THE EFFECT OF EXERCISE AND THE ALTERATION OF CARBOHYDRATE CONTENT OF A HYPOCALORIC DIET ON BLOOD LIPIDS

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(ABSTRACT)

Twelve obese young women (aged 22-36) were studied to determine the effects of the combination of an exercise program with either a high carbohydrate (HC) hypocaloric diet or low carbohydrate (LC) hypocaloric diet on total cholesterol, high density lipoprotein (HDL) cholesterol and triglycerides. Subjects were randomly placed in one of the diet groups (530 kcal/day) and participated in submaximal (60% VO_2max) exercise sessions three times per week for a period of 28 days. After the treatment period, the subjects consumed a 1000 kcal/day mixed diet for one week while continuing the exercise program. Blood samples were drawn weekly for the analysis of total cholesterol, HDL cholesterol and triglycerides. Weight significantly decreased in both groups (mean decrease = 9.8% for LC; 8.8% for HC). After week one of the diet, total cholesterol and HDL cholesterol decreased significantly throughout the rest of the study. Due to the changes in total cholesterol, the total cholesterol/HDL cholesterol ratio decreased throughout the study, reaching significance by the post-treatment period when the ratio was 20.6% below baseline levels for both groups. There were no significant changes in triglycerides for either group. However, triglycerides increased throughout the dietary treatment (mean increase = 9.5% for LC; 18.7% for HC). Triglyceride concentrations also changed during the post-treatment week as the LC group had a mean decrease of 38.3% and HC group, 8.2% from baseline values. These data suggest that both diets are equally effective in reducing body weight in young women. Also, in spite of the decreases noted in HDL cholesterol in both groups, total cholesterol decreased even further, thus producing a lower, more favorable total cholesterol/HDL cholesterol ratio.

Index Terms: total cholesterol; HDL cholesterol; total cholesterol/HDL cholesterol ratio; triglycerides hypocaloric diet; carbohydrate content.

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Chapter I

INTRODUCTION

Coronary heart disease and atherosclerosis account for a large percentage of the deaths in the United States. For many years, researchers have noted the association between obesity and the incidence of this disease. One of the major risk factors for coronary heart disease, elevated serum cholesterol, is often related to obesity and may be the underlying factor in the increased incidence of this disease in obese individuals (Berchtold, et al., 1977).

Until recently, researchers considered the total amount of cholesterol in the blood to be the only connection between coronary heart disease and blood lipids. However, the way in which the cholesterol is transported may be much more important (Miller and Miller, 1975). While total cholesterol and low density lipoprotein cholesterol are positively associated with the development of coronary heart disease and atherosclerosis, high density lipoprotein cholesterol is negatively related to the development of this disease and may be the most powerful predictor for coronary heart disease and atherosclerosis of all the known risk factors (Gotto and Rifkind, 1982; Miller, Forde, Thelle and Mjos, 1977; Gordon, Castelli, Hjortland, Kannel and Dawber, 1977). Also, in spite of a lack of research, serum triglyceride concentrations may be related to the incidence of these diseases (Castelli, et al., 1977; Lopez, Vial and Bolart, 1974).

The risk, however, of coronary heart disease appears to increase with increasing obesity (Keen, 1982). This risk does not seem to be due solely to the obesity, but appears to be related to abnormal blood lipid concentrations (Kannel, Gordon and Castelli, 1979; Berchtold, et al., 1981). Hypertriglyceridemia and hypercholesterolemia are commonly seen in the obese as well as decreased concentrations of HDL cholesterol (Berchtold, et al., 1981). Many types of weight loss programs have been implemented in attempts to improve blood lipid concentrations and provide optimal weight loss for the obese. Results from these studies are somewhat variable, but hypocaloric diets tend to result in decreases in total cholesterol and triglycerides, however many result in decreases in HDL cholesterol as well (Wechsler, Hutt, Wenzel, Klor and Ditschunett, 1981). Total starvation usually decreases triglycerides which were initially elevated, but may otherwise result in increases in triglycerides (Hendrikx, Boni, Kieckens, Meulepas and DeMoor, 1979).

Physical activity has become increasingly more important in the treatment of obesity as researchers try to achieve greater fat losses with favorable modifications in the blood lipids. Total cholesterol and triglycerides decrease, while HDL cholesterol may increase (Huttunen, et al., 1979) or remain the same (Weltman, Matter and Stamford, 1980), thus improving the total cholesterol/HDL cholesterol ratio. The combination of caloric restriction with exercise results in similar blood lipid responses with greater fat loss than with either diet or exercise alone (Bosella, et al., 1980). Research is needed on the optimal diet and exercise combination. Current studies seem to indicate that a hypocaloric diet high in carbohydrate allows more freedom in the type and intensity of exercise that may be performed, as well as results in favorable lipid responses (Bogardus, LaGrange, Horton and Sims, 1981).

No matter what method of weight loss treatment is used with the obese, reducing the risk of developing atherosclerosis and coronary heart disease must be an important consideration. According to recent research, this includes not only decreasing the total amount of cholesterol in the blood, but also increasing the HDL cholesterol fraction of the cholesterol and decreasing the level of triglycerides in the blood.

The purpose of this study was to determine the effect of the combination of an exercise program with two hypocaloric diets of different carbohydrate content on serum total cholesterol, HDL cholesterol and triglycerides. Although past research has emphasized the use of caloric restriction or exercise alone, this study attempted to determine if the combination of exercise with a high carbohydrate hypocaloric diet or a low carbohydrate hypocaloric diet is more effective in improving the blood lipid profiles and overall health of the obese.

Research Problem

The major problem addressed in this investigation was identifying the effects of an exercise program and two hypocaloric diets of different carbohydrate content on serum levels of total cholesterol, high density lipoprotein cholesterol and triglycerides. An attempt was made to determine whether a high or low carbohydrate hypocaloric diet is more effective in improving blood lipid levels in the obese.

Research Hypothesis

The following null hypotheses were tested:

1. There is no difference between the two treatments across time; the two treatments were a high carbohydrate hypocaloric diet combined with exercise and a low carbohydrate hypocaloric diet combined with exercise over a

28-day period. The dependent variables were: a) total cholesterol, b) high density lipoprotein cholesterol, and c) triglycerides.

2. Within the two treatment groups,

a. There is no difference across time in blood lipids after a high carbohydrate hypocaloric diet and an exercise program.

b. There is no difference across time in blood lipids after a low carbohydrate hypocaloric diet and an exercise program.

Significance of Study

Since obesity is associated with various coronary risk factors such as increased total cholesterol and triglycerides and decreased high density lipoprotein cholesterol, many types of weight loss programs involving the use of diet alone or in combination with exercise have been tried to help the obese lose weight and improve their serum lipid profiles. However, these programs have not been very successful and the most effective carbohydrate content for these diets has not been established. Thus, the present study attempted to determine if a weight loss program consisting of aerobic exercise and a very low calorie liquid formula with either a high or low carbohydrate content contribute to the reduction of these coronary risk factors and allow the obese to exercise safely.

Delimitations

The following delimitations were imposed by the investigator due to the availability of facilities and equipment:

1. The sample size was limited to 12.

2. The selection of subjects was limited to obese females, aged 22-36 years old, without any known health problems.

3. The dietary treatment was limited to one high carbohydrate hypocaloric diet and one low carbohydrate hypocaloric diet.

4. The exercise program was limited to a walking and jogging program three times per week.

5. The measurement of blood lipids was limited to total cholesterol, high density lipoprotein cholesterol and triglycerides.

Limitations

The following limitations of the study are recognized:

1. Sampling was non-random because the subjects were volunteers. Thus, the results of the study are generalizable only to similar samples.

2. Diet control in an out-patient program is difficult to obtain. However, since the liquid formula was the sole

source of nutrition, compliance may have been better. Also, the analysis of urine electrolytes served to check against any deviations from the diet.

3. The intensity of the exercise program was monitored solely by periodic pulse checks, thus decreasing the accuracy.

4. Blood lipid measurements included the analyses of total cholesterol, high density lipoprotein cholesterol and triglycerides.

Definitions and Symbols

The following definitions will be used:

1. Exercise program - an individualized walking and jogging program at an intensity which elicits a heart rate corresponding to 60% of VO_2max as determined by graded exercise testing.

2. High carbohydrate hypocaloric diet - a liquid formula diet consisting of 530 kilocalories, 31 grams protein, 4 grams fat and 94 grams carbohydrate.

3. Low carbohydrate hypocaloric diet - a liquid formula diet consisting of 530 kilocalories, 31 grams protein, 24 grams fat and 44 grams carbohydrate.

4. Total cholesterol - total amount of cholesterol in the blood.

5. High density lipoprotein cholesterol - lipoprotein consisting of 45-50% protein, 30% phospholipid and 20% cholesterol.

6. Low density lipoprotein cholesterol - lipoprotein consisting of approximately 25% protein and 45% cholesterol.

7. Triglycerides - compound consisting of three molecules of fatty acids bound with a molecule of glycerol.

The following symbols will be used throughout the text:

1. HDL: high density lipoprotein
2. CHD: coronary heart disease
3. Kcal: kilocalories
4. g: grams
5. kg: kilograms
6. LDL: low density lipoprotein

Basic Assumptions

The following assumptions were made:

1. It was assumed that the random assignment of the subjects to the treatment groups prevented biased results, in spite of non-random sampling.

2. It was assumed that all subjects consumed the liquid diet as the sole source of nutrition for the full 28 days.

3. It was assumed that all subjects followed instructions (12-hour fast) prior to the weekly blood tests.

4. It was assumed that the enzymatic assays resulted in accurate determinations of total cholesterol, HDL cholesterol and triglyceride.

Summary

The major objective of the study was to determine the effect of the combination of an exercise program with two hypocaloric diets of different carbohydrate content on blood lipid levels. Although past studies have emphasized the use of diet or exercise alone in the treatment of obesity, this study attempted to determine if the combination of caloric restriction and exercise was effective in improving blood lipid levels, while also determining whether a high carbohydrate hypocaloric diet or low carbohydrate hypocaloric diet was better in this regard.

Chapter II

LITERATURE REVIEW

The risk of developing atherosclerosis and coronary heart disease appears to increase with obesity, and hyperlipoproteinemia, a major risk factor may be an important underlying mechanism. The review of literature on this topic will be divided into six sections: 1) the general description of the blood lipids and the relationship between the lipids and atherosclerosis and coronary heart disease; 2) the relationship between obesity and blood lipids; 3) the effects of caloric restriction on blood lipids; 4) the effects of exercise on blood lipids; 5) the effects of caloric restriction with exercise on blood lipids; and 6) the effects of alterations of the carbohydrate content of a hypocaloric diet on blood lipids.

General Description of the Blood Lipids and the Relationship Between the Lipids and Atherosclerosis and Coronary Heart Disease

Atherosclerosis is a major contributing cause in more than 50% of all deaths in the United States (Heart Facts, American Heart Association, 1979). For many years elevated total serum cholesterol has been considered one of the major risk factors in the development of coronary heart disease and atherosclerosis (Berchtold, et al., 1977). However, recent research seems to indicate that the manner in which the cholesterol is transported in the blood may be much more important in the development of these diseases than are the total cholesterol concentrations (Miller and Miller, 1975). The present study focuses primarily on total serum cholesterol, HDL cholesterol and triglycerides.

Cholesterol and triglycerides are carried in the bound form as lipoproteins and transported in the blood (Gotto, 1979). Low density lipoprotein cholesterol, with its well-known atherogenic potential, has been studied to a greater extent than any of the other lipoproteins. The LDL cholesterol molecule has a density range of 1.019 to 1.063 g/ml and is approximately 45% cholesterol and 25% protein (Levy and Stone, 1977). Of the total amount of cholesterol in the blood, approximately one-half to two-thirds is carried by LDL cholesterol (Levy and Stone, 1977).

The high density lipoprotein cholesterol molecule, on the other hand, has a protein content of approximately 45 to 50% and a cholesterol content of only 20%. HDL cholesterol has a density range of 1.063 to 1.210 g/ml (Levy and Stone, 1977).

Serum triglycerides are compounds consisting of three molecules of fatty acids bound with one molecule of glycerol. Triglycerides are the main constituents of both chylomicrons, the largest of the lipoproteins, and very low density lipoprotein cholesterol molecules. Chylomicrons consist of 80-95% triglycerides and very low density lipoproteins contain 60-80% triglycerides. In the absence of chylomicrons, an increase in cholesterol VLDL can be directly correlated with increased plasma levels of triglycerides (Levy and Stone, 1977).

At this time, there are three theories as to the protective action of HDL cholesterol in the blood; 1) HDL may prevent the uptake of LDL cholesterol by the cells (Steinberg, 1978); 2) HDL may remove cholesterol from the arterial walls (Stein, Vanderhoek and Stein, 1976; Bates and Rothblat, 1974); and 3) HDL may accelerate the clearance of triglyceride-rich lipoproteins (Glomset, 1968). Recent studies also indicate that of all the correlations between blood lipids and coronary heart disease and atherosclerosis, the negative correlation of HDL cholesterol is the strongest and the strength of this correlation is as great or greater than that of any other known coronary risk factor (Gotto & Rikfind, 1982; Miller, Thelle, Forde, & Mjos, 1977; Gordon, Castelli, Hjortland, Kannel & Dawber, 1977).

In the Tromso Heart Study, Miller, et al. (1977) found that plasma HDL cholesterol made a three-fold greater contribution than did the LDL cholesterol concentration in the discrimination of those individuals who would have a coronary event within the next two years. Gordon, et al. (1977) found that coronary heart disease per 1000 subjects increased from 25 to 100 in men and from 14 to 164 in women as the HDL levels decreased from 65-74 mg/dl to 25-34 mg/dl. Thus, the predictive power of HDL cholesterol in this study was approximately four times greater than that of LDL cholesterol and eight times greater than that of total serum cholesterol.

Although the "optimal" concentrations of total serum cholesterol and HDL cholesterol are difficult to define, the American Health Foundation has concluded that the goal of most societies should be an average serum cholesterol of 160 mg/dl with ranges from 130 to 200 mg/dl. Of this total value, LDL cholesterol should be no higher than 90 to 100 mg/dl and the HDL cholesterol should be 50 mg/dl or higher -- levels which are associated with lower rates of coronary heart disease.

The role of triglycerides as an independent risk factor for the development of cardiovascular disease remains a controversy (Gotto, 1979). Castelli et al. (1977) and Lopez, Vial, and Bolart (1974) found triglycerides to be positively associated with the incidence of coronary heart disease and negatively associated with HDL cholesterol concentrations. Carlson and Ericsson (1975) also noted a negative correlation between triglycerides and HDL cholesterol but found that triglyceride concentrations had no impact on the risk of coronary heart disease even when considered independently. The role of triglycerides in the development of disease is even further confused by its strong association with obesity, another predisposing condition for disease (Berchtold et al., 1981; Hallenberg and Svandberg, 1967). In spite of the lack of conclusive evidence concerning the role of triglycerides in coronary heart disease, an upper limit of approximately 190 mg/dl has been set for triglycerides (Gotto, 1979).

In order to reduce the risk for coronary heart disease and atherosclerosis, abnormalities in blood lipids must be controlled. According to recent research, this includes not only decreasing the total amount of cholesterol in the blood, but also increasing the HDL fraction of the cholesterol and decreasing serum triglycerides.

Relationship Between Obesity and Blood Lipids

The risk of coronary heart disease and atherosclerosis is believed to increase stepwise with increasing obesity (Keen, 1982). This increased risk appears to be related to abnormal concentrations of serum total cholesterol, HDL cholesterol and triglycerides (Kannel, Gordon and Castelli, 1979; Berchtold, et al., 1981).

Berchtold, et al. (1981) investigated the prevalence of cardiovascular risk factors in obese patients and found that only 9-10% of the 1332 patients tested were without any risk factors. Hypertriglyceridemia and hypercholesterolemia were present in 31% and 18% of the patients, respectively. Serum HDL cholesterol concentrations were decreased as well, thus further increasing the risk for cardiovascular disease.

Hallenberg and Svandberg (1967) found the prevalence of hypertriglyceridemia to be three or four times higher in the obese than in the general population. Hypercholesterolemia has been found in other studies to be more frequent in the obese, ranging from 22% (Berchtold, et al., 1977) to 37% (Berkowitz, 1964), as compared to average weight groups, 3.7% (Gustafson, Elmfeldt, Wilhemsen and Tibblin, 1972) to 12.8% (Wood, et al., 1976).

Mancini, et al., (1981); Kannel, Gordon and Castelli, (1979); Waxler and Craig, (1964) found increased total cholesterol and triglycerides in obese subjects, but noted that decreased HDL cholesterol concentrations were the most strongly related to obesity.

The increased concentrations of total cholesterol and triglycerides in the obese may be due to an increased rate of cholesterol synthesis (Miettinen, 1971) and the decreased HDL cholesterol concentrations may be explained by a proposed inverse relationship between the total pool of cholesterol in the body and HDL cholesterol (Miller and Miller, 1975). Whatever the source of these abnormal blood lipid concentrations treatment of the obese must include methods which will improve these values and decrease the risk of coronary heart disease and atherosclerosis.

The Effects of Caloric Restriction on Blood Lipids

Caloric restriction has long been the most popular method of treatment for obesity. While moderate restriction accompanied by a slow steady weight loss is usually preferred, very low calorie diets are often used with the obese because of the quicker and more substantial weight loss associated with them. These diets, with daily intakes of approximately 600 calories or less, usually result in good compliance due to the absence of hunger after the first 48 hours of the diet and have been found to be safe and effective methods of treatment for obesity for periods up to two months (Baird, 1981). While these very low calorie diets are effective in producing substantial weight loss, do they produce favorable changes in blood lipid levels? Studies involving the use of very low calorie diets have yielded conflicting results.

Scheen, Luyckx, Scheen-Lavigne and Lefebvre (1982) placed severely obese subjects on a 300 kcal/day diet for 13 days and found total cholesterol to have decreased 26% and triglycerides, 35%. Schouten, Van Gent, Popp-Snijders, Van der Veen and Van der Voort (1981) conducted a study in which obese patients consumed a 240 kcal/day diet for two weeks. Total serum cholesterol and HDL cholesterol were significantly reduced and their ratio remained unchanged. The direction of the changes in triglycerides was related to pre-diet levels, subjects with a level below 120 mg/dl before the diet showed no change or a slight increase, subjects with a level over 120 mg/dl before the diet showed a significant decrease in triglycerides.

Wechsler, Hutt, Wenzel, Klor and Ditschunett (1981) placed massively obese subjects on a 240 kcal/day diet. Total serum cholesterol and triglycerides decreased 26% and 19%, respectively. However, HDL cholesterol decreased a total of 29%, thus increasing the total cholesterol/HDL cholesterol ratio as opposed to favorably decreasing it. Tokunga, Ishikawa and Matsuzawa (1982) treated massively obese patients with a less severe diet consisting of 600 to 800 kcal/day and found results similar to those in Wechsler's (1981) study. However, in a follow-up analysis two weeks after the diet, HDL cholesterol had returned to pre-diet levels, while total cholesterol and triglycerides remained decreased for eight weeks after the diet, thus producing a significant improvement in all of these blood lipid levels.

Total starvation creates a maximum energy deficit and is effective in producing rapid weight loss (Cahill, 1976). But, what happens to blood lipids when the obese are subjected to total withdrawal of food? Weisweiler and Schwandt (1981) measured blood lipids before and after a four day fast. Serum triglycerides decreased significantly, while total and HDL cholesterol both increased significantly. Hendrikx, Boni, Kieckens, Meulepas and DeMoor (1979) subjected obese patients to a 7-day fast and found an overall increase in triglycerides even though changes were related to the pre-fast triglyceride concentrations. They found no consistent pattern of change in serum total cholesterol levels, thus resulting in no significant change across the whole group. Huttunen, Ehnholm, Nikkila and Ohta (1975) and Streja, Marliss and Steiner (1977) also noted decreased triglycerides following short-term fasts.

At this time, there are conflicting results concerning the effects of very low calorie diets, as well as total fasting, on blood lipids. However, when deciding which diet is best for the obese patient, researchers must not only be concerned with the amount of weight loss obtained, but must also be aware of the possible effects of the diet on blood lipids.

The Effects of Exercise on Blood Lipids

Exercise has become increasingly important in the past few years as a method of treatment for obesity. In spite of a slower rate of weight loss as compared with caloric restriction, exercise may be one of the long-term answers to obesity and related problems.

Physical inactivity plays an important role in the pathogenesis of obesity and hyperlipoproteinemia. Obese, as well as non-obese, sedentary subjects are characterized by higher levels of total cholesterol and triglycerides as compared to age matched active subjects (Bjorntop, 1976; Schaefer, 1974; Wood, et al., 1976). These individuals also tend to have decreased HDL cholesterol concentrations, believed to be caused, in part, by this lack of physical activity (Berchtold, 1976; Kannel, et al., 1979; Miller & Miller, 1975).

Recent studies indicate that mild-to-moderate exercise results in favorable blood lipid changes. Weltman, Matter and Stamford (1980) found a 10-week exercise program consisting of brisk walking to significantly decrease triglycerides and total cholesterol and improve the total cholesterol/HDL cholesterol ratio in spite of no significant changes in HDL cholesterol concentrations. Huttunen et al., (1979) exercised non-obese middle-aged males at 40% of maximal heart rate for 8 weeks and at 66% of maximal heart rate for 8 additional weeks. The results of the study revealed a progressive decrease over the 16 weeks in serum triglycerides, as well as a significant decrease in total cholesterol. HDL cholesterol increased progressively across time and there was evidence that HDL cholesterol can be altered in previously inactive middle-aged men regardless of the initial HDL cholesterol values. Hanefield et al., (1981) found similar changes in serum triglycerides and total cholesterol after only 22 days of exercise, but found no significant changes in HDL levels. However, due to the decreased total cholesterol, the total cholesterol/HDL cholesterol ratio decreased.

Other studies investigating the effects of exercise on blood lipids have conflicting results. Altekruse and Wilson (1973) found significant decreases in total cholesterol in male subjects after a 10-week physical conditioning program, however, triglyceride concentrations increased slightly. In another 10-week exercise program, consisting of working at 70% of maximal heart rate, Frey, Doerr, Laubach, Mann and Glueck (1982) found no differences between pre- and post-training levels of HDL cholesterol and triglycerides and even noted a slight increase in total cholesterol concentrations in sedentary women aged 19 to 29. Franklin (1979) tested sedentary middle-aged women and found a 12-week conditioning program to have no significant effects on serum lipids.

Reasons for variations in the effect of exercise on blood lipids are not conclusive. The mechanism of triglyceride reduction after physical conditioning is related to weight loss, however, increased uptake of serum triglycerides by the working muscles may occur during prolonged heavy exercise (Huttunen, et al., 1979). This theory does not explain the changes that can occur with mild-to-moderate exercise. It is also not clear whether the exercise-induced increase in HDL cholesterol is a direct result of the increase in physical exercise or is due to other factors such as changes in diet, cigarette smoking or alcohol intake (Huttunen, et al., 1979). These extraneous factors may become especially important in short-term studies where lipid levels may not have the time to stabilize once they are exposed to treatments. In spite of conflicting results, these studies seem to indicate that exercise produces decreases in total cholesterol and triglycerides while maintaining or even increasing HDL cholesterol.

The Effects of Caloric Restriction With Exercise on Blood Lipids

Both caloric restriction and exercise alone are effective in treating obesity. Caloric restriction generally results in faster, more substantial weight loss than exercise, which is characterized by slow, steady weight losses. Caloric restriction also usually results in favorable decreases in total cholesterol and triglycerides, (Lopez, et al., 1974), but often produces decreases in HDL cholesterol as well (Scheen, et al., 1982; Schouten, et al., 1981; Wechsler, et al., 1981). Exercise also produces decreases in total cholesterol and triglycerides, however, HDL cholesterol may increase or remain unchanged, thus producing a decreased total cholesterol/HDL cholesterol ratio (Weltman, et al., 1980; Huttunen, et al., 1979; Hanefield et al., 1981; Bosello, et al., 1981).

What happens to blood lipids when caloric restriction is combined with exercise? Weltman, Matter and Stamford (1980) placed subjects into one of four groups: caloric restriction (500 kcal/day), mild exercise (brisk walking), caloric restriction with mild exercise (500 kcal/day and brisk walking) and control. All three experimental groups resulted in significant reductions in total serum cholesterol. The two groups utilizing exercise also had significant reductions in LDL cholesterol and no change in

HDL cholesterol. Caloric restriction alone resulted in significant decreases in HDL cholesterol and no change in LDL cholesterol thus resulting in a less favorable LDL/HDL ratio. The combination of diet and exercise also resulted in greater fat loss, thus making the method of treatment even more effective than either diet or exercise alone.

Bosello, et al. (1981) placed ten obese females on a very low calorie diet (375 kcal/day) while ten other subjects added 30 minutes of exercise (50% of maximal working capacity) twice a day to the diet for 28 days. Serum triglycerides showed a significant reduction only in the group that exercised, while serum cholesterol fell significantly in both groups. HDL cholesterol did not change in either group. This study also resulted in greater fat loss in the subjects who combined caloric restriction with exercise.

In spite of a lack of research on the combination of diet and exercise in the treatment of obesity, the evidence available seems to indicate that the combination of treatments produces favorable changes in both blood lipids and body composition changes.

The Effects of the Alteration of the Carbohydrate Content of a Hypocaloric Diet

Caloric restriction has long been recognized as an effective method of treatment for obesity. However, when caloric restriction and exercise are combined, it is not yet clear as to what diet composition is necessary to produce optimal weight loss and exercise compliance when as well as desirable blood lipid responses.

