THE EFFECT OF AN AEROBIC EXERCISE PROGRAM AND TWO HYPOCALORIC DIETS OF DIFFERENT CARBOHYDRATE CONTENT ON BLOOD PRESSURE AND SODIUM BALANCE IN OBESE FEMALES

by

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(ABSTRACT)

Twelve obese normotensive females were studied to determine the effects of either a 71% carbohydrate (HC) hypocaloric diet or a 33% carbohydrate (LC) hypocaloric diet concommitant with an aerobic exercise program on sodium (Na) balance and blood pressure changes. Subjects participated three times a week in a submaximal periodic exercise session and were placed on one of the diets for 28 days. Post-treatment, each participant consumed a 1000 kcal mixed diet while remaining in the exercise program. Daily Na losses were measured by 24 hr urine collection, and blood pressure measurements were made weekly. Both treatment groups significantly decreased in weight with LC losing more than HC (8.0 kg by LC group; 6.7 kg by HC group). Although urine Na balance was negative for the first 2 days of both VLCD's, Na excretion fell over time to result in net Na retention over the experimental period. Though the LC group lost more Na during the first week than HC during subsequent weeks, the differences between groups were nonsignificant. There were no significant differences between groups in serum Na

or urine Na balance. However, Na urinary loss significantly decreased across time. Both systolic and diastolic blood pressure decreased non-significantly an average of 4% from baseline values throughout the treatment (5.2/4.0 mmHg in the HC group and 4.3/2.3 mmHg in the LC group). Carbohydrate inclusion in both diets was found to be effective in retaining Na after 4 days on a VLCD. Changes on different postural positions did not reveal evidence of hypotension. Overweight normotensive individuals did not reduce blood pressure values below normal levels.

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Chapter I

INTRODUCTION

Excessive body fat, termed obesity, has become a health problem in the more affluent parts of the world and rapidly becoming so in the developing countries. Obesity in America affects over 50% of the adult population (Getchell, 1983). Studies show that in the United States, it is the most prevalent form of malnutrition and is progressively increasing.

Complications associated with obesity are far reaching. It is closely related to respiratory, kidney and gall bladder diseases. In fact, most of the excess morality associated with obesity has been due to cardiovascular disease. Other disorders are hypertension, diabetes, bone and joint complications, hyperlipidemia, hyperuricemia glucose intolerance, hypercholesterolemia, hypertriglycer-demia, osteoarthrosis, liver steatosis, cirrhosis (Mancini, Diabiase, Contaldo, Fischetti, Grasso, Mattioli, 1981), and, in some people, emotional imbalance. Obese individuals are prone to have more fatigue, indigestion, constipation and complaints of numerous aches and pains. Of equal concern is the psychological, emotional and social coping that each person constantly faces (Getchell, 1983). Dietary alteration has been a proven approach to obesity

intervention with widely varying degrees of long term success. By reducing the amount of calories consumed many of the serious effects of obesity are reduced or abolished. Very low calorie diets (VLCD) used in the last few years have proven to be effective. However, the correct combination of required nutrients is still not clear. Inclusion of quality proteins and carbohydrates (CHO) supplemented with adequate RDA of vitamins and minerals have proven to be safe and effective diets.

When reduced dietary intake brings the intake below daily energy requirement, initial decrease in body weight occurs primarily from water loss and corresponding depletion of the body's carbohydrate reserves. As the weight loss continues, a larger portion of body fat is metabolized to supply the caloric deficit created by reduced food consumption or increased exercise.

It has been postulated that carbohydrate overeating may be a nutritional factor linking the tendency for sodium retention with subsequent high occurrence of arterial hypertension in obese individuals (Kolanowski, 1981). This association has been found true regardless of salt intake restriction. Consequently, a significant caloric reduction will result in loss of fluid and electrolytes that often leads to a reduction in blood pressure (Reisen, 1978; Young,

1978). Individuals with the highest initial blood pressure tend to elicit the largest reduction during the diet. Normotensive patients, however, may experience postural hypotension during hypocaloric diets (Dehaven, 1980).

The carbohydrate content of the diet has been found to influence sodium balance in obese individuals and therefore may influence blood pressure changes. The increased loss of sodium during hypocaloric diets helps in reducing blood pressure in hypertensive patients (Dehaven, 1980).

Obese individuals with normotensive blood pressure experience less postural hypotension when carbohydrate content of the diet is high. This symptom has been found to be more common in patients consuming low carbohydrate as compared to 50% carbohydrate diets (Dehaven, 1980).

The changes in carbohydrate metabolism and/or intake may play an important role in fluctuation sodium balance in different nutritional conditions. Sodium retention, as well as fast-induced salt and water losses occurring upon carbohydrate refeeding after starvation, suggest a possible relation between carbohydrate metabolism and sodium balance (Bloom, 1962). Sodium loss through urine or natriuresis, of fasting peaks after two to four days of starvation and declines spontaneously thereafter even if starvation is continued (Kolanowski, 1977). However, the reasons for the

enhancement in renal sodium excretion at the onset of fasting and for the antinatriuretic effect of carbohydrate refeeding remains unclear.

Although most studies agree that more sodium and water will be lost on a low as compared to high carbohydrate low calorie diet, the long term effects of dietary carbohydrate restriction and the quantity of electrolytes loss are less clear. Investigators Young (1971) and Lewis (1977) found no difference in overall sodium and potassium balance when comparing moderate carbohydrate diets to low carbohydrate diet when tested over a period up to 9 weeks. However, DeHaven (1980) reported an increased sodium loss over days on low carbohydrate compared to 50% carbohydrate hypocaloric diets. Yet another study (Rabast, 1981), measured an increase in total cumulative sodium loss with high as compared to low carbohydrate diet over 28 days and concluded that excess initial sodium loss with carbohydrate restriction is reversible.

The addition of exercise to a weight control program has favorably modified the composition of weight loss. VLCD that excluded exercise resulted in more lean tissue loss and less fat reduced when compared to similar weight losses that included aerobic exercise. Combination of physical activity and diet offer considerably more flexibility in achieving a

negative balance and accompanying fat loss than either diet or exercise alone. The inclusion of aerobic activity to a weight management program may facilitate a more permanent weight loss than total reliance on caloric restriction.

Research Problem

The effect of two treatments diets of different carbohydrate content in combination with an aerobic exercise program on sodium balance and blood pressure changes of overweight women were examined in this investigation. The study tried to determine if a high or low carbohydrate very low calorie diet (VLCD) in combination with an exercise program differentially affected sodium loss and blood pressure changes during the weight loss program.

Research Hypothesis

The specific group hypothesis of interest is as follows:

There is no group (diet) difference or group interaction across time between treatment with a high carbohydrate hypocaloric diet combined with an aerobic exercise program and treatment with a low carbohydrate hypocaloric diet combined with an aerobic exercise program over a four-week period on sodium balance and blood pressure. When examining both groups together, there is no

change in the dependent variables (BP, Urine Na, Serum Na), over the experimental period.

Significance of the study

It is the goal of many obese individuals to reduce their weight. However, many cannot achieve this through the preferred method of moderately changing diet and activity which theoretically results in one to two pounds of weight loss per week. Since VLCD have been recognized as an effective way to reduce weight rapidly and more and more obese individuals are using them without medical supervision. It is imperative to understand their effects and safety on bodily functions. Because hypertension is directly correlated to obesity and this increases the risk of cardiovascular disease, the effect of the VLCD may reduce or alleviate the risk of the associated medical problems.

Knowledge of the relationship between carbohydrate content of a diet and sodium balance and how that in turn affects blood pressure may prove beneficial to obese individuals with hypertension. A reduction in blood pressure could ultimately lower the chances of cardiovascular disease. At the same time, CHO inclusion may eliminate the hypotensive symptoms brought on by carbohydrate free diets.

The addition of exercise to the hypocaloric diet may facilitate and enhance weight loss maintenance. Physical training has also been demonstrated to show modest reductions in both systolic and diastolic pressures. Since diet content may play an important aspect in compliance, carbohydrate altered diets need to be examined.

Delimitations

The following delimitations were placed upon the investigation:

1. The study was limited to twelve normotensive obese (>35% fat) female subjects between the ages of 18-35, without orthopedic problems, diabetes, heart disease, or gout.

2. The study was limited to the investigation of liquid formula diets with two levels of carbohydrate as the sole source of nutrition.

3. The study was limited to the observation and review of changes in cardiovascular and metabolic disturbances, specifically blood pressure and sodium balance.

4. The study was limited to exercise and diet compliance for 28 days.

5. The study was limited to walk/jog exercise sessions conducted three times per week at an intensity level of 60% maximum heartrate for 30 minutes duration.

Limitations

1. Subjects were volunteers; consequently results may be applicable to similar samples of a non-random nature.

2. Total compliance of the diet was difficult to enforce because of the individual reactions to diet tastes.

3. Accuracy of exercise intensity may not have been accurate due to the pulse rate method used.

4. Total daily sodium loss was difficult to measure because other potential sources of sodium loss (feces, sweat) were not measured.

5. Blood pressure measures were made using an indirect method.

6. Lack of control of certain variables which may have affected the subjects' performance, such as sleep, physical involvement and emotional stress, could influence results.

7. Total measured volume of urine excreted per 24 hours was contingent on subjects doing a complete collection and turning in all amounts to investigators.

Definition of Terms

Aerobic exercise program. An individualized walk/jog program at the intensity corresponding to 60% of their VO_2max performed three times per week.

Urinary Na balance. Calculations obtained by subtracting 24 hour, daily urine Na excretions from daily Na

intake (1555 mg/day Na for HC group; 1504 mg/day Na for LC group).

High-carbohydrate-hypocaloric diet. The liquid formula consisting of 530 kilocalories, 94 grams carbohydrate, 33 grams protein and 2 grams fat.

Low-carbohydrate-hypocaloric diet. The liquid formula consisting of 530 kilocalories, 44 grams carbohydrate, 33 grams protein, and 24 grams fat.

VLCD. Very-low-calorie diets. Diets containing carbohydrates as well as protein and fat calories with a caloric value of less than 800 kcal/day.

PSMF. Protein sparing modified fast. A diet consisting of quality protein plus vitamin/mineral supplements with a caloric value of 300-500 kcal/day and virtually no carbohydrate calories.

Hypocaloric diet. Very low calorie diet containing less than 800 kcal.

Obesity. Excessive quantities of total body fat (>20% men and >30% women) relative to height.

Systolic blood pressure. At rest the highest pressure generated in the large arteries by the heart during the contraction of the left ventricle (normal = 120 mmHg).

Diastolic blood pressure. The pressure in the large arteries during the relaxation phase between contraction of the left ventricle (normal = 70-80 mmHg).

Peripheral resistance. The resistance to the flow of blood from the arterioles into the capillaries.

Hypertension. The level of blood pressure which exceeds 150/90 mmHg in the sitting position after five minutes or more of quiet rest (Iaina et al. 1981).

Essential hypertension. Hypertension usually of unknown origin.

Postural hypotension. Dramatic decrease in blood pressure when assuming an upright from supine position. Typical symptoms are dizziness and fainting.

Kcal. Kilocalorie or kilogram calorie, which is a measure used to express heat or energy value of food and physical activity. It is defined as the amount of heat necessary to raise the temperature of 1 kg (1 liter) of water 1°C.

Basic Assumptions

The following assumptions were made:

1. It was assumed that the subjects in the treatment groups were randomly assigned to prevent biased results, despite the non-random sampling group.

2. It was assumed that all participants consumed all the allocated diet each day for the full 28 days as their only caloric intake.

3. It was assumed that all subjects exercised at the proper intensity during the required exercise sessions.

4. It was assumed that the investigator accurately recorded blood pressure readings.

5. It was assumed that the atomic absorption unit used to analyze sodium loss in serum and urine gave accurate determinations on sodium concentration.

6. It was assumed that all subjects' urine samples were in fact thier own collections and represented urine excreted within 24 hours.

Summary

The medical complications arising from obesity are severe and many. The association of hypertension and excess weight in the incidence of cardiovascular disease is crippling over 20 million Americans each year. With treatment, many of these complications are reversed and in many cases abolished. Successful combination for weight reduction have been very low calorie diets with exercise and behavior modification techniques. Continuation of physical activity after low caloric restriction has been one of the major reason attributed to maintenance of weight loss. Success and safety of the overall weight loss treatment related to quality and quantity of the nutrients consumed. Of specific importance may be the carbohydrate content.

Therefore it was the purpose of this study to identify the effectiveness of varying carbohydrate content of VLCD combined with sustained submaximal aerobic physical activity on blood pressure alterations and sodium balance. Literature revealed success of hypertension reduction with caloric decreases. Electrolyte balance has also been shown to stabilize depending on the carbohydrate content of the diet.

With more and more people needing and searching for a solution to their overweight problem, more research was needed to identify effectiveness and safety of VLCD.

Chapter II

LITERATURE REVIEW

There has been considerable controversy in the past 20 years about the effect diet composition has on the quality and quantity of weight loss. Metabolic abnormalities such as electrolyte balance and blood pressure changes are associated with weight loss. This relationship was examined during a very low-calorie diet and exercise program. Thus the following literature review will summarize the present knowledge on sodium (Na) loss, hypertension, blood pressure and physical exercise. Hence, the review was subdivided into the following areas:

1. obesity and hypertension,
2. nutrients in diet affecting blood pressure
3. effect of various diets on sodium loss,
    a. fasting
    b. refeeding
    c. high and low carbohydrate diets
4. effect of sodium loss on blood pressure,
5. effect of exercise on blood pressure.

Obesity and Hypertension

There is ample evidence that obesity is a significant risk factor for hypertension (Eliahou, Iaina, Goan,

Sochat and Modan 1981; Dustan, 1983; Havlik, Hubert, Fabsitz and Feinlaib, 1983), and that a significant amount of hypertensive individuals are overweight (Eliahou et al., 1981). In the hypertensive screening of a million Americans by Stambler et al., (1978), the frequency of hypertension in overweight persons aged 20-39 years was found to be double that of normal weight individuals and triple that of underweight persons. Of those aged 40-64 years, the overweight had a 50 percent greater prevalence rate of hypertension than those of normal weight and 100 percent greater than those underweight (Sims, 1981; Havlik et al., 1983). If caloric restriction could be performed over an extended period of time, blood pressure in these individuals in the white population in the United States could be reduced by 50 percent merely by controlling obesity (Reisin, 1978).

The cause for the elevated arterial pressure in 95 percent or more of the 60 million hypertensive Americans cannot be determined (Frohlich, 1983). Many of these patients have a family history of hypertension. Consequently, it is likely that metabolic or enzymatic heritable defects produce an imbalance of the mechanisms that normally control pressure. These defects also disrupt the relation of pressor and depressor mechanisms (Frohlich,

1983). Therefore, essential hypertension is not a homogenous disease, but "a disorder of dysregulation," with different pathophysiology and treatment (Frohlich, 1983).

The physiological changes occurring with obesity are many. With tissue mass increase, blood volume, cardiac output, cardiac oxygen consumption and arteriovenous oxygen differences also increase (Kaplan, 1983; Dustan, 1983; Frohlich, 1983). Alexander (1963) suggested that elevated blood volume in obesity may play a role in hypertension. Metabolic and endocrine changers, which include hyperinsulinemia, insulin resistance, decreased carbohydrate tolerance, increased serum triglycerides and cholesterol are occurring (Dustan, 1983). Also, increased cortisol secretion rate and metabolic clearance without increased urinary free cortisol or plasma cortisol, and possibly elevated sympathetic nervous activity, have been observed (Dustan, 1983).

In the early development of hypertension, several hemodynamic alterations may exist. An increase in arteriolar and venular smooth muscle tone increases vascular resistance, myocardial contractility (ventricular hyperfunction) and heartrate while decreasing vascular capacitance. Thus, along with venoconstriction (with normal or even reduced intravascular volume), the total effect is

an "overfilled" circulation which produces increased mean circulatory filling pressure and increased cardiac output (Dustan, 1983; Frohlich, 1983).

Decrease in body weight has resulted in a significant decrease in blood pressure (Reisin et al., 1978; Eliahou et al., 1981, Iaina, 1981). Ramsy et al. (1978) found an average loss of 5.1 kg to be associated with an average decrease in blood pressure of 11.9/6.9 mmHg. Their regression equations predicted a reduction of 2.5/1.5 mmHg for every kilogram of weight loss (Eliahou, 1981). Long term follow-up by other investigators has shown blood pressure reduction being maintained as long as body weight was maintained (Eliahou, 1981). In most of the essential hypertensive overweight subjects studied by Eliahou (1981), normal blood pressure was achieved in two-thirds of the patients when only half of their excess weight was lost, even if they were still severely overweight. The rate of reduction in blood pressure during weight loss was not correlated to initial overweight but with the initial blood pressure. Investigator Iaina et al. (1981) also found that the reduction was not transient but maintained. However, individual response of blood pressure to weight reduction varied considerably even when given the same initial blood pressure status.

Experiments conducted with spontaneous hypertensive rats (SHR) which display some characteristics of human essential hypertension (ES), show a striking and highly significant reduction in blood pressure with caloric reduction (Young, Mullen and Landberg, 1978).

Nutrients in Diet Affecting Blood Pressure

People vary in their susceptibility to the development of hypertension from increased sodium intake. Dahl (1958) suggested that additional intake of sodium in the obese above the recommended consumption associated with their increased intake of food, may explain hypertension. This assumes gross overeating by the overweight individual, which may not necessarily be the case. He found hypertension was corrected, without restriction of caloric intake, when the consumption of sodium by hypertensive overweight patients was severely restricted over a prolonged period (Sims, 1983). On the other hand Resin et al. (1978), found that hypertensive patients returned to normal blood pressure readings even thought salt was provided generously. It has been shown that a marked reduction in sodium intake has a minimal or no effect on persons with normal blood pressure, yet for individuals with salt-sensitive hypertension, blood pressure immediately normalizes. Likewise, salt loading does not produce hypertension in normotensive persons

(Dustan, 1983), but increases pressure in patients with salt-sensitive hypertension. Long term follow up has shown blood pressure reduction was maintained as long as weight reduction was maintained (Dustan, 1983).

Recent evidence suggests that elevations in blood pressure, initially attributed to high salt intake, may be due to other factors in the diet, such as the type and level of fat consumed. Studies in humans and animal models suggest that blood pressure can be lowered during high salt feeding by supplementing the diet with polyunsaturated fatty acids such as linoleic acids (Smith-Barbaro, 1983).

Several case control, clinical and epidemiologic studies have examined the effects of dietary fats on blood pressure. Polyunsaturated fats have been shown to have a hypotensive role (Smith-Barbara and Puca, 1983). Data from Iacono and colleagues (1975) reported blood pressure of normal men and women could be lowered by increasing the ratio of polyunsaturated to saturated fat in a high fat diet from 0.2 to 1.0. Similar results were seen by Fleishman and co-workers (1979) in a study with mild hypertensive patients (mean age, 63.2 years). Within one month of substituting a high linoleate diet for saturated fats, significant reductions in systolic and diastolic blood pressure were seen. When safflower oil was used to supplement existing

antihypertensive therapy, Rao and associates (1981) found a significantly greater drop in both systolic and diastolic pressure, than if by drug treatment alone.

Animal studies done on Sprague Dawley rats examining the effects of differing quantity as well as quality of fats suggest that when the level of salts in a diet is low, the blood pressure-regulating effect of diet depends on the type as well as the level of fat in the diet (Quinn, Fisher, Hegsted, 1981).

The results from several studies suggest that high levels of dietary salt may elevate arterial pressure when intake is with a low fat diet (Smith-Barbaro and Pucak, 1983). High fat feeding, however, may minimize the effects of salt on blood pressure (Hodges, ReBello, 1983).

Another nutrient in the diet that may contribute to hypertension is carbohydrates. Evidence indicates that sucrose feeding elevates blood pressure in the salt-sensitive rats. It has not been established whether the potentiating effects of sucrose are due to the sugar itself or to increased salt ingestion and retension in animals (Smith-Barbaro and Pucak, 1983). As of yet, evidence for an acute effect of simple carbohydrates on blood pressure in humans is inconclusive.

Effects of Various Diets on Sodium Loss

Fasting. Benedict (1915) reported an enhanced excretion of sodium (Na) in urine during a long-term period of fast (Hamwi, 1967). The marked negativity of the Na balances during the early phases of starvation are associated with a considerable loss of water (Spencer, 1966). The negative balance and natriuresis reaches a peak after 2 to 4 days (Kolanowski, 1983). Mobilization of extracellular fluid was cited as the most likely explanation for this natriuresis. Another explanation at least in part for the excessive Na excretion may be due to an enhanced excretion of organic acids (Kolanowski, 1983). As the fast continues, marked reduction in urinary excretion of Na is seen by a decreasing negative balance possibly due to hypovolemia and the second rise in aldosterone secretion (Kolanowski, 1983). Hamwi and associates (1967) obtained a positive Na balance in their subjects when Na was administered during the fast.

Interpretations made by Gamble et al. (1923) credit the natriuresis of fasting essentially to an increase in ketone body excretion. Because ammonium excretion increases significantly after only three to four days of fasting, the Na excreted in excess during this initial phase occurs as cation matching anionic ketoacids so as to maintain urinary

electroneutrality (Bloom, 1962; Kolanowski, 1983). Changes in ketone body excretion, however, cannot be a sole factor influencing Na excretion during fasting. After fasting for 3 days, 35 obese subjects exhibited mean increases in Na and 3-hydroxybutyrate excretion in keeping with an essential role of ketonuria in the natruresis of fast. When several subjects were individually analyzed, sodium excretation was found excessive on the third day, yet significant ketonuria was absent. Investigator Kolanowski (1983) proposed that most but not all of sodium lost during the early stages of a fast resulted from rapidly increasing organic acid excretion.

It has been postulated that insulin plays a role in renal sodium handling in fasting subjects since this hormone may stimulate the active Na transport by amphibian epithelia and Na reabsorption by mamalian kidney (Kolanowski, 1983). This direct influence of insulin on renal sodium handling in various nutritional situation is difficult to assess, because of the associated changes in glucose metabolism or availability, which may possibly influence renal tubular function (Bloom, 1962; Kolanowski, 1983). However, changes in insulin secretion occurring under fasting conditions are almost always correlated with opposite changes in glucagon secretion (Kolanowski, 1983). It has been reported that

glucagon may exert a natriuretic effect in fasting subjects and can prevent the carbohydrate-induced sodium retention when administered in large amounts (Kolanowski, 1983). Consequently, the respective roles of these two pancreatic hormones on renal sodium excretion is difficult to dissociate. It appears that the hormonal mechanism of fasting natriuresis results from changes in insulin rather than glucagon secretion that triggers natriuresis and ketogenic responses to starvation (Kolanowski, 1983).

The ingestion of exogenous sodium chloride on salt excretion in fasting has an obvious effect on sodium excretion. There was an increase in sodium excretion during the period of salt ingestion in excess of that seen in Bloom's (1962) fasting patients.

Refeeding. Despite duration of a fast, various researchers (Bloom, 1962; Smith and Drenick, 1966) have shown that there was prompt and in some instances, almost complete termination of Na excretion in the urine when food was ingested regardless of Na in the diet. Weight loss of fasting subjects promptly stops with the administration of hypocaloric diet with or without Na. Patients receiving salt may gain weight for several days despite low calorie intake (Smith and Drenick, 1966; Bloom, 1962). If the caloric restriction period is continued, weight loss

continues after a temporary readjustment period (Bloom, 1962).

Glucose ingestion via diet or intravenously (Kolanowski, 1983) in isocaloric amounts produces in some instances almost complete cessation of Na excretion in urine in the succeeding 24 hours (Bloom, 1962). Weight loss decreases or completely terminates in association with this Na retention following carbohydrate ingestion despite the patient remaining in negative caloric balance (Bloom, 1962).

When subjects are reintroduced to fat, protein and NaCl after fasting, all patients increase Na excretion and continue to lose weight. However, Kolanowski (1983) reported a comparable antiatriuretic for carbohydrate refeeding when protein was administered as the sole nutrient after a few days of fasting. The retention of Na is somewhat delayed and concomitant with a progressive increase in blood glucose level (Koanowski, 1983). Therefore, it has been proposed that the antiatriuretic effects of proteins observed following a few days of fast may be due to a rapid conversion of protein into glucose, as a consequence of the fast-enhanced gluconeogenesis (Kolanowski, 1983). In comparison, the ingestion of fat does not enhance or modify fasting natriuresis (Kolanowski, 1983). However, a fat-protein diet has been shown to cause body conservation of Na (Hamwi et al., 1967).

High and Low Carbohydrate Diets. The addition of carbohydrate to VLCD is a matter which is debated by many investigators (Blackburn and Bistrain, and Apfelbaun, Howard, 1981). More importantly, inclusion of carbohydrates has a retaining effect on electrolyte balance (Howard, 1981), which is noted to be the greatest potential danger of electrolyte balance. Inclusion of 31g protein and 45g carbohydrate, 67 mEq//day Na and 50 mEq/day potassium has been shown to prevent the diuresis seen in complete starvation and the re-feeding oedema occurring after termination of VLCD consisting only of protein (Howard, 1981). The kidney eventually adapts to VLCD consisting only of protein by controlling Na loss via the urine. Introduction of carbohydrate to the diet after PSMF is finished, causes intense water and sodium retension due to the kideny not being able to re-adapt quickly enough (Howard, 1981). Other advantages investigators have found to carbohydrate inclusion in the diet; are the reduced prevention of hyperuricemia, loss of muscular work performance and a reduction in diuresis.

Rabast and associates (1979) found that obese patients given low carbohydrate formula diet (1000 kcal) lost 14.0 ± 1.4 kg and those given an isoenergetic high carbohydrate diet 9.8 ± .9 kg. The urine level of Na per 24 hours did

not differ significantly. Yet, comparative studies by the same investigators using high and low carbohydrate formula diets had a greater mean weight loss (351g/day) on the low carbohydrate diet than that of the high carbohydrate diet group (292g/day).

Subjects placed on a high carbohydrate low fat diet by investigators Lewis et al., (1977) showed comparable weight loss as when placed on a high-fat low-carbohydrate diet and appreciable decreases in serum triglycerides without deleterious effect on glucose tolerance. However, the low-carbohydrate diet showed greater hyperketonemia and hyperuricemia with more striking alterations in the insulin-glucagon ratio.

In three different diet groups varying in carbohydrate content, Young et al., (1971) noticed average daily Na urinary excretions ranged about the same in all three diet groups. In the first three weeks the average sodium excretion fell to create a slightly more positive balance. However, in a few cases, the seventh through ninth week showed Na excretion slightly higher, causing a lower Na balance. Subjects in this study who were exercising vigorously consistently had lower urinary Na excretions and higher balances than non-exercisers. This was undoubtedly due to more Na lost in sweat. The least Na retention was

found in the first week of reduction with the greatest urinary sodium excretion for all subjects in the group with the lowest carbohydrate intake. When urine Na was cumulatively collected throughout the entire 28 days of treatment period, Kasper and Schonborn (1980) demonstrated electrolyte balance did not differ significantly for subjects in low or high carbohydrate diets. Even though urinary Na excretion did increase significantly within the first seven days during the low carbohydrate regimen, total urinary Na excretion did not result in a significant difference between the two diets after two weeks. Thus, the initial increase in Na excretion during the low-carbohydrate appears to be a reversible phenomenon (Rabast et al., 1980).

In another study where the nutrient being considered was carbohydrate, the effects of Na balance were examined when subjects were treated with a low calorie protein diet or mixed diet of which 50% was carbohydrates. Researchers, Dehaven et al. (1980) demonstrated that net Na loss was significantly greater with the protein diet than with the mixed-diet. The increased losses of Na and fluids were accounted as the reason for the greater weight loss observed with the protein diet than with the mixed-diet.

The Effect of Carbohydrate Content
On Blood Pressure Via Sodium Loss

In the same study by Dehaven et al. (1980) subjects on carbohydrate free diet experienced larger postural declines in systolic blood pressure that were accompanied by an increase in adverse symptoms than subjects on a mixed diet. The increased sodium loss is associated with the development of orthostatic hypotension by these patients.

Rabast and Vornberger found blood pressures (systolic and diastolic) reverted towards normal in all of three three different diet groups of varying carbohydrate content. The changes measured during consumption of diet two which consisted of low-carbohydrate (40g vs 225g in the high-carbohydrate content) were statistically significant when compared before the treatment.

Atkinson and Kaiser (1981) found that obese patients placed on VLCD composed of .5g of sucrose per kg of ideal body weight per day, had impressive blood pressure responses. The mean systolic and diastolic blood pressure for the whole group at the same time of history and physical examination was 133/86 mmHg. For all of these patients, MBP was 111 mmHg systolic and diastolic blood pressure fel from 145/95 to 125/81 with the initial mean blood pressure of 111 mmHg to 102 mmHg. After 12 weeks on behavior modification

and nutrition education, subjects were not on any specific diet but encouraged to limit intake to the number of calories estimated to maintain self selected target weight. The MBP of 92 mmHg was reached in the second phase after 10 weeks of VLCD. The MBP decrease during VLCD was highly correlated with weight loss. The MBP reduction, however, did not correlate with exercise compliance determined via questionnaire.

Mancini et al. (1981) reported obese hypertensive patients treated initially by 80 kcal (20g protein, 0 fat, CHO traces) or 180 kcal (40g protein, 2g fat, CHO traces) VLCD diet reduce systolic and diastolic blood pressure (171 ± 3 to 146 ± 4 SBP and 104 ± 3 to 86 ± 2 DBP) after four weeks of treatment. In the obese non-hypertensive patients only systolic blood pressure slightly declined. They did not observe clinical signs of orthostatic hypotension. The same group of patients were examined 12-15 (group 1); 16-47 (group 2); > 48 (group 3) months post hospitalization. Patients began consuming a formula diet (Cambridge) of 330 kcal and gradually were administered higher calorie content diets. Long term results showed blood pressure decreased according to weight loss, with groups 1 and 2 benefiting the most. Patients observed in group 3 regained weight and showed an increase in all investigated clinical parameters.

The Effects of Exercise on Blood Pressure

Physical training involving supervised programs of isotonic or dynamic exercise in small groups of hypertensive patients has been demonstrated to achieve modest reductions in both systolic and diastolic pressures (Boyer, Kasch, 1970).

An effective treatment for hypertension may be the role of exercise concomitant with a hypocaloric diet. Bosello et al. (1981) studied the effects of regular physical exercise in conjunction with a VLCD. They reported systolic and diastolic blood pressure significantly decreased both in group 1 (VLCD + no exercise) (systolic 137 ± 20 vs 115 ± 13 mmHg; Diastolic: 87 ± 9 vs 72 ± 13 mmHg) and group 2 (VLCD + regular physical activity) (systolic 130 ± 19 vs 119 ± 18mmHg; diastolic 83 ± 10 vs 69 ± 15 mmHg).

In other investigations (Seal and Hagberg, 1984), reduction in blood pressure after training showed an overall mean decrease of 9 mmHg or 6% systolic and 7 mmHg or 7% diastolic. However, the review by Seal and Hagberg suggest caution with interpretation of the results because study design was inadequate and methodology techniques were questionable. Most studies, however, do not find a significant reduction in blood pressure at rest in normotensive subjects following an exercise training program (Ekblom, Astrand, Saltin, Steinberg, and Wallstrom, 1968).

Both a chronic (Bjorntorp, 1982) and acute (Hagberg, 1984) response to exercise have been cited as possible mechanisms by which a reduction in blood pressure could occur as a result of exercise. First, because of its vasodilating effect, regular exercise could produce a chronic state of vasodilation and consequently reduce vascular resistance and blood pressure at rest. Secondly, the reduction of heart rate at rest commonly reported following exercise training (Ekblom et al., 1968) has been proposed as a means of lowering the blood pressure of hypertensive individuals with hyperkinetic circulation at rest. Both or either of these mechanisms could involve the reduction in sympathetic tone common in normotensive individuals who train (Winder, Hickson, Hagberg, Ehsani, McLane, 1979).

It has been postulated that borderline hypertensive individuals exhibiting hyperkinetic circulation benefit more from exercise training than persons with established hypertension (Bjorntorp, 1982). However, because the comparisons are based strictly on initial blood pressure levels at rest without additional hemodynamic data, inappropriate extrapolations of these comparisons cannot be generalized to all hypertensive populations. It may be that substantial changes in VO_2max obtained through an exercise

training program may be necessary to evoke marked reductions in blood pressure in hypertensive individuals (Seal and Hagberg, 1984). At the same time it is noted that some cardiovascular adaptations at rest or during submaximal exercise after training occurred without resulting increases in VO_2max.

Summary

The association of obesity and hypertension has been known for 60 years. These hypertensive individuals are frequently more overweight than normotensive individuals. Body mass rather than body-fat has been found to correlate statistically with obesity and blood pressure. For many hypertensives, weight loss has resulted in a reduction of blood pressure.

Several studies suggest that various nutrients in the diet may explain the increased elevation of pressure. Salt has been found to effect salt-sensitive hypertensives. Other nutrients such as the level and type of fat and simple carbohydrate may cause blood pressure elevation.

Weight loss achieved by fasting and a combination of various diets results in excess Na excretion (negative balance) during the first week of a fast and a VLCD. Termination of the fast will prompt almost complete cessation of natriuresis, especially if glucose is consumed.

Inclusion of carbohydrates in VLCD has been shown to prevent excessive Na loss at the onset of a diet and to stabilize electrolytic balance. The combination of weight loss and increase in Na output has exhibited a decline in blood pressure readings. Many times, however, the diet may cause too much of a decrease resulting in the development of orthostatic hypotension in the patient. However, inclusion of carbohydrates in the diet has eliminated this condition.

Aerobic exercise may also result in decreased blood pressure. The data shows that the combination of diet and exercise results in more significant weight loss and blood pressure balance.

Chapter III

JOURNAL MANUSCRIPT

The Effect of an Aerobic Exercise Program and Two Hypocaloric Diets of Different Carbohydrate Content on Blood Pressure and Sodium Balance in Obese Females

Karina Ruiz

ABSTRACT

Twelve obese normotensive females were studied to determine the effects of either a 71% carbohydrate (HC) hypocaloric diet or a 33% carbohydrate (LC) hypocaloric diet concommitant with an aerobic exercise program on sodium (Na) balance and blood pressure changes. Subjects participated three times a week in a submaximal periodic exercise session and were placed on one of the diets for 28 days. Post-treatment, each participant consumed a 1000 kcal mixed diet while remaining in the exercise program. Daily Na losses were measured by 24 hr urine collection, and blood pressure measurements were made weekly. Both treatment groups significantly decreased in weight with LC losing more than HC (8.0 kg by LC group; 6.7 kg by HC group). Although urine Na balance was negative for the first 2 days of both VLCD's, Na excretion fell over time to result in net Na retention over the experimental period. Though the LC group lost more Na during the first week than HC during subsequent weeks, the differences between groups were nonsignificant. There were no significant differences between groups in serum Na or

or urine Na balance. However, Na urinary loss significantly decreased across time. Both systolic and diastolic blood pressure decreased non-significantly an average of 4% from baseline values throughout the treatment (5.2/4.0 mmHg in the HC group and 4.3/2.3 mmHg in the LC group). Carbohydrate inclusion in both diets was found to be effective in retaining Na after 4 days on a VLCD. Changes on different postural positions did not reveal evidence of hypotension. Overweight normotensive individuals did not reduce blood pressure values below normal levels.

Introduction

Hypertension is frequently found in obese individuals (Mancini et al., 1981). This association has been shown to increase the risk of cardiac disease. Yet with effective weight loss, elevated blood pressure often normalizes. The nutrient content of a diet can also have a negative effect on blood pressure. Carbohydrate free protein diets have been shown to cause postural hypotension because of the drop in blood pressure. Fasting subjects have also shown this phenomena as a result of excessive water and sodium loss. Investigators have reported some success in reducing blood presure has been through weight reduction programs using a very-low-calorie diet (VLCD) of less than 800 kcal with the inclusion of carbohydrates. The changes in carbohydrate metabolism and/or intake may play a crucial role in fluctuation of sodium (Na) balance in different nutritional conditions. Sodium retention occurring upon carbohydrate refeeding after starvation suggests a possible relation between carbohydrate metabolism and sodium balance (Bloom, 1962). