sequence with a 210 ms repetition time and a 17 ms echo time was used to obtain optimal contrast between lean tissue and adipose tissue in the MRI data. The MRI image acquisition protocol is described in detail elsewhere (Ross et al., 1992). Briefly, six data sets of seven images were obtained while the subject lay in a prone position, with arms extended straight beyond the head. The intervertebral space between the fourth and fifth lumbar vertebrae (L4-L5) was used as the point of origin. A total of 41 transverse images (10 mm thickness) were obtained at 50 mm intervals from hand to foot using the previously mentioned origin. The total time required to obtain the MRI data for each subject was approximately 25 minutes. All MRI

data was transferred to a computer workstation (Silicon Graphics Inc., Mountain View, CA) for analysis using image analysis software (Tomovision, Inc., Montreal).

Segmentation and calculation of tissue areas and volumes

The model used to segment the various tissues is fully described and illustrated elsewhere (Ross et al., 1996). Tissue area (cm^2) was identified for a given MRI image using a multiple step procedure. In the first step of this procedure a threshold was selected for adipose tissue and lean tissue based on the analysis of grey level histograms for a sample of typical images. Each image was then reviewed by an interactive slice editor programme which allowed for verification, and where necessary, correction of the segmented results. The original grey level image was then superimposed on the binary segmented image using a transparency mode to facilitate the corrections. In the final step, the different tissues were labeled manually by assigning each tissue a unique code.

The area of each tissue in each slice was calculated by multiplying the number of pixels of a given tissue by the pixel surface area. The volume (cm^3) of each tissue in each slice was calculated by multiplying the tissue area by the slice thickness. The volume of each tissue in the space between two consecutive slices was calculated using a mathematical algorithm previously reported (Ross et al., 1996).

Determination of tissue mass

For adipose tissue and skeletal muscle, volume units (L) were converted to mass units (kg) by multiplying the volumes by the assumed constant densities of 0.92 kg/L and 1.04 kg/L respectively (Snyder et al., 1975). Data from the only two overweight human

cadavers (>20% body fat) which report both chemical composition and individual tissue weights (Forbes et al, 1953; Forbes et al., 1956), a density of 1.08kg/L was used to estimate lean tissue density.

Plasma lipid and lipoprotein analyses

Blood samples were drawn during the follicular phase of the menstrual cycle, following an overnight fast. Serum total cholesterol (TC) and triglyceride (TG) levels were determined using standard techniques. High density lipoprotein cholesterol (HDL-C) levels were determined after isoelectric-polyanionic precipitation of low density lipoprotein cholesterol (LDL-C). LDL-C was subsequently determined using the following equation: LDL-C = TC – [HDL-C + (0.46 x TG)]. Apolipoprotein A and B were determined by rate nephelometry using reagents obtained from Beckman Instruments Inc. (Fullerton, CA). Coefficients of variation for the lipid measurements were: TC, 2.1%; TG, 4.3%; HDL-C, 5%.

Diet and exercise regimens

Dietary protocol: Average daily energy requirements for weight maintenance were determined for each subject by multiplying the Harris-Benedict equation (Harris & Benedict, 1919) by a factor of 1.5. This has been reported to be within ~8% of actual energy requirements for weight maintenance in healthy subjects (Mahalko & Johnson, 1980). Throughout pre- and post-treatment testing periods (~2 weeks each) subjects consumed a weight maintenance diet. During the 16 week treatment period, the weight maintenance energy intake was reduced by 4.19 MJ/day (1000 kcal/day) for all groups.

The subjects were asked to limit consumption of dietary fat to less than 30% of the total energy intake. All foods were self-selected and no supplements were prescribed. All subjects were required to maintain daily diet records for the duration of the study. The diet records were reviewed on a weekly basis using standard food tables (Katahn & Pope, 1994) to ensure maintenance of adequate nutrition in addition to compliance to the prescribed diet. All subjects were requested to attend weekly meetings to discuss individual success strategies and to obtain dietary counsel.

Aerobic exercise protocol: In addition to the energy restriction outlined above, subjects in the DA group performed aerobic exercise 5 days per week. Initial exercise sessions lasted for ~15 minutes and progressed to a maximum of 60 minutes depending of the capability of the subject. The mode of aerobic exercise was determined by the subject and consisted of either brisk walking on a motorized treadmill (Quinton Instruments, Seattle, WA), stationary cycling on a cycle ergometer (Monark, Stockholm, Sweden), or stair stepping on an electronic stairmaster (StairMaster 4000, Tri-Tech Inc., Tulsa, OK). Exercise intensity was monitored using an automated heart rate monitor (Polar USA, Stanford, CT). The intensity of exercise progressed from 50% to 85% of the maximal heart rate that was achieved during a maximal oxygen uptake ($\dot{V}O_{2MAX}$) test. All of the exercise sessions were by appointment and supervised by a physical educator to ensure compliance to the prescribed programme.

Resistance training protocol: In addition to the previously mentioned energy restriction, subjects in the DR group performed resistance exercise 3 days per week using Nautilus weight-training equipment (Nautilus, Deland, FL). Training sessions began with a 5-10 minute warm-up of low intensity stationary cycling followed by 5 minutes of

static stretching. Seven resistance exercises were performed at each session: leg extension, leg flexion, super pullover (latissiums dorsi), bench press, shoulder press, triceps extension and biceps curl. For each exercise, one set of 8-12 repetitions was performed to the point of volitional fatigue. The concentric contraction phase was completed in ~2 s and the eccentric contraction phase was completed in ~4 s for each repetition. As soon as 12 repetitions could be performed at a given weight, the weight was increased by an amount that permitted ~8 repetitions to be performed. Large increases in strength have been reported in men and women using a similar training protocol with the same equipment (Braith et al., 1993). Partial curl-ups were performed for the abdominal muscles in addition to the other seven exercises. Each resistance exercise session lasted ~30 minutes. All of the exercise sessions were by appointment and supervised by a physical educator. The exercise monitor provided verbal encouragement to promote proper form and to ensure that physiological failure was attained for each exercise.

Evaluation of training performance

Aerobic capacity: $\dot{V}O_{2MAX}$ was determined using a graded treadmill test that employed a constant walking speed of 4.8 to 5.6 km/h. For the initial two minutes the grade was set at 0%, after which time it was increased to 2% for the third minute and by 1% every minute thereafter. Standard open-circuit spirometry techniques using a Beckman metabolic cart (Sensormedics, Fullerton, CA) were used to determine oxygen uptake ($\dot{V}O_2$). It was assumed that $\dot{V}O_{2MAX}$ was obtained when at least two of the following three criterion were achieved: no increases in $\dot{V}O_{2MAX}$ despite further increases

in treadmill grade, a heart rate equal to or exceeding the age predicted maximum (220 – age), and a respiratory exchange ratio above 1.0.

Muscular strength: Increases in strength were determined using the following formula: [(b-a)/a]x100, where a is the number of weight plates (10 lbs/plate) lifted at the beginning of week 4, and b is the number of weight plates lifted at the completion of the 16 week programme. Week 4 was selected as the initial week in an attempt to represent changes in muscular strength that were primarily due to skeletal muscle hypertrophy, thereby omitting initial increases in strength that were predominately attributable to neuromuscular factors. Linear relationships between the 7-10 RM and the 1RM both pre- ($r=0.94$) and post-training ($r=0.95$) have been demonstrated with the use of a Nautilus programme similar to that of the present study (Braith et al., 1993). Increases in upper-body strength were calculated using the bench press and the super pullover exercises, whereas lower-body strength improvements were determined using the leg extension and leg curl exercises.

Energy cost of exercise

Aerobic exercise: The oxygen cost of both treadmill walking and stationary cycling were determined using the equations provided by the American College of Sports Medicine (ACSM, 1991). Howley et al. (1991) have previously reported that direct measurement of metabolic equivalent (MET) values with the use of a StairMaster 4000 were ~20% lower than those determined using the equation provided by the equipment manufacturer. For this reason, the MET values obtained when using the stair stepper were reduced by 20% before estimation of the oxygen cost of the activity. Energy

expenditure for all three modes of exercise was subsequently determined by multiplying the oxygen cost by 21.1 kJ/L (5.04 kcal/L).

Resistance exercise: On the basis of data reported by Ballor et al. (1988), the energy expenditure of the resistance exercise programme was estimated to be 28 kJ (120 kcal) per session.

Statistical analyses

Data are presented as group means ± SD. Prior to the intervention, a one-way analysis of variance (ANOVA) was performed to examine the differences between groups for each variable. A two-way ANOVA with repeated measures was used to evaluate main effects and interactions of group and time on all dependent variables. When the ANOVA p-value was $< .05$, a Scheffé post hoc comparison test was used to identify main treatment effects. In the case where differences existed at baseline, an ANCOVA was used to evaluate main effects and interactions of group, time and the co-variate. Paired t-tests were used to assess within group changes (pre- to post-treatment) for all dependent variables. Bonferonni adjustments ($P < .017$, .05/number of groups) were used to interpret all t-test results. Pearson-product moment correlations were used to determine the strength of relationships between different dependent variables and between the initial value and change score of dependent variables.

Although traditional statistical analyses allow the determination of mean changes in lipid variables, they do not provide adequate indication of the clinical significance of the changes. The Canadian Consensus Conference on Cholesterol (CCCC) has established guidelines that are commonly used by Canadian physicians for the

identification of dyslipidemia (Maclean et al., 1999a). Numerical cut-offs are used to identify desirable, moderate risk and high risk levels for each plasma lipid and lipoprotein fraction. The Z-test for a proportion allows statistical comparison of the percentage of subjects in a risk category before and after the intervention (Ness Evans, 1998). A Z-test for a proportion was used to assess the prevalence of dyslipidemia pre- and post-treatment. With the exception of the Z-test for proportion, statistical procedures were performed using SYSTAT (SYSTAT Inc., Evanston, IL).

Results

Adherence to diet and exercise

Dietary Restriction: Complete dietary intake records were submitted by all subjects with few exceptions (< 2%). Analysis of the daily diet records indicated that the mean diet-induced energy deficit for the DO, DA and DR groups were 1,212 ± 265, 1,474 ± 284 and 1,229 ± 205 kcal/day respectively. The corresponding fat intakes expressed as a percentage of total energy consumed were 21.8 ± 4.8, 23.6 ± 6.3 and 23.0 ± 5.5%. The mean diet-induced energy deficit and the mean fat intake were not different between treatments ($p > .05$).

Aerobic Exercise: Attendance at the aerobic exercise sessions (DA group only) averaged 91% (range 85-97%). The duration of the aerobic exercise sessions averaged 35.5 ± 5.1 minutes. The average intensity of the aerobic exercise sessions was 78.0 ± 4.3% of the maximal predicted heart rate (220 – age). The average total energy expenditure elicited by the aerobic exercise component of this treatment was 19,917 ± 4,715 kcal/subject. Self-selected modes of aerobic exercise were ~63% stair stepping, ~30% treadmill walking and ~7% stationary cycling, however, there was considerable variation between subjects.

Resistance Exercise: Attendance at the resistance exercise sessions (DR group only) averaged 93% (range 79-98%). Assuming an energy cost of 28 kJ (120 kcal) per session (Ballor et al., 1988), it was estimated that the average energy expenditure elicited by the resistance exercise component of this treatment was 5,381 ± 324 kcal/subject. This value was significantly lower than the mean energy expenditure elicited by the aerobic exercise sessions ($p < .05$).

Functional capacity

In response to the aerobic exercise training programme, $\dot{V}O_{2MAX}$ increased by 9% (0.21 ± 0.16 L/min) within the DA group ($p < .01$) only. In the DR group, the mean increase for the two lower-body exercises was 23 ± 5% ($p < .01$). The mean increase in the two upper-body exercises was 42 ± 9% ($p < .01$).

Anthropometric variables

The descriptive characteristics of subjects at baseline and following the intervention are summarized in Table 1. Weight loss within each group was ~11 kg (~11%) ($p < .001$). Waist circumference decreased within each group by ~9 cm (~9%) ($p < .001$). The changes in these anthropometric variables were not different between groups ($p > .05$). WHR was not altered within any treatment ($p > .05$). There was a significant correlation between weight loss and the weight at baseline ($r=-.45$, $p < .01$).

Tissue measurements by MRI

Within all groups, significant ($p < .001$) reductions were observed for both SAT (~21%) and VAT (~31%). The changes in these variables were not different between groups ($p > .05$). Skeletal muscle mass decreased significantly within the DO group ($p < .001$) alone. However, when pre-treatment differences in skeletal muscle mass (DR<DA; $p < .05$) were controlled for by ANCOVA, treatment differences did not exist between intervention groups ($p > .05$).

TABLE 1: Descriptive characteristics of subjects at baseline and following the intervention

Variable	DO (n = 12)		DA (n = 8)		DR (n = 13)	
	Pre	*Post*	*Pre*	*Post*	*Pre*	*Post*
Anthropometric						
Age (yr)	39.7 ± 6.8		38.0 ± 6.5		35.8 ± 5.7	
Weight (kg)	91.2 ± 15.1	81.2 ± 12.9†	102.3 ± 17.5	90.5 ± 15.0†	88.0 ± 9.2	77.3 ± 10.8†
BMI (kg/m^2)	33.8 ± 4.3	30.1 ± 3.6†	36.7 ± 5.4	32.4 ± 4.5†	32.5 ± 3.8	28.6 ± 4.4†
WCUM (cm)	111.9 ± 14.9	103.0 ± 12.7†	115.7 ± 16.8	108.4 ± 15.6†	113.8 ± 9.9	102.2 ± 11.3†
WCLR (cm)	100.4 ± 13.0	93.3 ± 12.5†	105.1 ± 12.2	94.6 ± 11.9†	97.4 ± 8.3	87.0 ± 10.5†
WHR	0.93 ± 0.04	0.93 ± 0.04	0.91 ± 0.07	0.93 ± 0.08	0.95 ± 0.06	0.90 ± 0.06
MRI (kg)						
Subcutaneous AT	37.2 ± 10.2	30.5 ± 8.4†	42.3 ± 12.6	33.2 ± 10.0†	35.4 ± 7.7	27.1 ± 7.9†
Visceral AT	2.3 ± 1.1	1.6 ± 0.8†	2.2 ± 0.9	1.4 ± 0.7†	3.3 ± 1.7	2.1 ± 0.6†
Skeletal Muscle	22.9 ± 3.4	21.7 ± 3.1†	25.0 ± 3.8	24.4 ± 3.2	21.1 ± 2.1*	20.7 ± 2.6

Mean ± SD

DO, diet only; DA, diet plus aerobic exercise; DR, diet plus resistance exercise; BMI, body mass index; WCUM, waist circumference at the umbilicus; WCLR, waist circumference at the last rib; WHR, waist (at the umbilicus) to hip ratio; MRI, magnetic resonance imaging; AT, adipose tissue.

* DR<DA at baseline (ANOVA, $p < .05$)

† significantly different from baseline (paired t-test, $p < .017$)

Lipid variables

Without exception, treatment effects were not different between groups for any lipid variable ($p > .05$). However, collapsed across group, there were significant reductions in total cholesterol, LDL-C, Apo B, HDL-C and Apo A ($p < .05$). Total cholesterol levels were reduced within the DO and DR groups ($p < .017$). LDL-C levels were reduced within the DO and DR treatment groups ($p < .017$). Apo-B was reduced within all three treatment groups ($p < .017$). HDL-C levels were reduced within the DR treatment group ($p < .017$). Apo-A was reduced within the DR group ($p < .017$). Plasma lipid and lipoprotein characteristics at baseline and following the intervention are summarized in Table 2. The relative changes observed for each lipid variable are illustrated in Figure 1.

Clinical significance of diet and exercise treatments

The total number of subjects identified as having elevated triglyceride levels did not change following the intervention. Approximately half of the subjects with elevated triglyceride levels at baseline were able to achieve desirable levels after 16 weeks of treatment. However, the number of subjects who successfully reduced their triglyceride levels was equal to the number of subjects who increased their plasma triglyceride levels from a desirable level at baseline to a level associated with moderate risk following the intervention. This resulted in an equal number of subjects with elevated triglyceride levels at baseline and following the intervention.

TABLE 2: Plasma lipid and lipoprotein characteristics of subjects at baseline and following the intervention

	DO (n = 12)		DA (n = 8)		DR (n = 13)	
	Pre	*Post*	*Pre*	*Post*	*Pre*	*Post*
TG (mmol/L)	1.37 ± 0.33	1.27 ± 0.43	1.36 ± 0.72	1.27 ± 0.67	1.48 ± 0.78	1.09 ± 0.45
TC (mmol/L)	5.22 ± 0.74	4.43 ± 0.87†	4.56 ± 1.00	4.14 ± 0.98	5.11 ± 0.78	4.35 ± 0.80†
HDL-C (mmol/L)	1.12 ± 0.22	1.02 ± 0.23	1.09 ± 0.28	1.05 ± 0.37	1.16 ± 0.26	1.05 ± 0.24†
LDL-C (mmol/L)	3.48 ± 0.68	2.81 ± 0.80†	2.85 ± 0.81	2.47 ± 0.70	3.26 ± 0.76	2.80 ± 0.71†
Apo-A (g/L)	1.26 ± 0.19	1.09 ± 0.17	1.24 ± 0.24	1.12 ± 0.26	1.23 ± 0.11	1.12 ± 0.16†
Apo-B (g/L)	1.14 ± 0.27	1.04 ± 0.32†	1.06 ± 0.26	0.89 ± 0.22	0.96 ± 0.28	0.96 ± 0.28†

Mean ± SD
DO, diet only; DA, diet plus aerobic exercise; DR, diet plus resistance exercise; TG, triglyceride; TC, total cholesterol; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; Apo-A, apolipoprotein A; Apo-B, apolipoprotein B.

† significantly different from baseline (paired t-test, $p < .017$)

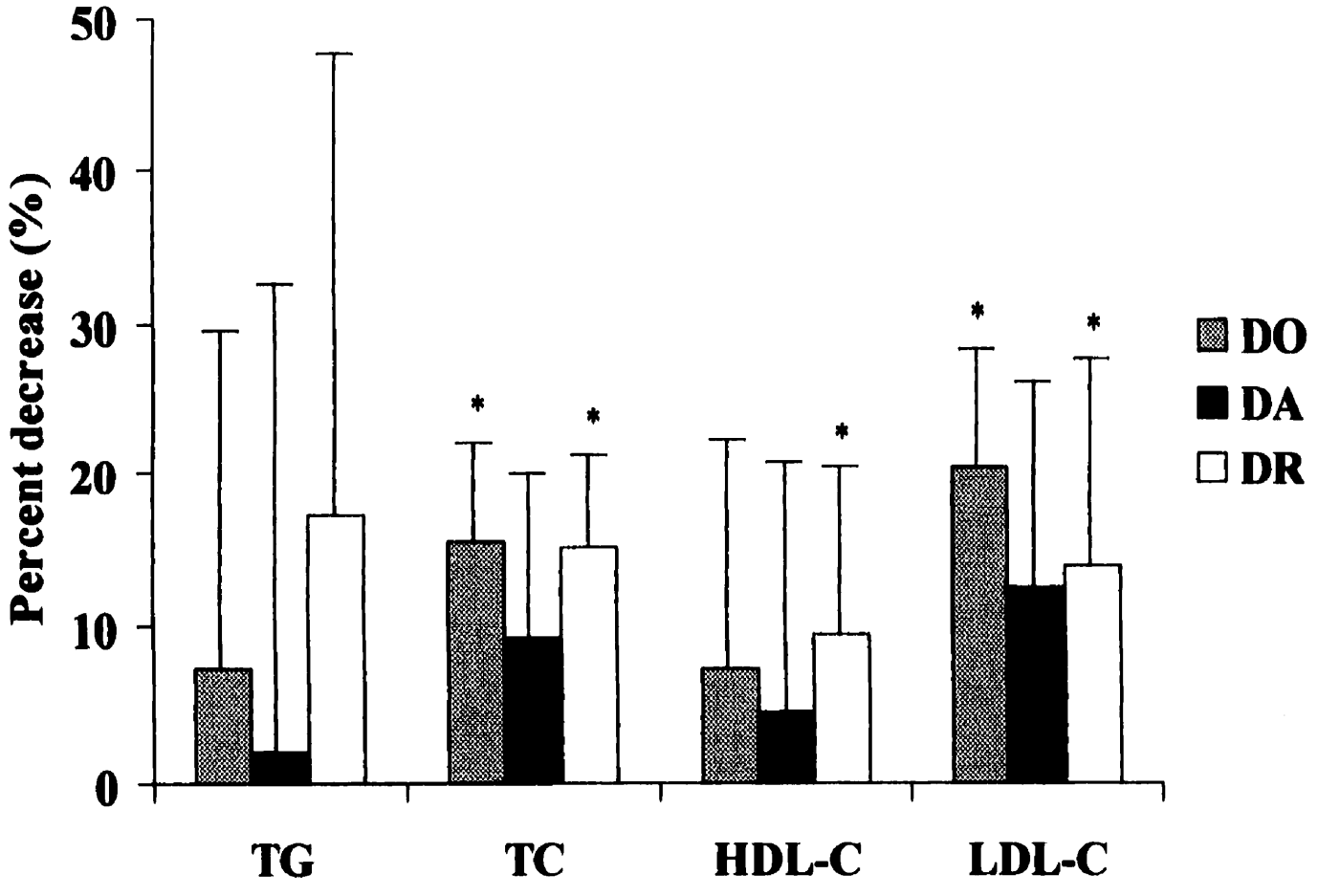

Figure 1: Percent changes in plasma lipid and lipoprotein levels after 16 weeks
Mean ± SD
DO, diet only; DA, diet plus aerobic exercise; DR, diet plus resistance exercise; TG, triglyceride; TC, total cholesterol; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol

* significantly different from baseline for absolute change (paired t-test, $p < .017$)

There was an increase in the number of subjects identified as having low levels of HDL-C following the intervention. All subjects who demonstrated this risk factor prior to the intervention, continued to be at risk post-treatment.

Approximately half of the subjects exhibiting elevated levels of total cholesterol and LDL-C at baseline were able to reduce these levels to a desirable level. In the case of these lipid variables, no subjects demonstrated an increase in risk status following the intervention.

A summary of the percentage of subjects demonstrating lipid levels recognized to be associated with an increased risk of cardiovasular disease is presented in Figure 2.

Relationship between MRI and lipid variables

There were no significant correlations between any tissue mass and any lipid variable at baseline or following the intervention. As well, there were no significant correlations between the change in any tissue mass and the change in any lipid variable.

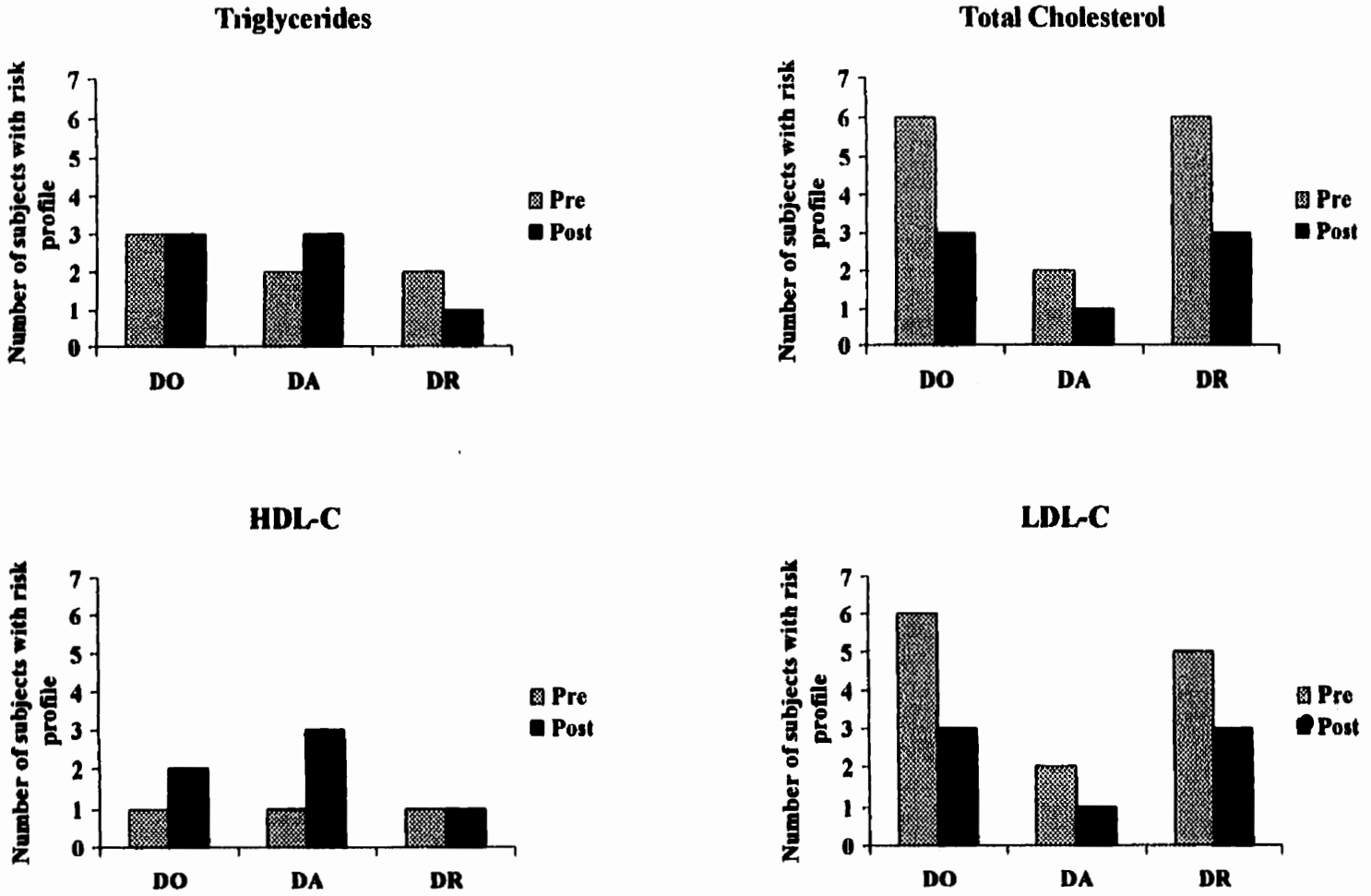

Figure 2: Effect of weight loss on the prevalence of dyslipidemia[1]

[1] Lipid or lipoprotein level greater than desirable, as stated by the Canadian Consensus Conference on Cholesterol (1988)
DO, diet only; DA, diet plus aerobic exercise; DR, plus resistance exercise; LDL-C low density lipoprotein cholesterol; HDL-C, high density lipoprotein cholesterol

Discussion

The findings of this study indicate that in obese, premenopausal women, weight loss (~12%) is associated with significant improvements in total cholesterol, LDL-C and Apo-B levels as well as significant decreases in HDL-C and Apo-A. However, aerobic or resistance exercise in addition to caloric restriction did not enhance any of the changes in the plasma lipid and lipoprotein profile.

In this study we were unable to demonstrate that exercise in addition to caloric restriction results in enhanced improvements in the plasma lipid and lipoprotein profile compared to those achieved by diet alone, despite significant improvements in functional capacity with exercise. That aerobic exercise did not enhance the improvements in the plasma lipid and lipoprotein profile achieved with weight loss was an unexpected finding. We anticipated that aerobic exercise in addition to weight loss would enhance the improvements in the plasma lipid and lipoprotein levels that were achieved with weight loss, as aerobic exercise in the absence of weight loss is associated with improvements in plasma triglyceride (Weintraub et al., 1989; Thompson et al., 1997) and HDL-C (Thompson et al., 1997) levels. However, similar to the results of the present study, Hagan et al. (1986) reported that aerobic exercise in addition to caloric restriction did not enhance improvements in the plasma lipid and lipoprotein profile compared to those achieved with weight loss alone.

Studies have confirmed the beneficial effects of walking on cardiovascular disease risk factors in men (Leon et al., 1979) and women (Hardman et al., 1989). Based on the results of these and numerous other studies, Després and Lamarche (1994) recommended prolonged endurance exercise of low intensity to significantly improve

metabolic variables and decrease the resulting risk of cardiovascular disease. Haskell (1984) suggested that approximately 1,000 kcal of energy expenditure (from moderate intensity exercise) per week is required to elicit plasma lipid and lipoprotein changes. Above this threshold a dose response exists, with greater changes occurring up to an expenditure of 4,500 kcal per week (Haskell, 1984). In the present study, the average exercise induced energy expenditure in the DA group was approximately 1,250 kcal per week. The average weekly energy expenditures for aerobic exercise treatment groups reported by Weintraub et al. (1989), Thomson et al. (1997), and Hagan et al. (1986) were approximately 2,100, 2,555, and 1,100 kcal per week respectively. It is therefore possible that the volume of exercise in the Hagan (1986) and present study protocols, which barely exceeded the proposed minimum threshold, was inadequate to achieve a treatment effect.

That resistance exercise did not enhance the improvements in the plasma lipid and lipoprotein profile achieved with weight loss was also unexpected. We anticipated that resistance exercise in addition to weight loss would enhance the improvements in the plasma lipid and lipoprotein levels that were achieved with weight loss, as resistance exercise without weight loss has been reported to be associated with significant improvements in LDL-C and HDL-C in healthy untrained males (Hurley et al., 1988). However, similar to the results of the present study, Manning et al. (1991) reported that in the absence of weight loss, their resistance training programme did not alter plasma lipid and lipoprotein levels in sedentary obese women.

Based on previous results from his laboratory (Goldberg et al., 1986; Hurley et al., 1988), Goldberg (1989) proposed that dynamic forms of resistance exercise (e.g.

circuit training) with high repetitions and short rest intervals promote the utilization of glucose and fat by muscles which improves plasma lipid and lipoprotein levels. The protocol of Hurley et al. (1988) was identical in frequency, intensity and total duration to that of the present study. However, compared to the present study protocol, the Hurley protocol consisted of more exercises (14 vs. 8 in the present study), more repetitions for lower body exercises (15-20 vs. 8-12 in the present study) and shorter rest intervals between exercises (less than 15s vs. ~60s in the present study). The protocol of Manning et al. (1991) allowed a 50-60s rest period between exercises. It is possible that discrepancies with respect to the influence of resistance training exercise on plasma lipid and lipoprotein levels is explained in part by the number of repetitions and/or the duration of the rest interval between exercises.

It was anticipated that the increased energy expenditure resulting from the exercise treatments in combination with caloric restriction would result in greater weight loss than that of identical caloric restriction without increased energy expenditure. As a consequence of the increased weight loss, greater improvements in the plasma lipid and lipoprotein profile in the exercise groups compared to the diet only group were expected. However, in the present study, exercise in addition to caloric restriction was not found to enhance the weight loss achieved by caloric restriction alone. This is in contrast to the findings of Hagan et al. (1986) who reported significantly greater weight loss from diet in combination with exercise compared to diet alone in men and women. This increased weight loss was associated with enhanced improvements in plasma triglyceride and total cholesterol levels in men but not women (Hagan et al., 1986). In the present study, it is possible that the subjects who participated in formal exercise programmes expended less

energy throughout the day in activities of daily living, resulting in a similar net energy expenditure to the diet only subjects. Despite the use of MRI to measure changes in the adipose tissue depots, exercise in addition to caloric restriction was not found to enhance reductions in subcutaneous or visceral adipose tissue. Whether the improvements in plasma lipid and lipoprotein levels in the present study would be further enhanced with increased weight loss and/or fat loss is unclear.

The significant decrease in total cholesterol and LDL-C with weight loss was consistent with our expectations. Weight loss of approximately 10% of initial body weight is consistently reported to be associated with reductions in total cholesterol and LDL-C (Van Gaal et al., 1997). However, the significant decrease in HDL-C and the absence of significant changes in triglyceride levels with this magnitude of weight loss were unexpected. Excessive reduction of dietary fat intake can increase triglyceride and decrease HDL-C levels (Grundy et al., 1989). Hudgins et al. (1996) determined that after a ten day eucaloric, low fat, high carbohydrate diet (10% of calories as fat and 75% as glucose polymers) fatty acid synthesis was increased. Mensink and Katan (1987) have demonstrated that a high carbohydrate, low fat diet resulted in significant reductions in HDL-C and increases in triglycerides compared with a diet higher in fat. In the present study, the mean dietary fat intake was reported to be 23% of total calories, with only one subject reporting a dietary fat intake of less than 15% of total calories. As such, excessive reduction of dietary fat is insufficient to completely explain our findings with respect to triglyceride and HDL-C levels.

Williams et al. (1994) suggested that high initial levels of HDL-C predict the greatest absolute increase in HDL-C due to genetic deficiencies in factors that regulate

HDL-C or structural defects in the HDL-C particles themselves in individuals with low initial levels of HDL-C. Zmuda et al. (1998) also proposed that men with low HDL-C concentrations have a limited ability to increase HDL-C levels. However, a meta-analysis by Tran et al. (1983) demonstrated that increases in HDL-C were greatest in studies with the lowest pre-training concentrations of HDL-C. In the present study, there was no correlation between HDL-C concentrations at baseline and the change in this variable.

The final report of the Canadian Consensus Conference on Cholesterol (1988) established guidelines that are commonly used by Canadian physicians for the identification of dyslipidemia. Numerical cut-offs are used to identify moderate and high risk levels for each lipid and lipoprotein fraction. Using these values, we attempted to evaluate whether changes in the prevalence of plasma lipid and lipoprotein levels associated with a risk of cardiovascular disease decreased with weight loss. The prevalence of elevated triglyceride and reduced HDL-C levels did not change following the intervention. However, approximately half of the subjects with elevated total cholesterol and LDL-C levels were able to achieve desirable levels following the intervention. The subjects who were able achieve desirable levels for these lipid variables were found to have lower baseline values for total cholesterol and LDL-C respectively. The mean absolute change in total cholesterol and LDL-C levels was not different for the subjects who achieved desirable levels compared to those who did not.

It has been reported that a waist circumference in excess of 100 cm is associated with increased risk of major disturbances in the plasma lipid and lipoprotein profile (Pouliot et al., 1992). In addition to lower initial levels of total cholesterol and LDL-C,

the subjects who were able to achieve desirable levels of these variables were found to have smaller waist circumferences (measured at the umbilicus) before and after treatment, than the subjects who did not achieve this level of reduction. However, at baseline, both groups had waist circumference measurements in excess of 100 cm. The subjects who achieved successful reduction of these variables had a mean waist circumference of less than 100 cm following the intervention whereas the subjects who did not achieve successful reduction of these variables had a mean waist circumference in excess of 110 cm following the intervention. Although the sample size is small, these findings substantiate the importance of abdominal obesity and confirm the clinical utility of the waist circumference measurement.

In summary, the findings of this study indicate that in obese, premenopausal women, improvements in total cholesterol, LDL-C and Apo B are induced in association with weight loss. Weight loss was also associated with reductions in HDL-C and Apo A. Improvements in aerobic capacity or strength do not appear to enhance the improvements in the plasma lipid and lipoprotein profile that are achieved with weight loss. However, insufficient volume of aerobic exercise and excessive rest intervals between resistance exercises may have limited the expected changes in the plasma lipid and lipoprotein profile following the exercise interventions. Diet composition, initial concentrations of the plasma lipid and lipoprotein fractions, and final measures of abdominal circumference, may each have some predictive value in determining the expected changes in the plasma lipid and lipoprotein profile following a weight loss intervention.

4.0.0 CONCLUSIONS

The results of this study indicate that the combination of diet and either aerobic or resistance exercise improves functional capacity, but does not improve plasma lipid and lipoprotein levels to a greater extent than diet alone. In addition, the results of this study indicate that independent of modality, exercise in addition to diet does not result in greater weight loss, fat loss or visceral fat loss compared to diet alone. Whether the improvements in plasma lipid and lipoprotein levels would be further enhanced with increased weight loss and/or fat loss is unclear.

A limitation of this study is that beyond the supervised exercise sessions, daily energy expenditure is not quantified. That the weight loss between treatment groups is not different is difficult to explain. Doubly-labeled water, a technique used to measure 24-hour energy expenditure could be used in future studies to obtain this information (Schoeller, 1988).

A further limitation of this study is that subfractions of HDL-C and LDL-C were not measured. Current research suggests that the atherogenic properties of these lipoprotein subfractions differ. More sophisticated methods of lipoprotein analysis are required to investigate the relationship between weight loss, VAT and lipoprotein subfractions.

Many questions remain unanswered with respect to improving metabolic variables such as plasma lipid and lipoprotein levels with exercise and/or diet. How much exercise is enough? What intensity of exercise is enough? How much weight loss is enough? At what point do further increases in exercise volume, exercise intensity and

weight loss cease to provide additional benefits? The answers to all of these questions are currently unresolved.

The effects of weight loss induced by exercise alone and exercise in the absence of weight loss on metabolic variables are inadequately addressed in the current literature. These issues may be more accurately explored using a randomized controlled design. Strict control of caloric intake and expenditure would be essential for this type of study.

The results of the present study suggest that weight loss approximating 0.5 to 1.0 kg per week is associated with significant improvements in total cholesterol, LDL-C and Apo B. Exercise has been shown to improve the long-term maintenance of weight loss (Pronk & Wing, 1994). As such, although exercise in combination with diet does not result in enhanced improvements in plasma lipid and lipoprotein levels compared to diet alone, this combination may be an effective therapeutic approach for the perpetuation of improved plasma lipid and lipoprotein levels.

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Appendix A: Informed Consent

QUEEN'S UNIVERSITY

DIET AND EXERCISE STUDY

INFORMED CONSENT

The following brief is intended to provide you with the details you should be aware of prior to your consent as a participant in this research project. Please read the following information carefully and feel free to ask any question that you may have.

Objective of the study

In recent years a number of studies have clearly shown that a relationship exists between obesity and the development of numerous health problems -including cardiovascular disease and diabetes. In fact, the relationship is strengthened if one considers the regional distribution of body fat (i.e where your body fat is located). Given the relationship between obesity with ill health, and the fact that obesity is a condition characterized by large amounts of body fat, it follows that an important component of an effective prevention program would be the ability to lose body fat. Hence the purpose of this research project will be to investigate different methods of changing body composition through diet and or exercise.

EXPLANATION OF PROCEDURES

Pre-participation screening

Prior to participation in this study you will be required to have a medical exam. The exam will be conducted by a medical doctor at the Kingston General Hospital. The examination will include a fasting blood sample that will be used to measure your glucose and fat levels, and the levels of certain hormones that may be related to fat metabolism. This procedure is explained in further detail on the last page of this form.

Diet and Exercise Protocol

The study will be 18 weeks in duration. The low calorie diet and exercise part of the study will last 16 weeks. The 16 week treatment period will be prefaced and followed by a 1 week weight maintenace period - hence 18 weeks in total. By volunteering to participate in this study, your name will be selected by chance and placed into one of the following five groups: control (no diet or exercise program), diet (diet only), diet plus aerobic exercise, diet plus strength training exercise and diet plus both aerobic and strength training exercises.

Diet Procedure

The diet will consist of regular foods that you will buy and prepare yourself. After a 1 week weight-maintenance period, the diet you follow will total approximately 1000 calories less than the amount you need to maintain your present weight. You will follow that diet for 16 weeks. After the 16 week period, you will be given a diet that will increase your total caloric intake to a level that will maintain your new weight. All aspects of the diet plan will be explained to you in detail. The session will take place at the beginning of the study, with several additional sessions planned throughout to help you follow the diet plan. If someone else shops for your food or prepares your meals, or if you share those tasks with someone else, that person is invited to meet with the dietitian as well. You will be required to record the food you eat each day for one week, 5 times during the the 18 week study. All of your meetings with the dietitian will be at the Fitness Center in the Physical Education building at Queen's.

Exercise Procedure - Aerobic Group

If you are a participant in this group, in *addition* to following the same diet procedures described above, you will be required to perform aerobic exercise (walk/run type exercise) 5 times per week. The aerobic exercise program will be designed to meet your abilities. The duration of the sessions will range from approximately 15 minutes at the beginning of the program to a maximum of 60 minutes by the end. Each exercise session will be supervised by a trained physical educator.

Exercise Procedure - Strength Training Group

If you are a participant in this group, in *addition* to following the same diet procedures described above, you will be required to perform strength training exercises using Nautilus equipment 3 times per week. As with the aerobic exercise group, the strength training exercises will begin at a very easy level and progress slowly. A total of 8 exercises will be performed each session assuring that all the major muscles of the body are used. Each exercise session will be supervised by a physical educator.

Although as a participant in this study you will follow all the appropriate safety precautions including a pre-participation medical exam, there are risks associated with exercise. These risks include a slight chance of fainting and a remote chance of heart attack. As indicated, all your exercise sessions will be supervised by a masters level physical educator. This person will be trained in emergency procedures including cardio-pulmonary resusitation (CPR).

Assessment of Body Composition

Magnetic Resonance Imaging

Magnetic resonance imaging is a new technique for imaging or creating pictures of body structures or organs. Magnetic resonance (MR) gives images in slices comparable to those produced by x-ray tomography or CT (CAT) scan. One of the primary advantages of MR is that it does not employ x-rays or other potentially harmful forms of radiation, contrary to ordinary radiography or nuclear medicine. Instead, a large magnet, a radio transmitter/receiver and a computer are used to gather chemical information from the body, and to produce images or pictures of internal anatomy. No harmful effects have been associated with MR under existing conditions of use.

It is important that you fill out the enclosed questionnaire. The purpose of the questionnaire is to identify any metallic pieces which would have been implanted during a surgery or would have been lodged in your body during an accident.

As mentioned, the MR procedure is very similar to a scanner examination. You will be placed on a table and you will be moved smoothly into the scanner. A loud-speaker within the magnet makes it possible for you to keep in constant contact with the staff. At all times the operator can see and hear you if you need help or have questions, and you can be removed from the machine if necessary. The scanning procedure takes 45 to 60 minutes. All MR images will be obtained at the Kingston General Hospital.

Bioelectrical Impedance

This is a very simple and safe procedure requiring no more than 5 minutes to complete. Laying on your back, 2 electrodes will be placed on the surface of your right hand and foot. Two of the electrodes will introduce an alternating current that you can't feel into the body, while the other 2 record the resistance. In order to obtain accurate results with this technique it is very important that you follow the following procedure prior to your assessment. Prior to the test you should not:

1) have eaten or consumed caffeine for the 4 to 5 hours immediately preceding the test,

2) have exercised or consumed alcohol for 24 hours.

Anthropometry/Summation of skinfolds

Many circumference and diameter measurements will be taken at numerous sites on the body. These measure can be used to derive estimates of body composition. In addition, through the use of skinfold callipers, skinfold thickness will

be measured at 10 different sites on your body. This is a simple procedure requiring no special preparation on your part.

Underwater weighing

Recognized by many researchers as the best method of measuring body composition (i.e. percent body fat), the intent of the procedure is to weigh you while you are submerged in water. In a seated position, you will be submerged in water (comfortable temperature) to the shoulder level. Approximately 10 times during the test you will be asked to put your head in the water, exhale completely, and hold your breath for 5 to 10 seconds while your body weight is measured. At any time during the procedure you can come out of the water by simply lifting your head.

With the exception of the MRI measurements, the anthropometric measurements (bioelectrical impedance, skinfolds and underwater weighing) will be obtained at the School of Physical and Health Education, Queen's University.

Assessment of Cardiovascular Fitness

In addition to body composition measurements we will measure your cardiovascular fitness by using either a stationary bicycle or a treadmill procedure. The work level will begin at a level you can easily accomplish and will be advanced in stages, depending on your capacity to do so. We may stop the test at any time because of signs of fatigue or you may stop when you wish to because of persinal feelings of fatigue or discomfort.

Risks and Discomforts

The treadmill or bicycle test will involve risks comparable to any strenuous exercise situation. They include very rare instances of abnormal blood pressure, faintings, disorders of the heart beat, and heart attack. Every effort will be made to minimize them by preliminary medical examination and observation during the test.

Benefits to be expected

These test results will be used to help us give you the proper amount of aerobic exercise that is right for you, and, to check for any possible reasons why you should not participate in an exercise program. Quantification of your fitness level will also enable us to follow your improvement throughout the study.

Blood Chemistry Analysis

Fasting Blood Samples

At the beginning, after 8 weeks, and at the end of the 16 week study, you will have a fasting blood test in order to measure blood sugar, blood fats and hormones (including adrenal, thyroid and pancreatic hormones). This procedure will involve a venepuncture with a needle and the removal of about 30 ml (3 tablespoons) of blood. The only risk from this is possible local pain and bruising at the time of the blood test. In addition, at the beginning and end of the study, you will be given a glucose tolerance test. The purpose of this test is to determine your bodie's response to sugar.

Subject's Name: _____

I have been given an opportunity to ask any questions concerning the procedures. All of my questions regarding the research project have been satisfactorily answered. I understand that my test results will be considered confidential and will never be released in a form traceable to me, except to my family physician or myself. I do understand that I am free to deny consent if I so desire, and that I may withdraw from the study at any time. I understand that I may contact Dr. Robert Ross, 545-6583, or the head of the School of Physical and Health Education, Dr. Gavin Reid 545-2666, should I have any questions about the study. In addition, I release the principals and Queen's University from all claims arising out of my participation in this study that do not arise due to negligence.

Signature of Subject: _____

Witness: _____

Date: _____

Appendix B: Medical Questionnaire

QUEEN'S UNIVERSITY

DIET AND EXERCISE PROGRAM

MEDICAL QUESTIONNAIRE

Please follow the instructions for each section carefully, and answer every question unless otherwise indicated, or unless you choose not to.

1. **PERSONAL DATA (Please print)**

Name:	_____	Date:	_____
Home Address:	_____	Home Tel:	_____
City:	_____	Postal Code:	_____
Position:	_____		
Business Address:	_____	Business Tel:	_____
City:	_____	Province:	_____
Birth Date:	_____	Age:	_____

2. **MEDICAL HISTORY**

***N.B. There are two parts to medical and health history. Please complete your parts on page 1 and 2, and have your physician fill out pages 3, 4 and half of page 5.**

		Yes	No
1.	Has your doctor ever said that you have heart trouble?	___	___
2.	Do you have pains in your chest?	___	___
3.	Do you often feel faint, or experience severe dizziness?	___	___
4.	Has your doctor told you that you have high blood pressure?	___	___
5.	Has your doctor ever told you that you have a bone or joint problem (arthritis) that might be made worse by exercise?	___	___
6.	Is there a good reason, not mentioned here, why you should not follow an exercise program, even if you'd like to?	___	___

7. Do you have, or have you had any of the following health problems or diseases?

		Yes	No	Comment
1)	Heart, Cardiovascular	___	___	_____
2)	Neurological	___	___	_____
3)	Respiratory (asthma, etc.)	___	___	_____
4)	Gastrointestinal (ulcers, etc.)	___	___	_____
5)	Genito-urinary	___	___	_____
6)	Endocrine (glandular)	___	___	_____
7)	Musculoskeletal (low back pain, etc)	___	___	_____

	Yes	No	Comment
8) Skin	____	____	_____
9) Gynaecological	____	____	_____
10) Other (Women - are you pregnant?)	____	____	_____

8. Please list any serious injuries suffered, or surgery undergone:

_____ Date:_____

_____ Date:_____

9. If you have undergone surgery, was any metal (ie. pins or screws to repair broken bones) left in your body?

_____

_____

10. Are you presently taking any medication including vitamin or mineral supplements? If yes, please specify what type, and reasons:

_____

9. If you have undergone surgery, was any metal (i.e. pins or screws used to repair bone fractures) left in your body?

_____

_____

10. Are you presently taking any medication including vitamin or mineral supplements? If yes, please specify what type, and reasons:

_____

11. Are you presently undergoing any physiotherapy, or any other sort of treatment? If yes, please specify:

_____

12. Are you presently under the care of a physician? If so for what?

_____

3. MEDICAL REFERRAL

To The Physician:

The applicant is considering participation in a research project that intends to investigate the effects of different methods of exercise, in combination with caloric restriction, on body composition. A brief that describes the details of the study is appended to the Medical Questionnaire. Should you have any questions regarding the participation of your patient in this project, please contact Robert Ross Ph.D., School of Physical and Health Education, Queen's University (545-6583/2666), or Robert Hudson M.D., Department of Endocrinology, Kingston General Hospital.

ACSM - Contraindications to Exercise Testing

Absolute Contraindications

1. A recent significant change in the resting ECG suggesting infarction or other acute cardiac events
2. Recent complicated myocardial infarction
3. Unstable angina
4. Uncontrolled ventricular dysrhythmia
5. Uncontrolled atrial dysrhythmia that compromises cardiac function
6. Third-degree A-V block
7. Acute congestive heart failure
8. Severe aortic stenosis
9. Suspected or known dissecting aneurysm
10. Active or suspected myocarditis or pericarditis
11. Thrombophlebitis or intracardiac thrombi
12. Recent systemic or pulmonary embolus
13. Acute infection
14. Significant emotional distress (psychosis)

Relative Contraindications

1. Resting diastolic blood pressure >120 mm Hg or resting systolic blood pressure >200 mm Hg
2. Moderate valvular heart disease
3. Known electrolyte abnormalities (hypokalemia, hypomagnesemia)
4. Fixed-rate pacemaker (rarely used)
5. Frequent or complex ventricular ectopy
6. Ventricular aneurysm
7. Cardiomyopathy, including hypertrophic cardiomyopathy
8. Uncontrolled metabolic disease (e.g., diabetes, thyrotoxicosis, or myxoedema)
9. Chronic infectious disease (e.g., mononucleosis, hepatitis, AIDS)
10. Neuromuscular, musculoskeletal, or rheumatoid disorders that are exacerbated by exercise
11. Advanced or complicated pregnancy

I **REVIEW OF SYSTEMS**

a) Cardiovascular _____

b) Respiratory _____

c) Neurological _____

d) Gastrointestinal _____

e) Genitourinary _____

f) Endocrine _____

g) Musculoskeletal _____

h) Skin _____

i) Gynaecological _____

II. **PHYSICAL EXAMINATION**

Blood Pressure Supine ___RA___LA Bruits _____

Standing ___RA___LA Pulses _____

Evidence of chronic Lung Disease _____

Heart rate _____ _____

Heart sounds _____ Bone or Joint Abnormalities _____

_____

EKG interpretation, 12 lead, resting. **Enclose copy if available**

_____

III. **LABORATORY FINDINGS (NOT MANDATORY)** Date of Test(s): _____

Hb _____ Het _____ RBC _____ WBC _____

Total Cholesterol _____ HDL _____ LDL _____

Triglycerides _____ Uric acid _____

Glucose _____ post dexicola 30 min _____ 1 hr _____ 2 hr _____

3 hr _____ 4 hr _____

IV. Additional Abnormalities you are aware of _____

_____

_____

V. Current medications and dosages _____

_____

_____

VI. Impression of above information _____

_____

_____

On the basis of your knowledge and medical evaluation of the applicant, you would recommend:

- participation in a fitness appraisal with supervision by physical education graduate _____
- participation only with physician in attendance _____
- participation not recommended _____

Signed_____M.D.

Name of Physician_____
(Please print or type)

Address_____

Telephone_____

Date_____

4. **FAMILY MEDICAL HISTORY (Should be filled out by participant)**

Have either of your parents or any brothers or sisters ever suffered from any cardiovascular disease (heart attack, high blood pressure, stroke, angina, etc.) or diabetes? If yes, please describe which relative, the type of problem, and the approximate age of the relative at the first diagnosis of the disease.

_____

_____

_____

5. **SMOKING**

Are you a: smoker _____

ex-smoker (stopped) _____

non-smoker (never smoked) _____

Enter average amount smoked per day in the last five years, or in the last five years prior to quitting:

cigarettes per day _____

pipes/cigars inhaled per day _____

pipes/cigars not inhaled per day _____

If you are an ex-smoker, how many years ago did you start? _____ quit? _____

6. **DIET**

Weight now: _____ 1 year ago: _____ at age 21: _____

What do you consider a good weight for you? _____

What is the most you've ever weighed? _____ at age? _____

Do you regularly eat:			Are these meals:		
	yes	no	light	moderate	heavy
Breakfast	_____	_____	_____	_____	_____
Lunch	_____	_____	_____	_____	_____
Dinner	_____	_____	_____	_____	_____
Snacks	_____	_____	_____	_____	_____

Have you ever dieted? _____ If yes, for what reasons? _____

_____

Are you presently on a diet? _____ If yes, what kind? _____

_____

Do you have any special dietary needs, e.g., vegetarian? _____

Do you drink alcoholic beverages? _____ If yes, how much?:

	none	occasional	often	drinks per week
Wine (4 oz.)	_____	_____	_____	_____
Hard Liquor (1 - 1½ oz.)	_____	_____	_____	_____
Beer (12 oz.)	_____	_____	_____	_____

7. **EXERCISE**

Are you currently involved in a regular exercise program? _____

Physical activity in your present occupation is:

none _____ light _____ moderate _____ heavy _____

How many hours per day are you presently active? (at work and play/or exercise)

none _____ 0 - ½ _____ ½ - 1 _____ 1 - 2 _____ 2 or more _____

Please list the moderate to vigorous activities (such as brisk walking, jogging, aerobics) that you are presently involved in and the # of times per week that you participate.

_____

_____

Please list the recreational or leisure activities (such as casual walking, etc.) you are presently involved in and the # of times per week.

_____

_____

What activity or activities would you prefer to be included for you in an exercise program (if you are not presently involved)?

_____

_____

If you have been involved in an exercise program in the past, and quit, or had difficulty participating regularly, what were the reasons?

_____

_____

8. **PERSONAL INTERESTS**

Please list in order of importance to you, what you would like to change in terms of your present lifestyle?

1. _____
2. _____
3. _____

What areas of health or fitness would you like to learn more about?

_____

_____

Appendix C: Anthropometric Data Collection Form

MRI DIET AND EXERCISE
ANTHROPOMETRIC DATA COLLECTION FORM

NAME:_____ **M F DATE:**_____ **TIME:**_____

WEIGHT:_____**kg AGE (yr.mo):**_____ **TEST #:**_____

ARM LENGTH:_____**(cm) STANDING HEIGHT:**_____**(cm)**

ACROMION HEIGHT:_____**(cm) SITTING HEIGHT:**_____**(cm)**

IMPEDANCE (ohms) **R:** Arm ___ Torso ___ Leg ___ Whole L___ R___

Xc: ___ ___ ___ ___ ___

SKINFOLDS (mm)

	1	2	3	$\bar{X}$
Chest	___	___	___	___
Tricep	___	___	___	___
Bicep	___	___	___	___
Mid-Axillary	___	___	___	___
Subscapular	___	___	___	___
Iliac	___	___	___	___
Abdomen	___	___	___	___
Thigh	___	___	___	___
Suprapatellar	___	___	___	___
Calf	___	___	___	___

NAME:_____ **DATE:**_____ **TIME:**_____

CIRCUMFERENCE MEASURES (cm):

Chest:_____ Hip:_____

Waist (standing): _____(L) _____Last Rib_____(U)

Waist (supine): _____Last Rib_____(U)

Bicep:	_____(R)	_____(L)	Thigh:	_____(PR)	_____(PL)	
Forearm:	_____(R)	_____(L)		_____(MR)	_____(ML)	
Calf:	_____(R)	_____(L)		_____(DR)	_____(DL)	

Appendix D: Diet Record

Name: _____

Date: _____

FOOD DIARY

Food and Amount	Time	Calories	Fat(grams)
BREAKFAST			
LUNCH			
DINNER			
SNACKS			
Total			

Fat Calories = Fat(grams) x 9 _____

Daily Calorie Total = Total Calories _____

%Fat = Fat Calories / Total Calories _____

Appendix E: Aerobic Exercise Record

AEROBIC TRAINING PROGRAM

Name: _____

Week	1					2					3					4					5					6				
Date																													
Activity																													
Duration																													
Intensity/Workrate																													
Mean Heart Rate																													

Week	7					8					9					10					11					12				
Date																													
Activity																													
Duration																													
Intensity/Workrate																													
Mean Heart Rate																													

Week	13					14					15					16				
Date																				
Activity																				
Duration																				
Intensity/Workrate																				
Mean Heart Rate																				

Appendix F: Resistance Exercise Record

NAUTILUS TRAINING PROGRAM

TECHNIQUE: Select a weight with which you can obtain total momentary failure in between 8 and 12 repetitions. One repetition should take approximately 7 seconds.

POSITIVE – 2 seconds lifting / PAUSE – 1 second hold / NEGATIVE – 4 seconds lowering.

Perform each repetition smoothly and with good form.

Legend: Name: _____

Total Repetitions → 12/4 ← Exercise Weight

RECORD EXERCISE WEIGHTS AND TOTAL REPETITIONS FOR EACH EXERCISE (See Legend)

Exercise		Seat Pos.	R	Week	Week	* SEE INSTRUCTOR *	Week	Week	Week	Week	Week	Week
LOWER BODY												
Hip and Back												
Compound Leg	Extension											
	Press											
Leg Curl												
UPPER BODY												
Super Pullover												
Rowing												
Double Chest	Cross											
	Press											
HIP	Abduction ← →											
	Adduction → ←											
Torso Arm												
Double Shoulder	Lateral											
	Overhead											
Bicep												
Tricep												
Rotary Torso												
Abdominal												
4-way Neck	Lateral											
	Anterior											
	Posterior											
Neck and Shoulder												
Multi-Exercise	Heel Raises											
	Wrist Rollers											
SIT UPS	TOTAL REPETITIONS											

Appendix G: Z-Test for a Proportion

Z-TEST FOR A PROPORTION

The Z-test for a proportion allows statistical analysis of changes in population proportions. For example, it can be used to compare the prevalence of a condition within a population before and after treatment.

Hypotheses

Ho: $A = B$
Ha: $A \neq B$

(where A is equal to the number of subjects with the condition before the treatment/total number of subjects and B is equal to the number of subjects with the condition after the treatment/total number of subjects)

Formula

$$Z = \frac{B - A}{\left[\frac{(A)(1-A)}{n}\right]^{1/2}}$$

(A and B as above; n is equal to the total number of subjects)

Decision Rules

If $Z_{obtained} \geq Z_{critical}$, reject the Ho
If $Z_{obtained} < Z_{critical}$, do not reject the Ho

Assumptions

1. Subjects are randomly selected.
2. Sampling distribution of the statistic is normal.
3. Observations are dichotomous.

(from Ness Evans, 1998)