Lewis, Wallin, Kane and Gerich (1977) studied the effects of diet composition on metabolic responses to caloric restriction and found that subjects lost more weight and had greater decreases in triglycerides after a high fat-low carbohydrate diet than after a high carbohydrate-low fat diet. The high fat-low carbohydrate diet also resulted in significant decreases in total serum cholesterol. Other studies indicate that high carbohydrate diets may result in increased triglycerides (Reaven and Olefsky, 1974; Ginsburg, Olefsky and Kimmerling, 1976), while either decreasing (Ahrens, et al., 1957; Hatch, Abell and Kendall, 1955) or not changing total cholesterol (Coulston, Liu and Reaven, 1983). Gonen and Patsch (1981) found HDL cholesterol concentrations decreased after a high carbohydrate diet.

Obviously, both diets, high fat-low carbohydrate and high carbohydrate-low fat, have varying effects on blood lipids. But which diet composition is better when exercise is combined with the caloric restriction? Bogardus, LaGrange, Horton and Sims (1981) found the capacity to exercise and subjective ratings of well-being to be reduced after only a few days of carbohydrate restriction. This study has important implications for weight-loss programs consisting of diet combined with exercise. Subjects consuming a high carbohydrate diet may be able to work at a broad range of exercise intensities whereas subjects taking a low carbohydrate diet may not be able to start an exercise program requiring work at high submaximal workloads. This information may be important in determining the best diet composition for use with exercise than the actual effects of the diet on blood lipids.

At this time, more research is needed in order to develop an exercise with caloric restriction program which produces desirable changes in body weight and blood lipid concentrations, while, at the same time, allows subjects to exercise safely and go about their daily routine without any harmful side effects.

Summary

The review of current literature on the topic of obesity and the risk of coronary heart disease and atherosclerosis reveals that part of the underlying mechanism for this relationship may be abnormal levels of blood lipids. Obese individuals tend to have increased total cholesterol and triglycerides and decreased HDL cholesterol. Very low calorie diets generally produce decreases in total cholesterol and triglycerides, however, HDL cholesterol is often decreased as well. Exercise also decreases total cholesterol and triglycerides, while HDL cholesterol usually increases or does not change, thus producing favorable changes in the total cholesterol/HDL cholesterol ratio. The disadvantage of exercise alone as treatment for obesity is the slower rate of weight loss. The combination of caloric restriction and exercise may be the best method of treatment for obesity as blood lipid profiles improve and a greater percentage of the weight loss is fat. More research is needed on the effects of diet with exercise on blood lipids and on the diet composition necessary to allow individuals to exercise at a moderate intensity.

Chapter III

JOURNAL MANUSCRIPT

The Effect of Exercise and the Alteration of Carbohydrate Content of a Hypocaloric Diet on Blood Lipids

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ABSTRACT

Twelve obese young women (aged 22-36) were studied to determine the effects of the combination of an exercise program with either a high carbohydrate (HC) hypocaloric diet or low carbohydrate (LC) hypocaloric diet on total cholesterol, high density lipoprotein (HDL) cholesterol and triglycerides. Subjects were randomly placed in one of the diet groups (530 kcal/day) and participated in submaximal (60% VO_2max) exercise sessions three times per week for a period of 28 days. After the treatment period, the subjects consumed a 1000 kcal/day mixed diet for one week while continuing the exercise program. Blood samples were drawn weekly for the analysis of total cholesterol, HDL cholesterol and triglycerides. Weight significantly decreased in both groups (mean decrease = 9.8% for LC; 8.8% for HC). After week one of the diet, total cholesterol and HDL cholesterol decreased significantly throughout the rest of the study. Due to the changes in total cholesterol, the total cholesterol/HDL cholesterol ratio decreased throughout the study, reaching significance by the post-treatment

period when the ratio was 20.6% below baseline levels for both groups. There were no significant changes in triglycerides for either group. However, triglycerides increased throughout the dietary treatment (mean increase = 9.5% for LC; 18.7% for HC). Triglyceride concentrations also changed during the post-treatment week as the LC group had a mean decrease of 38.3% and HC group, 8.2% from baseline values. These data suggest that both diets are equally effective in reducing body weight in young women. Also, in spite of the decreases noted in HDL cholesterol in both groups, total cholesterol decreased even further, thus producing a lower, more favorable total cholesterol/HDL cholesterol ratio.

Index Terms: total cholesterol; HDL cholesterol; total cholesterol/HDL cholesterol ratio; triglycerides; hypocaloric diet; carbohydrate content.

Introduction

Coronary heart disease and atherosclerosis account for a large percentage of the deaths in the United States. For many years, researchers have noted the association between obesity and the incidence of this disease (13). One of the major risk factors for coronary heart disease, elevated serum cholesterol, is often associated with obesity and may be the underlying factor in the increased incidence of this disease in obese individuals (1). However, the way in which the cholesterol is transported may be much more important than the gross concentrations (14). While total cholesterol and low density lipoprotein cholesterol are positively associated with the development of coronary heart disease and atherosclerosis, high density lipoprotein cholesterol is negatively related and may be the most powerful predictor for coronary heart disease and atherosclerosis of all the known risk factors (6,7,15). Recent research indicates that the total cholesterol/HDL cholesterol ratio may also be a useful summary of risk for coronary heart disease (8). In spite of a lack of conclusive research, the reduction of the amount of triglycerides in the blood may prove to be important in decreasing the risk for these diseases (9,25).

Hypertriglyceridemia and hypercholesterolemia are commonly seen in the obese as well as decreased levels of

HDL cholesterol (2). Many types of weight loss programs have been implemented in attempts to improve blood lipid concentrations. Caloric restriction tends to result in decreases in total cholesterol and triglycerides, however HDL cholesterol may also decrease (23). Physical activity generally results in decreases in total cholesterol and triglycerides, while HDL cholesterol may increase (11) or remain the same (24), thus decreasing the total cholesterol/HDL cholesterol ratio and the risk for disease (8). The combination of caloric restriction with exercise results in favorable blood lipid responses and greater fat loss than with either diet or exercise alone (4). However, research is needed on the optimal diet and exercise combination. Current research seems to indicate that a hypocaloric diet high in carbohydrate allows more freedom in the type and intensity of exercise that may be performed, as well as results in favorable lipid responses (3).

No matter what method of weight loss treatment is used with the obese, reducing the risk of developing atherosclerosis and coronary heart disease must be an important consideration. The purpose of this study was to determine the effect of the combination of an exercise program with two hypocaloric diets of different carbohydrate content on total cholesterol, HDL cholesterol and triglycerides. Although past research has emphasized the use of caloric restriction or exercise alone, this study attempted to determine if the combination of exercise with a high carbohydrate hypocaloric diet or a low carbohydrate hypocaloric diet is more effective in improving the blood lipid profiles and overall health of the obese.

Methods

Twelve obese young women (aged 22-36), mean body weight = 79.1 ± 9.2 kg) without any other known health problems voluntarily participated in this study. The average percent of ideal body weight (calculated relative to the midpoint body weight for medium frame size of the tables of the Metropolitan Life Insurance Company, 1983) was 130±5% for LC and 126±2% for HC. Subjects were randomly assigned to one of two treatment groups: a high carbohydrate (HC) hypocaloric diet group (n = 5) and low carbohydrate (LC) hypocaloric diet group (n = 7). Prior to the hypocaloric diet, each subject consumed a prescribed weight maintenance diet for one week to provide baseline values. This mixed diet consisted of 20% protein, 45% carbohydrate and 35% fat. A treadmill graded exercise test with a modified Balke protocol was performed by each subject in order to determine the individual's VO_2max. During the 28 day dietary treatment period, the HC group consumed a liquid diet containing 530 kcal, 31 g protein, 2 g fat and 94 g carbohydrate per day. The LC group consumed a daily liquid diet of 530 kcal, 31 g protein, 24 g fat and 44 g carbohydrate. Both diet groups participated in the same exercise program which consisted of walking and jogging at an intensity corresponding to 60% $\dot{V}O_2max$ for 30-45 minutes, three times per week. Exercise sessions were supervised by the experimenters. At the end of the dietary treatment period, subjects followed a 1000 kcal mixed diet which was estimated to consist of 20% protein, 45% carbohydrate and 35% fat for one week. Exercise sessions continued throughout the post-treatment period.

Blood samples were taken at the end of each week of the pre-treatment, treatment and post-treatment periods after an overnight fast. Serum was separated from the whole blood and refrigerated for all HDL cholesterol assays and either frozen or refrigerated for the total cholesterol and triglycerides assays. Serum values for total cholesterol, HDL (LDL and VLDL precipitation by phosphotungstate/magnesium) cholesterol and triglycerides were determined enzymatically (Sigma Technical Bulletin No. 350-HDL and No. 320-UV).

All data were analyzed by a two-factor analysis of variance (ANOVA) with repeated measures using the General

Linear Model procedure. The alpha level was set at .05. The Tukey post hoc procedure was used to determine statistically significant differences between means. A correlational analysis was performed on changes in group means during the treatment period to determine the relationship between variables.

Results

Values for weight, total cholesterol, HDL cholesterol, total cholesterol/HDL cholesterol ratio and triglycerides during the experiment are given in Table 1. The means across time for both groups are shown graphically in Figure 1. Weight loss was significant for both groups throughout the dietary treatment period, however, the LC group (mean decrease = 8.0 kg) lost significantly more weight than the HC group (mean decrease = 6.7 kg).

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INSERT TABLE 1 AND FIGURE 1 ABOUT HERE

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The means for total cholesterol during the treatment period are shown in Figure 2. Total cholesterol for LC group increased by 2.1% in the first week of the diet and decreased to 19.3% from baseline. The HC group decreased to 17.6%, by week two of the diet, but increased to within 6.8% from baseline during the next week. Total cholesterol for the HC group decreased to 15.5% from baseline by the end of the diet. In the post-treatment period, total cholesterol for the LC group was 22.4% lower than the pre-diet value while total cholesterol for the HC group was 25.0% lower than the pre-diet value. The decreases in total cholesterol in both groups were significant during each week of the diet and the post-diet period. There was no significant group interaction across time during the treatment period and the post-treatment week.

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INSERT FIGURE 2 ABOUT HERE.

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The means for HDL cholesterol during the experiment are shown in Figure 3. HDL cholesterol values for the LC group increased 0.7% during the first week of the diet, but then decreased significantly throughout the diet to 19.3% below baseline. The HC group had similar changes with an initial increase of 3.8% during week one of the diet followed by decreases reaching 11.7% from baseline by the end of the diet. HDL cholesterol concentrations during the post-treatment period were 0.2% lower than the pre-treatment values for the LC group and 5.6% lower for the HC group. There was no significant interaction between the treatment groups across time.

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INSERT FIGURE 3 ABOUT HERE.

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Group means for the total cholesterol/HDL cholesterol ratio are shown in Figure 4. The ratio for the LC group decreased 8.8% from baseline during the study while the HC group decreased 14.7% by the second week of the diet and increased the third week of the diet so that the ratio was only 2.9% below baseline after the diet. The total cholesterol/HDL cholesterol ratio for both groups were 20.6% from baseline after the post-treatment period. There was no significant interaction between the treatment groups across time.

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INSERT FIGURE 4 ABOUT HERE.

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The means for triglycerides are shown graphically in Figure 5. There was no significant changes across time for either group and no significant interaction between treatment groups across time. However, serum triglycerides for the LC group increased 11.6% from baseline during the diet. The HC group experienced increased 11.3% over the treatment period. The LC group had an increase of 38.3% from baseline during the post-treatment period, while the HC group was only 8% above baseline during the same period.

Discussion

The present investigation was designed to determine the effect of the combination of an exercise program with two hypocaloric diets of different carbohydrate content on total cholesterol, HDL cholesterol and triglycerides. The results include significant decreases in body weight, total cholesterol and HDL cholesterol for both diet groups.

Both groups experienced significant decreases in body weight. However, the weight loss for the LC group (mean decrease = 8.0 kg) was significantly greater than that of the HC group (mean decrease = 6.7 kg). The pattern of weight loss was also varied as the LC group lost a greater amount of weight during week one of the diet (mean decrease = 2.8 kg) than the HC group (mean decrease = 1.8 kg). There are several possible reasons for this variation. The LC group may have had increased water loss during the week because of the breakdown of liver glycogen for energy (5,44). Also, differences in pre-diet weights may have influenced weight loss as the LC group averaged 81.3 kg and the HC group averaged 76.0 kg.

During the post-diet week of the study in which 1000 kcal/day was consumed, the LC group gained 0.8 kg while the HC group gained only 0.2 kg. This rebound in body weight after a high fat diet has been observed previously (23) and may be due to increased water retention occurring with some glycogen repletion upon consuming the mixed diet (44).

Total cholesterol decreased significantly for both groups during the study. This response is often seen with caloric restriction (35,36,38,41) and is usually due to decreases in HDL cholesterol and VLDL cholesterol with or without decreases in LDL cholesterol (41,42). However, when exercise is added to caloric restriction, decreases in total cholesterol tend to be due to reductions in LDL cholesterol and VLDL cholesterol without decreases in HDL cholesterol (6,42). Thus, exercise may have a protective effect on HDL cholesterol (42).

In the present study, total serum cholesterol changed only slightly during the first week of the diet and then decreased significantly throughout the rest of the study. The decrease appears, in part, to be related to the decreases in HDL cholesterol portion of the total amount of cholesterol as this fraction also decreased significantly during the study. LDL and VLDL cholesterol fractions were not measured, however, calculations of LDL cholesterol and VLDL cholesterol by difference (total cholesterol - HDL cholesterol) indicate that these lipoproteins also decreased from about 100 mg/dl to 80 mg/dl during the liquid diet and 70 mg/dl by the end of the post-diet week. Since a significant decline was observed in HDL cholesterol, the exercise program implemented in this study was not sufficient to prevent HDL cholesterol decreases caused by the very low calorie diet.

Serum HDL cholesterol showed a similar response as total cholesterol in both treatment groups as values increased slightly during the first week and then decreased throughout the rest of the study, reaching significance by week three of the low calorie formula diet. This response is in agreement with other studies in which very low calorie diets resulted in decreased HDL cholesterol levels (35,36,42), and may be due to decreased cholesterol ingestion or synthesis which can result in decreased transported cholesterol. However, HDL cholesterol increased during the post-diet week so that concentrations for the LC group were only 0.2% below baseline and the HC group, 5.6% below baseline. Reasons for the increase are not clear cut, but may be a result of the exercise, as the severe caloric restriction was discontinued.

Huttunen et al. (19) exercised male subjects three to four times per week for four months and found an increase in HDL cholesterol. Weltman et al. (41) trained subjects for ten weeks, and found HDL cholesterol to remain unchanged. When endurance-trained women were compared with sedentary controls, higher HDL cholesterol concentrations were noted (9,28,29,37,41). However, there have been fewer studies involving the effect of exercise on HDL cholesterol concentrations of previously sedentary women and the results have not been consistent. The reported HDL cholesterol responses have varied from no change (2,7,23,27), significant decreases (1), significant increases (10). Haskell (16) proposed that the discrepancy between the higher HDL cholesterol found in trained female athletes and the failure of HDL cholesterol to consistently increase with exercise, may be due to the relatively short duration of some of the exercise programs implemented for women. Another factor which may, in part, affect HDL cholesterol responses to exercise is the frequency of the exercise sessions. Bosello et al. (4) treated obese females for 28 days with a very low calorie diet and 30 minutes of exercise twice daily and found no change in HDL cholesterol. This very high frequency of exercise sessions may have compensated for the short treatment period and prevented decreases in HDL cholesterol levels. Another possible mechanism behind these changes may be related to differential sex-hormone responses to exercise. In adult men, plasma testosterone is positively related to HDL cholesterol levels (11). Frey (11) suggests that exercise increases the testosterone levels in men, but not in women and results in testosterone-mediated increase in HDL cholesterol concentrations. Thus, sedentary women may need more frequent, more intensive and longer exercise sessions than men in order to maintain or increase HDL cholesterol, especially when caloric restriction is added.

The total cholesterol/HDL cholesterol ratio decreased significantly across time for both groups in spite of decreases in HDL cholesterol. This decrease in the ratio was due primarily to a proportionally larger decrease in total serum cholesterol than in HDL cholesterol, a result seen in several studies (16,20,42). In the Cooperative Lipoprotein Phenotyping Study, Castelli et al. (9) found that for each concentration of serum LDL cholesterol, subjects with low HDL cholesterol had an increased risk of coronary heart disease. Also, for each concentration of HDL cholesterol, higher concentrations of LDL cholesterol were associated with a greater chance of coronary heart disease. Wood et al. (43) proposed that if the ratio of HDL cholesterol to LDL cholesterol is improved, then the risk of developing coronary heart disease is decreased. Since LDL cholesterol is positively associated with the total amount of cholesterol in the blood, decreasing total cholesterol at the expense of LDL cholesterol is desired. However, this is not always the case and very little is presently known concerning the most desirable way to improve the total cholesterol/HDL ratio. Since the ratio did decrease in the present study, one would assume that the risk of cardiovascular disease is also decreased.

Triglycerides showed no significant change over time. Triglycerides commonly decrease during caloric restriction (35,41) and with exercise (19,20,25) probably due to decreased production of very low density lipoproteins by the liver or increased removal by the periphery (20). Triglyceride reduction that accompanies weight loss occurs mainly when concentrations are initially elevated (19,33). In the present study, subjects in both groups had rather low initial triglyceride concentrations (94.3 mg/dl = LC; 77.7 mg/dl = HC). Schouten et al. (36) found subjects with levels below 120 mg/dl before caloric restriction to exhibit no change or a slight increase in triglycerides. Thus, the direction of the changes in triglyceride levels are often related to the initial levels. Low initial concentrations of triglycerides are not affected in quite the same manner as high levels, possibly because at low levels a larger proportion of the total plasma triglyceride is carried in the LDL and HDL fractions, and less in the VLDL fraction, which is the lipoprotein fraction most affected by exercise and caloric restriction (32,43).

During the post-diet week the serum triglycerides of the LC group increased to 38.3% above baseline compared to 8.2% above baseline for the HC group. This final change in the triglyceride levels may be a rebound effect, a more pronounced response to the carbohydrate containing mixed diet after consuming the low carbohydrate diet.

In summary, the comparison of the combination of exercise with either a high carbohydrate hypocaloric diet or a low carbohydrate hypocaloric diet indicates that both treatments are effective in reducing body weight in obese women. Both treatments resulted in significant decreases in total cholesterol and HDL cholesterol. The total cholesterol/HDL cholesterol ratio, however, improved, due to larger decreases in total cholesterol, than HDL cholesterol. Thus, the risk for coronary heart disease was decreased. More research is necessary, however, to determine the optimal combination of diet and exercise which produces decreases in total cholesterol, while, at the same time prevents decreases in HDL cholesterol.

Table 1. Group Means for Weight, Total Cholesterol, HDL Cholesterol, Total Cholesterol/HDL Cholesterol Ratio and Triglycerides

Week of Treatment	Weight (mg/dl)		Total Cholesterol (mg/dl)		HDL Cholesterol (mg/dl)		Total Cholesterol/HDL Cholesterol Ratio		Triglycerides (mg/dl)	
	LC	HC	LC	HC	LC	HC	LC	HC	LC	HC
Pre-Diet	81.3±3.8	76.0±3.4	148.2±6.5	161.6±10.5	45.1±2.6	47.8±4.3	3.4±0.2	3.4±0.2	94.3±13.4	77.7±7.2
Week 1 Diet	78.5±3.6*	74.2±3.6*	151.3±10.5	156.4±10.2	45.4±3.1	49.6±3.9	3.3±0.2	3.1±0.2	95.2±5.3	83.1±9.3
Week 2 Diet	76.6±3.6*	72.7±3.8*	122.4±9.0*	133.1±13.3*	42.0±2.8	46.4±4.7	1.9±0.2*	2.9±0.2*	106.0±3.6	101.0±7.6
Week 3 Diet	74.7±3.6*	71.3±3.7*	117.1±5.6*	150.6±15.1*	39.6±2.8*	42.6±3.9*	3.0±0.2	3.6±0.4	106.5±5.2	98.4±11.0
Week 4 Diet	73.3±3.5*	69.3±3.7*	119.6±3.9*	136.6±10.6*	39.4±2.2*	42.2±4.0*	3.1±0.2	3.3±0.3	105.2±7.5	86.5±10.6
Post-Diet	74.1±3.7*	69.5±3.7*	115.0±5.4*	121.2±7.6*	45.0±2.1	45.1±3.3	2.7±0.3*	2.7±0.4*	130.4±15.9	84.1±10.2

Values are means + SEM; LC = Low carbohydrate group (n = 7); HC = high carbohydrate group (n = 5); *significantly different (p<.05) from pre-diet value.

Table 2. Statistical Summary of Analysis of Variance

Source	df	WT ms	Total Cholesterol ms	HDL Cholesterol ms	Total Cholesterol/ HDL Chol Ratio ms	Triglycerides ms
Group**	1	320.22	3571.48	142.65	0.24	5548.77
Subject (Group)	10	490.05	1768.58	188.20	1.23	1190.48
Time	5	94.18*	2652.14*	88.92*	0.82*	842.56
Group*Time	5	1.08*	314.92	7.11	0.22	642.85
Error	50	0.42	221.82	16.9852	0.12	442.71

**Group tested by Subject (Group)
*$p<.05$
df = degrees of freedom
ms = mean square

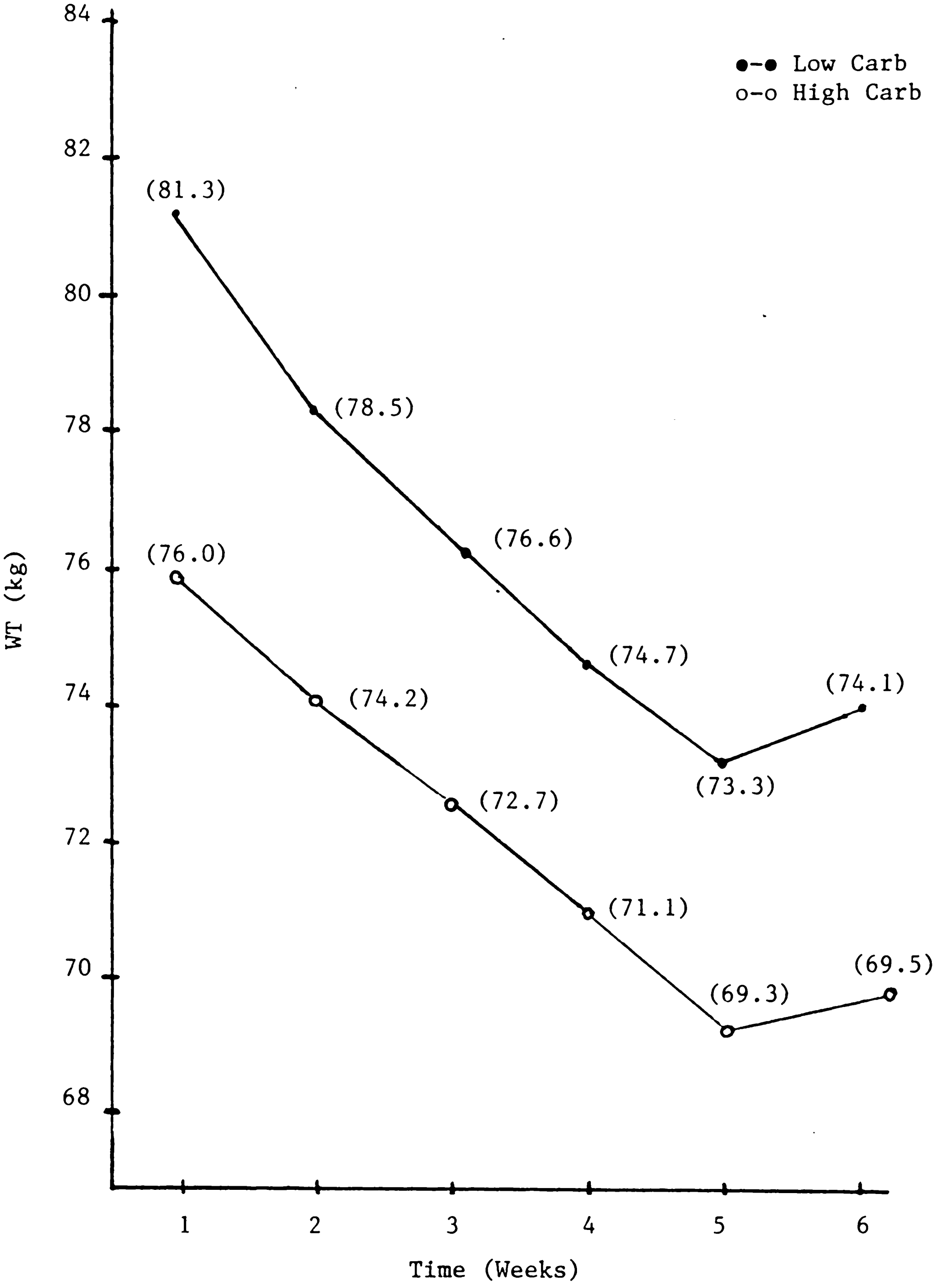

Figure 1. Changes in body weight for obese females on either a low or high carbohydrate hypocaloric diet with exercise.

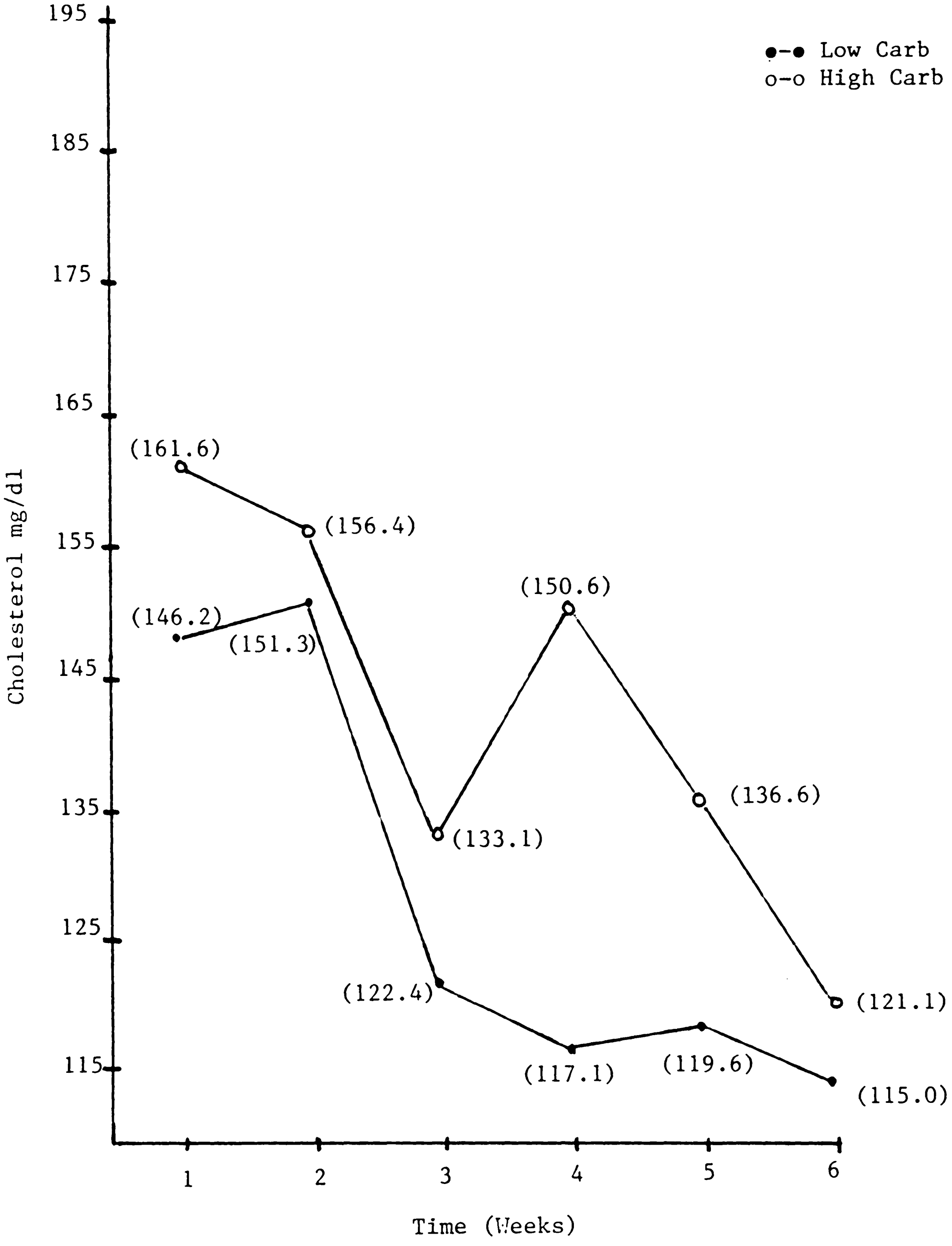

Figure 2. Changes in total serum cholesterol for obese females on either a low or high carbohydrate hypocaloric diet with exercise.

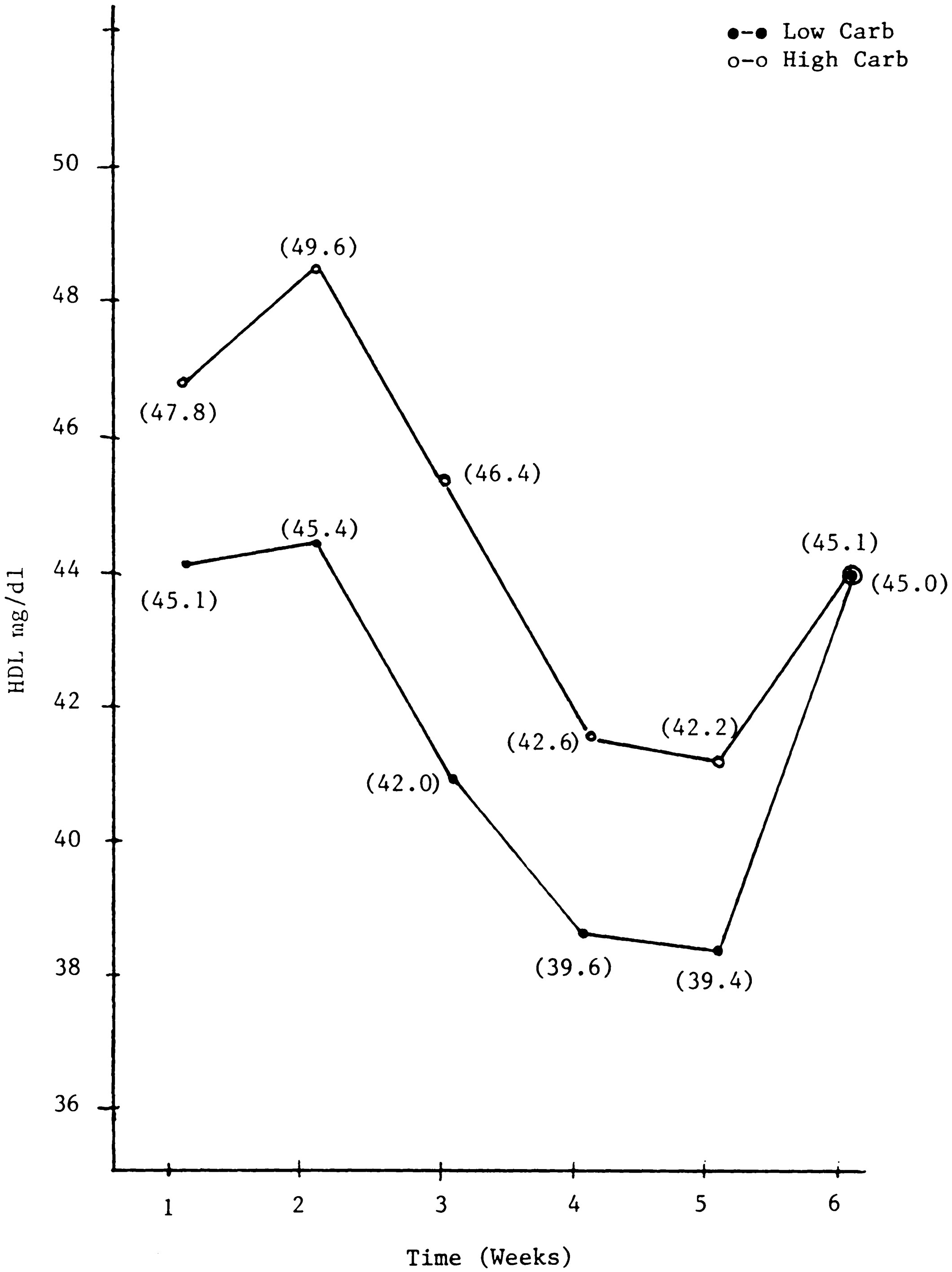

Figure 3. Changes in HDL serum cholesterol for obese females on either a low or high carbohydrate hypocaloric diet with exercise.

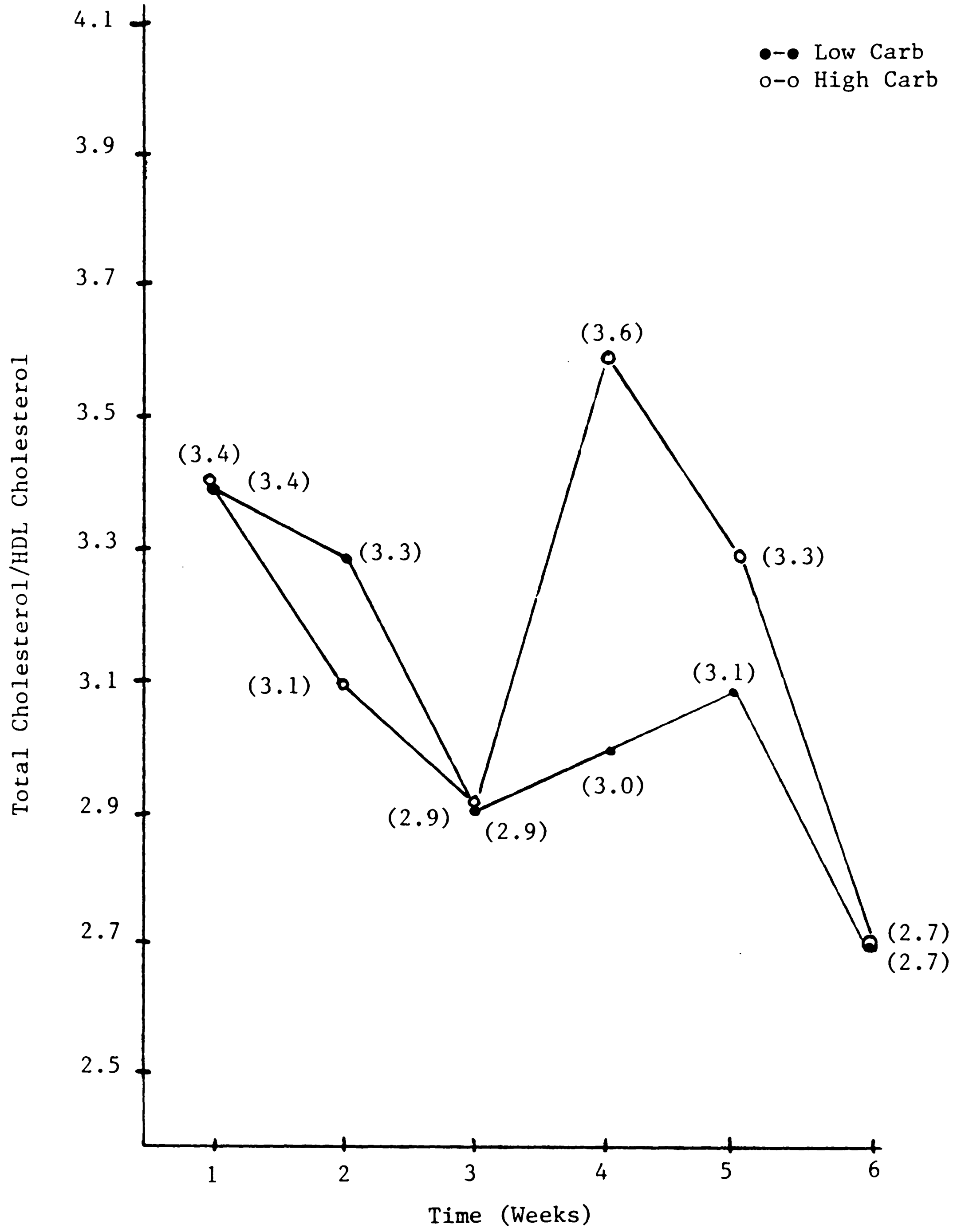

Figure 4. Changes in total serum cholesterol/HDL cholesterol ratio for obese females on either a low or high carbohydrate hypocaloric diet with exercise.

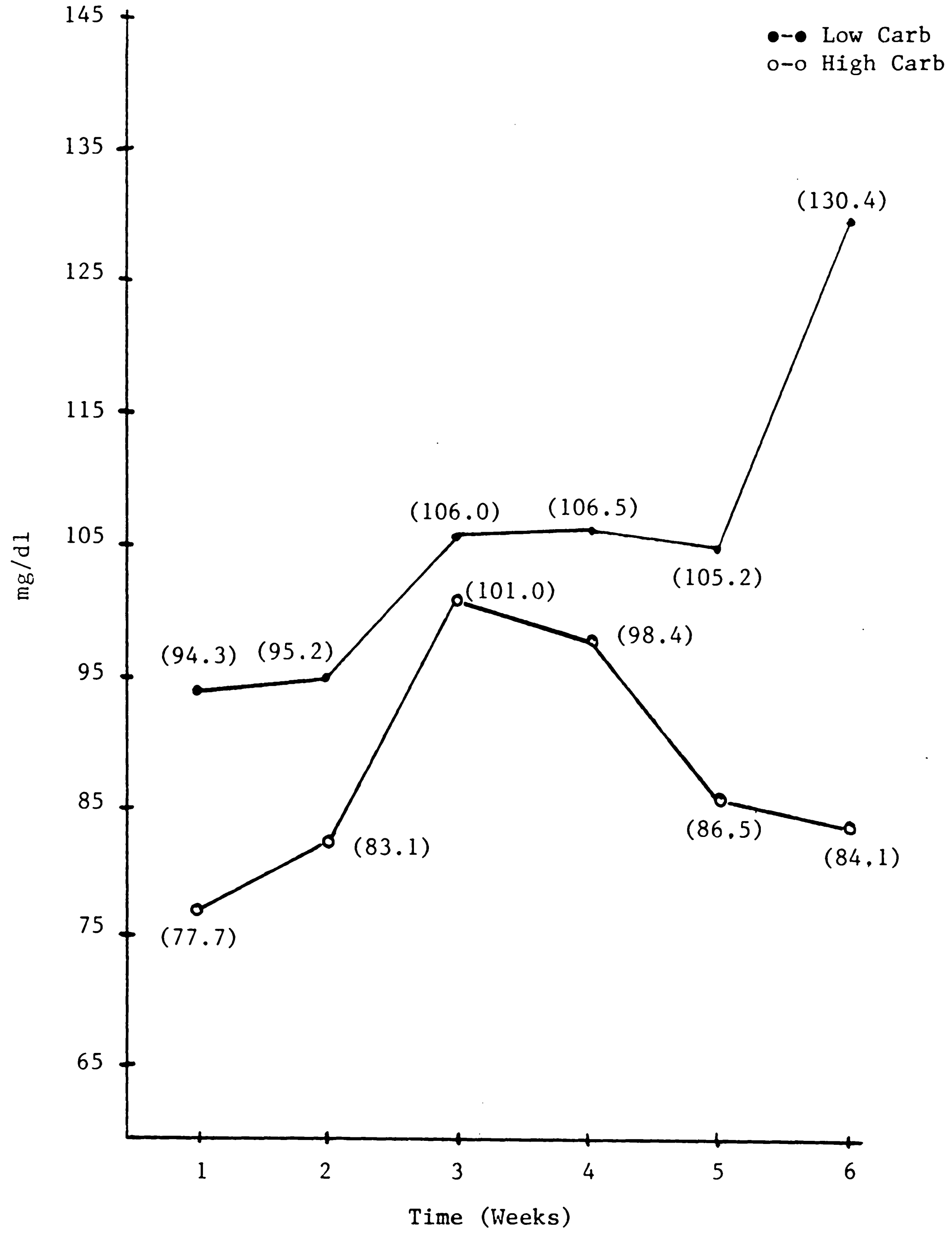

Figure 5. Changes in serum triglycerides for obese females on either a low or high carbohydrate hypocaloric diet with exercise.

Figure Captions

Figure 1. Changes in body weight for obese females on either a low or high carbohydrate hypocaloric diet with exercise.

Figure 2. Changes in total serum cholesterol for obese females on either a low or high carbohydrate hypocaloric diet with exercise

Figure 3. Changes in HDL serum cholesterol for obese females on either a low or high carbohydrate hypocaloric diet with exercise.

Figure 4. Changes in total serum cholesterol/HDL cholesterol ratio for obese females on either a low or high carbohydrate hypocaloric diet with exercise.

Figure 5. Changes in serum triglycerides for obese females on either a low or high carbohydrate hypocaloric diet with exercise.

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Chapter IV

SUMMARY

Recent studies indicate that diet and exercise, either alone, or in combination are effective in producing weight loss in the obese. These treatments, however, have varying effects on blood lipids in these individuals. Caloric restriction tends to result in decreases in total cholesterol and triglycerides, however, HDL cholesterol may also decrease. Physical activity also results in decreases in total cholesterol and triglycerides, while HDL cholesterol may increase or remain the same, thus improving the total cholesterol/HDL cholesterol ratio. The combination of caloric restriction with exercise, although not studied as extensively, has resulted in responses similar to those seen with exercise but with greater fat loss than either diet or exercise alone.

Recent research indicates that a hypocaloric diet high in carbohydrate may allow more freedom in the type and intensity of exercise that can be performed, while producing favorable lipid responses. No matter what method of weight loss treatment is used with the obese, reducing the risk of atherosclerosis and coronary heart disease through alterations in blood lipids must be an important consideration. The purpose of this study was to determine the effect of the combination of an exercise program with two hypocaloric diets of different carbohydrate content on total cholesterol, HDL cholesterol and triglycerides.

Twelve obese young women volunteers (aged 22-36) were randomly assigned to one of two dietary treatments: a high carbohydrate hypocaloric diet consisting of 530 kcal, 31 g protein, 2 g fat and 94 g carbohydrate and a low carbohydrate hypocaloric diet consisting of 530 kcal 31 g protein, 24 g fat and 44 g carbohydrate. Both groups participated three times per week in an exercise program consisting of 30-45 minutes of jogging or walking at an intensity corresponding to 60% VO_2max. The dietary treatment period lasted for 28 days and was followed by a 1000 kcal mixed diet for both groups. The exercise program continued throughout the post-treatment period. Blood samples were drawn weekly for the analysis of total serum cholesterol, HDL cholesterol and triglycerides.

Weight significantly decreased throughout the treatment in both groups. Total serum cholesterol decreased significantly for both groups after week one of the diet. HDL cholesterol followed the same pattern of change with non-significant increases during week one followed by significant decreases throughout the rest of the study. Thus, the addition of exercise did not prevent a decrease in

HDL cholesterol as seen in past studies. The total cholesterol/HDL cholesterol ratio did improve, however, as the decrease in total cholesterol was greater than that of HDL cholesterol. Triglycerides were not significantly affected by either treatment, most likely a result of the low pre-diet triglyceride levels.

According to the results of this study, the use of either of these hypocaloric diets appears to be useful in the treatment of obesity as there were significant decreases in weight, total cholesterol and the total cholesterol/HDL cholesterol ratio. However, the addition of exercise did not prevent HDL cholesterol decreases.

Research Implications

Obesity is associated with the incidence of atherosclerosis and coronary heart disease and research concerning treatment for the obese is crucial. Past methods of weight loss have not been very successful in spite of the emergence of many types of diets. If an effective program of weight loss could be determined, the risk of disease could be greatly reduced.

This investigation suggests that the use of either of these hypocaloric diets is effective in producing weight loss as well as reducing total cholesterol and the total cholesterol/HDL cholesterol ratio. However, exercise did not prevent significant decreases in HDL cholesterol levels.

The lack of change in triglycerides may have been related to low pre-diet concentrations in both groups. Decreases in this blood lipid may occur in individuals with abnormally high initial triglycerides. A follow-up study may have determined whether these changes in triglycerides were transient.

Recommendations for Further Study

This investigation leaves many unanswered questions about the effects of caloric restriction with exercise. There is little research on the effects of dietary treatment on the subfractions of the HDL cholesterol molecule. There is also a lack of follow-up data on the long-term effects of caloric restriction with exercise on blood lipids. Research is also necessary to determine the optimal intensity, duration and frequency of exercise for use with caloric restriction. The following recommendations for further study are made to supplement the results of this investigation:

1. Determination of other lipoproteins such as LDL cholesterol, VLDL cholesterol, chylomicrons, and the subfractions HDL_2 and HDL_3 would give insight into the details of changes occurring in lipid metabolism.
2. More research is necessary regarding the effects of changes in HDL cholesterol to determine if risk of disease is actually reduced after these levels increase.

3. More research should be done to determine the intensity, duration, and frequency of exercise necessary to prevent decreases in HDL cholesterol that may occur with caloric restriction.
4. Inclusion of a much larger number of subjects could give researchers more insight into lipid responses as changes due to individual variability would be reduced.
5. A long-term follow-up would enable researchers to determine if changes in blood lipids after hypocaloric diet with exercise are transient or permanent.
6. Further work should be done with diets of higher caloric content in order to determine the effects of longer periods of dietary intervention on blood lipids and weight loss.

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Appendix A

DETAILED METHODOLOGY

METHODOLOGY

Introduction

Blood lipids were measured on a weekly basis throughout the weight loss program. The six week treatment period included the following phases: 1) the pre-treatment phase in which subjects consumed a weight maintenance diet, 2) the four week treatment phase in which each subject consumed one of the two diet formulas and followed an exercise program, and 3) the post-treatment phase in which the subjects consumed a 1000 kcal diet while continuing to exercise. The following parameters were measured in this study: total cholesterol, HDL cholesterol, triglycerides and body weight.

Subject Screening and Selection

Subjects were recruited through the use of an announcement printed in the Virginia Tech Spectrum. Potential subjects were screened and fourteen females were selected to participate in the weight loss program. Selection criteria included the following: 1) age between 18 and 36 years, 2) generally healthy individuals without any known health-related problems such as coronary heart disease, diabetes, hypertension, gout or orthopedic problems, 3) percent body fat greater than 30% and 4) willingness to adhere to all aspects of the dietary and exercise treatments. All subjects were given a physical examination prior to beginning the weight loss program.

Instructional Procedures

Once the subjects were selected, a meeting was held in order to give the subjects detailed information concerning the diet and exercise treatments. The subjects were given instruction on a weight maintenance diet to be followed for one week before the liquid formula diet and exercise program began. The weight maintenance diet was based on the exchange system and consisted of 20% protein, 45% carbohydrate and 35% fat. During this week, all baseline measurements were made. These measurements included body weight, a graded exercise test to determine VO_2max for exercise prescriptions and blood tests to be used for the analyses of total cholesterol, HDL cholesterol and triglycerides. At the end of the maintenance period, the hypocaloric diet and exercise sessions began and continued for 28 days. The subjects were divided into two groups: one group consuming a high carbohydrate hypocaloric diet while exercising three times per week and one group consuming a low carbohydrate hypocaloric diet while also exercising three times per week. At the end of the 28 day treatment period, each subject was instructed on a 1000 calorie diet (20% protein, 45% carbohydrate and 35% fat) which was to be followed for one week. Subjects continued the exercise program during this week as well. Measurements of total cholesterol, HDL cholesterol, triglycerides and body weight were made weekly during the pre-treatment, treatment and post-treatment periods.

Diet Protocol

A liquid formula diet was the sole source of nutrition for the 28 day treatment period. The daily diet consumed by the high carbohydrate group consisted of the following: Diet Base (Cambridge Plan International) consisting of 330 kcal, 31 g protein, 2 g fat, 44 g carbohydrate; Additional carbohydrate (Polycose, Ross Labs) consisting of 200 kcal and 50 g carbohydrate.

The diet for the low carbohydrate group consisted of the following: Diet Base (Cambridge Plan International) consisting of 330 kcal, 31 g protein, 2 g fat and 44 g carbohydrate; Additional fat source (Microlipid, Organon) consisting of 200 kcal and 22.2 g fat. The fatty acid distribution of the Microlipid was as follows: 74.8% polyunsaturated, 15.0% monounsaturated and 10.2% saturated fat. The polyunsaturated/saturated (P/S) fat ratio was 7.3:1.

Exercise Protocol

Each diet group participated in the same exercise program. The VO_2max for each subject was determined by graded exercise testing on a Quinton treadmill. A modified Balke protocol with increments of 2 METS (7.0 ml O_2/kg/min) per each two-minute work load was used. The percent grade was increased 5% every two minutes until the subject was exhausted. Expired air was measured by a Hewlett-Packard 47303A digital pneumotach and gas analysis was done on an Applied Electrochemistry S-3A oxygen analyzer and CD-3A carbon dioxide analyzer. Determinations of maximal oxygen consumption were made on a specifically programmed computer. The exercise prescription for each subject was set at a heart rate which corresponded to 60% of the VO_2max.

The exercise program consisted of a supervised 30-45 minute session, held three times per week. Each subject walked or jogged at an intensity which elicited a heart reate corresponding to 60% of VO_2max. Heart rates were checked at ten-minute intervals to assure proper intensity. The exercise program was followed throughout the diet as well as during the post-treatment 1000 kcal/day week.

Blood Lipid Determinations

Enzymatic Determination of HDL and Total Cholesterol (Sigma Technical Bulletin No. 350-HDL)

HDL Cholesterol Separation

Serum low density and very low density lipoproteins were selectively precipitated by Mg++ phosphotungstate and removed by centrifugation. The HDL fraction was then measured using enzymatic procedures.

Cholesterol Measurement

Cholesterol esters are hydrolyzed to free cholesterol and fatty acids by cholesterol esterase. The free cholesterol is then oxidized by cholesterol oxidase to cholest-4-en3-one and hydrogen perioxide. The hydrogen perioxide reacts with 4-aminoantipyrine and phenol in the presence of perixidase to yield a quinoeimine dye which has a maximum Absorbance at 500 nm.

$$\text{Cholesterol Esters} \xrightarrow[\text{Esterase}]{\text{Cholesterol}} \text{Cholesterol} + \text{Fatty Acids}$$

$$\text{Cholesterol} + O_2 \xrightarrow[\text{Oxidase}]{\text{Cholesterol}} \text{Cholest-4-3n-3-one} + H_2O_2$$

$$2\ H_2O_2 + \text{4-Aminoantipyrine} = \text{Phenol} \xrightarrow{\text{Peroxidase}} \text{Quinoeimine Dye} + 4H_2O$$

The amount of color produced is directly proportional to the concentration of HDL or total Cholesterol in the sample.

Specimen Collection and Preparation

HDL Cholesterol

Blood samples were drawn weekly throughout the pre-treatment, treatment and post-treatment of periods after an overnight fast. The whole blood was centrifuged and the serum was drawn off and refrigerated prior to assay. Assays were completed within the week.

Stability: HDL is stable in serum for at least one week stored refrigerated. HDL may not be frozen since this may cause structural changes in the lipoprotein.

Instruments and Materials

Instrument: Hitachi spectrophotometer

Materials: Pipets, centrifuge tubes, centrifuge, water bath and cuvets.

Manual Procedures - HDL Cholesterol

1. To a centrifuge tube add:
   0.4 mL of serum
   0.05 mL HDL Precipitating Reagent, Stock No. 350-3

   Mix well.

2. Centrifuge (2000 x g) for 5-10 minutes to obtain clear supernatant.

3. Label cuvets: BLANK, STANDARD, TEST 1, etc.

4\. To BLANK add: 0.05 ml water — To STANDARD add: 0.05 mL Cholesterol Aqueous Standard, Stock No. 350-50, 200 and 400 — To TEST add: 0.05 mL Supernatant (HDL fraction) from Step 2

To BLANK add:	To STANDARD add:	To TEST add:
0.05 ml water	0.05 mL Cholesterol Aqueous Standard, Stock No. 350-50, 200 and 400	0.05 mL Supernatant (HDL fraction) from Step 2

5\. To each add: 1.0 mL Cholesterol Enzymatic Reagent

Cover cuvet with Parafilm and invert several times to mix.

6\. Incubate cuvets at 37 C for 10-15 minutes.

7\. Read Absorbance of STANDARD and TEST vs BLANK as reference at 500 nm (±15nm). Complete readings within 30 minutes.

<u>Total Cholesterol</u>

Serum was obtained weekly after an overnight fast and either refrigerated and used within a week or frozen for later analysis.

<u>Stability</u>: Total serum cholesterol is stable for at least 7 days stored at room temperature and presumably longer when refrigerated.

<u>Manual Procedures - Total Cholesterol</u>

To ensure uniform BLANK absorbance for each series of assays, a sufficient quantity of Cholesterol Enzymatic Reagent was calculated and pooled.

1\. Label cuvets: BLANK, STANDARDS, TEST 1, etc.

2\.

To BLANK add:	To STANDARD add:	To TEST add:
0.01 mL water	0.01 mL Cholesterol Aqueous Standards, Nos. 50, 200 and 400	0.01 mL serum

3. To each add: 1.0 mL Cholesterol Enzymatic Reagent

   Cover cuvets with Parafilm and invert several times to mix.

4. Incubate cuvets at 37 C for 10-15 minutes.

5. Read Absorbance of STANDARDS and TEST vs BLANK as reference at 500 nm (±15nm). Complete readings within 30 minutes.

Quantitative Ultraviolet Determination of Triglycerides in serum at 340 nm (Sigma Technical Bulletin No. 320-UV)

Triglycerides - Principle

The assay involves saponification of triglyceride and subsequent reaction of glycerol with a coupled enzyme system as follows:

1. Saponification of triglycerides

$$\text{Triglycerides} \xrightarrow[\text{KOH}]{\text{Alcoholic}} \text{Glycerol} + \text{Free Fatty Acids}$$

2. Phosphorylation of glycerol:

$$\text{Glycerol} + \text{ATP} \xrightarrow{\text{Glycerokinase}} \text{Glycerol-1-Phosphate} + \text{ADP}$$

3. Formation of pyruvate:

$$\text{ADP} + \text{Phosphoenolpyruvate} \xrightarrow[\text{Kinase}]{\text{Pyruvate}} \text{Pyruvate} + \text{ATP}$$

4. Reduction of pyruvate to lactate:

$$\text{Pyruvate} + \underset{(\text{High } A_{340})}{\text{NADH}} \xrightarrow[\text{Dehydrogenase}]{\text{Lactic}} \text{Lactate} + \underset{(\text{Low } A_{340})}{\text{NAD}}$$

The amount of NADH oxidized, represented by a decrease in Absorbance, is equivalent to the glycerol formed, which in turn, is proportional to the original triglyceride concentration.

Specimen Collection and Preparation

Serum was obtained weekly after an overnight fast and either refrigerated and used within a week or frozen for later analysis.

Stability: No appreciable changes have been found during one week of refrigeration and triglyceride levels are essentially unchanged when specimens are stored 8 weeks at -20 C.

Instruments and Materials

Instrument: Hitachi spectrophotometer

Materials: cuvets (semimicro cuvets requiring small volumes (1-2 mL) were used to conserve reagent), pipets, centrifuge, centrifuge tubes and water bath.

Manual Procedures - Triglycerides

Any free glycerol was assayed as triglyceride (1 mg glycerol/100 mL is equal to 10 mg triglyceride/100 mL). Serum free glycerol levels of about 1 mg/100 mL are encountered normally and for most clinical considerations this can be disregarded.

Saponification

1. To a centrifuge tube, add:
   0.2 mL serum
   0.5 mL Ethanol, 95%
   1 drop Potassium Hydroxide Solution, Stock No. 17-8.

   Mix by swirling.

2. Cover tubes with Parafilm and incubate mixture in 60-70 C water bath for 20 minutes.

   Cool to room temperature with tap water.

3. Add 1.0 mL Magnesium Sulfate Solution to precipitate free fatty acids.

   Mix well.

   Centrifuge to obtain clear supernatant.

Triglyceride Assay:

4. To a cuvet, add:
   0.250 mL supernatant from Step 3 above
   1.250 mL Triglyceride Assay Solution

   Cover cuvet with Parafilm and invert several times to mix.

   Wait approximately 1 minute for equilibration.

5. Read and record Absorbance at 340 nm vs water as reference. This is the INITIAL A.

6. Add 0.01 mL Glycerokinase Solution, Stock No. 320-20.

   Mix by inversion.

   Let stand approximately 5 minutes.

7. Read and record Absorbance at 340 nm vs water as reference. This is the FINAL A.

Calculations:

HDL Cholesterol

$$\text{Serum HDL Cholesterol (mg/dl)} = \frac{A_{Test}}{A_{Standard}} \times 50 \times 1.125$$

Where:

50 = Concentration (mg/dl) of Cholesterol Aqueous Standard, Stock No. 350-50 (Standard curves were used to determine validity of standard solutions).

1.125 = Factor to correct for the dilution of serum during the isolation of HDL fraction.

Total Cholesterol:

$$\text{Cholesterol (mg/dl} = \frac{A_{Test}}{A_{Standard}} \times \text{Concentration of Standard (Stock No. 350-200)}$$

Where:

200 = Concentration (mg/dl) of Cholesterol Aqueous Standard as determined through the use of standard curves

Triglycerides:

A = INITIAL A - FINAL A

Serum Triglycerides (mg/dl) = A x 740

Research Design and Statistical Procedures

The research design in this study was a two-factor design with repeated measures on one factor. The two independent variables were: 1) the dietary treatments of a low carbohydrate hypocaloric diet and a high carbohydrate hypocaloric diet and 2) time. The dependent variables were weight, total cholesterol, HDL cholesterol, total cholesterol/HDL cholesterol ratio and triglycerides. These parameters were measured weekly throughout the study.

Subjects were randomly assigned to one of the two treatment groups. There were seven subjects in each group, initially, but health problems forced two subjects in the high carbohydrate group to discontinue the treatment. Data from these two subjects were not included in the statistical analyses.

All data were analyzed by computer utilizing the Statistical Analysis System (SAS). A two-factor analysis of variance (ANOVA) was used with the General Linear Model (GLM) SAS procedure. The alpha level was set at .05. The Tukey procedure was used to determine statistically significant differences between group means.

Statistical Analyses revealed that weight decreased significantly from baseline in both groups throughout the treatment period and in the post-treatment. Values for total cholesterol for the LC group increased slightly during the first week of the diet and then decreased significantly throughout the rest of the experiment. The HC group, however, exhibited a small decrease in week one of the diet followed by significant decreases during the rest of the study. There was no difference between groups across time.

HDL cholesterol values increased slightly during the first week of the diet for both groups and then decreased significantly from baseline throughout the rest of the study. There was no difference between groups across time. The total cholesterol/HDL cholesterol ratio for the LC group decreased throughout the study, while the ratio for the HC group decreased slightly during the first two weeks of the diet, then increased slightly during week three and decreased once again in week four. The ratio was significantly decreased for both groups by the post-diet period, however, there was no group interaction across time. Serum triglycerides increased throughout the study for both groups. However, these decreases were not significant and there were no differences between groups across time.

Summary ANOVA - Weight

Source	SS	df	MS	F	P
Group	320.2154	1	320.2154	.65	.4377
Error 1 (SN (Group)* Time)	4900.5361	10	490.0536	---	---
Time	470.027	5	94.1805	222.33	.0001
Group*Time	5.3827	5	1.0765	2.54	.0399
Error 2 (SN (Group)* Time)	21.1799	50	0.4236	---	---

Summary ANOVA - Total Cholesterol

Source	SS	df	MS	F	P
Group	3571.4762	1	3571.4762	2.02	.1857
Error 1 SN (Group)* Time)	17685.8055	10	1768.5806	---	---
Time	13210.6815	5	2642.1362	11.91	.0001
Group*Time	1574.5914	5	314.9183	1.42	.2334
Error 2 (SN (Group)* Time)	11091.22619	50	221.8245	---	---

Summary ANOVA - HDL Cholesterol

Source	SS	df	MS	F	P
Group	142.6525	1	142.6525	0.49	.4978
Error 1 (SN (Group)* Time)	2882.0428	10	288.2042	---	---
Time	444.6086	5	88.9217	5.24	.0006
Group*Time	35.5570	5	7.1114	0.42	.8335
Error 2 (SN (Group)* Time)	849.2611	50	16.9852	---	---

Summary ANOVA - Ratio (TC/HDL)

Source	SS	df	MS	F	P
Group	0.2431	1	0.2431	0.20	.6659
Error 1 (SN (Group)* Time)	12.2833	10	1.2283	---	---
Time	4.1019	5	0.8204	6.89	.0001
Group*Time	1.0845	5	0.2169	1.82	.1256
Error 2 (SN (Group)* Time)	5.9536	50	0.1191	---	---

Summary ANOVA - Triglycerides

Source	SS	df	MS	F	P
Group	5548.7641	1	5548.7651	4.66	.0562
Error 1 (SN (Group)* Time)	11904.8477	10	1190.4845	---	---
Time	4212.8000	5	842.56	1.90	.1104
Group*Time	3214.2461	5	642.8492	1.45	.2223
Error 2 (SN (Group)* Time)	22135.3031	50	442.7061	---	---

Tukey Procedure for Body Weight

Differences Between Weekly Means	LC Group Q	HC Group Q
Pre-diet and week 1 diet	11.38*	6.18*
Pre-diet and week 2 diet	19.11*	11.34*
Pre-diet and week 3 diet	26.83*	16.83*
Pre-diet and week 4 diet	32.52*	23.02*
Pre-diet and post-diet	29.27*	22.33*
Week 1 diet and week 2 diet	7.72*	5.15*
Week 1 diet and week 3 diet	15.45*	10.65*
Week 1 diet and week 4 diet	21.14*	16.83*
Week 1 diet and post-diet	17.89*	16.15*
Week 2 diet and week 3 diet	7.72*	5.50*
Week 2 diet and week 4 diet	13.40*	11.68*
Week 2 diet and post-diet	10.16*	10.99*
Week 3 diet and week 4 diet	5.69*	6.18*
Week 3 diet and post-diet	2.44	5.50*
Week 4 diet and post-diet	3.25	.69

Qcv = 4.20
df = 50
*p<.05

Tukey Procedure for Total Cholesterol

Differences Between Weekly Means	Both Treatment Groups Q
Pre-diet and week 1 diet	0.09
Pre-diet and week 2 diet	6.26*
Pre-diet and week 3 diet	5.28*
Pre-diet and week 4 diet	6.30*
Pre-diet and post-diet	8.42*
Week 1 diet and week 2 diet	6.16*
Week 1 diet and week 3 diet	5.19*
Week 1 diet and week 4 diet	6.21*
Week 1 diet and post-diet	8.33*
Week 2 diet and week 3 diet	0.98
Week 2 diet and week 4 diet	0.05
Week 2 diet and post-diet	2.16
Week 3 diet and week 4 diet	1.02
Week 3 diet and post-diet	3.14
Week 4 diet and post-diet	2.12

Qcv = 4.20
df = 50
*p<.05

Tukey Procedure for HDL Cholesterol

Differences Between Weekly Means	Both Treatment Groups Q
Pre-diet and week 1 diet	0.84
Pre-diet and week 2 diet	1.93
Pre-diet and week 3 diet	4.71*
Pre-diet and week 4 diet	4.54*
Pre-diet and post-diet	1.01
Week 1 diet and week 2 diet	2.77
Week 1 diet and week 3 diet	5.55*
Week 1 diet and week 4 diet	5.38*
Week 1 diet and post-diet	1.85
Week 2 diet and week 3 diet	2.77
Week 2 diet and week 4 diet	2.61
Week 2 diet and post-diet	0.92
Week 3 diet and week 4 diet	0.17
Week 3 diet and post-diet	3.70
Week 4 diet and post-diet	3.53

Qcv = 4.20
df = 50
*p<.05

Tukey Procedure for
Total Cholesterol/HDL Cholesterol Ratio

	Both Treatment Groups
Differences Between Weekly Means	*Q*
Pre-diet and week 1 diet	1.51
Pre-diet and week 2 diet	4.72*
Pre-diet and week 3 diet	1.31
Pre-diet and week 4 diet	2.11
Pre-diet and post-diet	7.03*
Week 1 diet and week 2 diet	3.21
Week 1 diet and week 3 diet	0.20
Week 1 diet and week 4 diet	0.60
Week 1 diet and post-diet	5.52*
Week 2 diet and week 3 diet	3.41
Week 2 diet and week 4 diet	2.61
Week 2 diet and post-diet	2.31
Week 3 diet and week 4 diet	0.80
Week 3 diet and post-diet	5.72*
Week 4 diet and post-diet	4.92

Qcv = 4.20
df = 50
*$p<.05$

Tukey Procedure for Triglycerides

Differences Between Weekly Means	Both Treatment Groups Q
Pre-diet and week 1 diet	0.46
Pre-diet and week 2 diet	2.73
Pre-diet and week 3 diet	2.60
Pre-diet and week 4 diet	1.66
Pre-diet and post-diet	3.92
Week 1 diet and week 2 diet	2.27
Week 1 diet and week 3 diet	2.14
Week 1 diet and week 4 diet	1.20
Week 1 diet and post-diet	3.46
Week 2 diet and week 3 diet	0.13
Week 2 diet and week 4 diet	1.07
Week 2 diet and post-diet	1.19
Week 3 diet and week 4 diet	0.94
Week 3 diet and post-diet	1.33
Week 4 diet and post-diet	2.26

Qcv = 4.20
df = 50
*p<.05

Selection of Criterion Score

In determining the criterion score for triglycerides, assays were done in triplicate and skewed values were disregarded. Assays for total cholesterol and HDL cholesterol were also done in triplicate except when chemicals were limited. During these times, weeks one and two of the diet for total cholesterol and weeks one through four for HDL cholesterol, assays were done in duplicate.

Appendix B

DATA TABLES

Individual Subject Data - Low Carbohydrate Group

Subject 1--LB

Week of Treatment	Wt (kg)	Total Chol (mg/dl)	HDL (mg/dl)	Ratio	Trig (mg/dl)
1	86.4	132.0	38.4	3.4	56.6
2	83.1	101.0	30.3	3.0	81.4
3	80.8	82.4	29.2	2.8	93.0
4	78.3	88.2	28.4	3.1	115.4
5	77.4	102.9	32.5	3.2	135.1
6	78.2	122.5	44.0	2.8	171.2

Subject 2--NB

Week of Treatment	Wt (kg)	Total Chol (mg/dl)	HDL (mg/dl)	Ratio	Trig (mg/dl)
1	92.6	137.6	38.1	3.6	64.4
2	88.7	161.8	49.2	3.3	99.9
3	87.3	129.3	43.3	3.0	101.0
4	85.9	115.7	41.9	2.8	100.6
5	84.1	117.0	38.8	3.0	94.4
6	84.3	115.9	43.8	2.7	98.1

Subject 3--SE

Week of Treatment	Wt (kg)	Total Chol (mg/dl)	HDL (mg/dl)	Ratio	Trig (mg/dl)
1	75.0	160.7	38.2	4.2	163.5
2	72.8	176.7	42.3	4.2	93.2
3	70.5	161.7	41.5	3.9	101.4
4	69.5	125.8	36.0	3.5	89.5
5	67.8	133.0	35.9	3.7	95.8
6	68.4	138.1	36.2	4.3	154.7

Subject 4--PO

Week of Treatment	Wt (kg)	Total Chol (mg/dl)	HDL (mg/dl)	Ratio	Trig (mg/dl)
1	86.0	142.4	49.1	2.9	91.4
2	84.2	177.7	47.1	3.8	124.0
3	82.3	116.7	43.7	2.7	120.6
4	81.1	125.0	34.5	3.6	121.4
5	79.6	112.3	36.2	3.1	120.3
6	68.4	90.2	42.0	2.2	106.8

Subject 5--SS

Week of Treatment	Wt (kg)	Total Chol (mg/dl)	HDL (mg/dl)	Ratio	Trig (mg/dl)
1	90.9	176.2	53.5	3.3	89.8
2	87.2	167.0	48.2	3.5	89.9
3	85.0	123.8	42.9	2.9	112.5
4	82.1	109.5	49.3	2.2	96.4
5	79.9	118.6	47.3	2.5	82.1
6	82.4	111.1	49.1	2.3	187.6

Subject 6--GT

Week of Treatment	Wt (kg)	Total Chol (mg/dl)	HDL (mg/dl)	Ratio	Trig (mg/dl)
1	70.2	129.8	45.4	2.9	83.1
2	67.7	143.1	57.6	2.5	84.4
3	66.4	130.0	54.6	2.4	100.1
4	64.1	123.6	47.8	2.5	97.3
5	63.2	125.5	47.5	2.7	88.4
6	62.5	115.9	53.4	2.2	72.0

Subject 7--ST

Week of Treatment	Wt (kg)	Total Chol (mg/dl)	HDL (mg/dl)	Ratio	Trig (mg/dl)
1	68.0	158.9	52.9	3.2	111.0
2	65.5	132.0	43.5	3.0	93.6
3	63.8	113.0	38.9	2.9	113.2
4	62.0	131.9	39.3	3.4	124.7
5	61.0	128.0	37.6	3.4	120.6
6	61.2	111.1	46.7	2.3	122.5

Individual Subject Data - High Carbohydrate Group

Subject 8--DJ

Week of Treatment	Wt (kg)	Total Chol (mg/dl)	HDL (mg/dl)	Ratio	Trig (mg/dl)
1	67.0	184.1	58.4	3.2	63.9
2	65.1	180.3	63.0	2.9	84.7
3	62.5	142.9	55.3	2.6	92.5
4	61.3	139.0	52.0	2.7	107.3
5	59.2	135.2	53.0	2.6	74.0
6	59.1	123.5	50.9	2.4	72.9

Subject 9--CM

Week of Treatment	Wt (kg)	Total Chol (mg/dl)	HDL (mg/dl)	Ratio	Trig (mg/dl)
1	71.7	136.3	35.3	3.9	92.9
2	69.1	143.9	38.8	3.8	84.4
3	67.8	104.3	31.3	3.3	101.0
4	66.1	125.5	31.3	4.0	92.9
5	64.7	123.6	30.9	4.0	84.1
6	65.9	101.1	33.5	3.0	73.6

Subject 10--LS

Week of Treatment	Wt (kg)	Total Chol (mg/dl)	HDL (mg/dl)	Ratio	Trig (mg/dl)
1	83.7	187.3	52.1	3.6	82.9
2	82.1	154.7	51.4	3.0	109.0
3	81.0	152.2	45.1	3.4	127.3
4	79.9	189.2	40.1	4.7	135.4
5	77.5	172.3	40.6	4.2	128.0
6	77.7	122.2	41.4	3.0	99.5

Subject 11--DS

Week of Treatment	Wt (kg)	Total Chol (mg/dl)	HDL (mg/dl)	Ratio	Trig (mg/dl)
1	84.2	142.1	40.2	3.5	57.7
2	83.3	126.1	48.0	2.6	51.1
3	81.7	99.4	43.3	2.3	81.4
4	79.8	115.7	38.5	3.0	70.3
5	78.2	109.2	37.1	2.9	73.3
6	78.0	111.9	50.4	2.2	59.2

Subject 12--PW

Week of Treatment	Wt (kg)	Total Chol (mg/dl)	HDL (mg/dl)	Ratio	Trig (mg/dl)
1	73.5	158.1	53.3	3.0	91.0
2	71.4	177.0	46.6	3.4	86.2
3	70.4	166.7	57.1	2.9	102.9
4	68.6	183.5	51.0	3.6	85.8
5	66.8	142.5	49.4	2.9	72.9
6	66.8	147.1	49.0	3.0	115.4

Appendix C

INFORMED CONSENT

LABORATORY FOR EXERCISE AND WORK PHYSIOLOGY

Division of Health, Physical Education and Recreation
College of Education
Virginia Tech
Blacksburg, VA 24061

INFORMED CONSENT

I, ______________________, do hereby voluntarily agree and consent to participate in a testing program conducted by the personnel of the Human Performance Laboratory of the Division of Health, Physical Education and Recreation at Virginia Tech.

TITLE OF STUDY: The effect of exercise and alteration of carbohydrate content of a very low calorie diet (VLCD) on anthropometric, cardiovascular, and metabolic parameters in obese individuals.

PURPOSE: Identify the effectiveness of the combination of exercise and two VLCD's of different carbohydrate content in altering anthropometric, cardiovascular, and metabolic disturbances of obesity.

MY PARTICIPATION WILL INCLUDE:

1. Clearance by personal physician.

2. Eating a weight maintenance diet for two weeks.

3. Performing a maximal exercise test and endurance exercise test before and after a very low calorie diet (VLCD).

4. Consumption of a 530 kcal formula diet as the only source of nutrition for 28 days.

5. Daily addition of either fat or carbohydrate in a pre-weighed form to the formula diet.

6. Weekly blood sampling after an overnight fast before and after the diet.

7. Assessment of body composition before and after the diet using underwater weighing and skinfold measurements.

8. Daily urine collection during the VLCD.

9. Attendance at weekly group meetings to discuss progress on the treatment.

10. Participation in three supervised exercise sessions per week at the prescribed intensity for 30-45 minutes during the 28 days of the diet.

11. Weekly electrocardiogram measurement.

12. Eating a balanced diet of 1000 kcal for two weeks after the VLCD.

THIS STUDY MAY PRODUCE CERTAIN RISKS AND DISCOMFORTS TO INCLUDE:

1. Temporary fatigue and possible muscle soreness during and following the exercise bouts.

2. Temporary discomfort (needle prick) with blood sampling.

3. Possible metabolic disturbances such as ketosis and changes in fluid/electrolyte balance.

4. Possible light headedness after sudden changes in posture such as standing from a supine position.

5. Occasional headache, tiredness, irritability, dry skin and depression.

PERSONAL BENEFITS MAY BE EXPECTED INCLUDING:

You can expect to lose a substantial amount of body weight and fat during the treatment. Elevated blood pressure and blood lipids may also be normalized during the VLCD. The changes in addition to cardiovascular benefits from regular exercise will decrease risk of cardiovascular disease.

I understand that any data of a personal nature will be held confidential and will be used for research purposes only. I also understand that these data may only be used when not identifiable with me.

I understand that I may abstain from participation in any part of the experiment or withdraw from the experiment should I feel the activities might be injurious to my health. The experimenter may also terminate my participation should he feel the activities might be injurious to my health.

I understand that it is my personal responsibility to advise the researchers of any pre-existing medical problem that may affect my participation or of any medical problems that might arise in the course of this experiment and that no medical treatment or compensation is available if injury is suffered as a result of this research. During the laboratory experiments at Virginia Tech, a telephone is available which would be used to call the local hospital for emergency service.

I have read the above statements and have had the opportunity to ask questions. I understand that the researchers will, at any time, answer my inquiries concerning the procedures used in this experiment.

Scientific inquiry is indispensable to the advancement of knowledge. Your participation in this experiment provides the investigator the opportunity to conduct meaningful scientific observations designed to make significant educational contribution.

If you would like to receive the results of this investigation, please indicate this choice by marking in the appropriate space provided below. A copy will then be distributed to you as soon as the results are made available by the investigator. Thank you for making this important contribution.

______ I request a copy of the results of this study.

Date ____________________________ Time _________ a.m./p.m.

Participant Signature ______________________________________

Witness ____
HPL Personnel

Project Director Dr. Janet Walberg Telephone 961-7545

HPER Human Subjects Chairman Dr. Don Sebolt Telephone 961-5104

Dr. Charles Waring, Chairman, Institutional Review Board for Research Involving Human Subjects. Phone 961-5284.

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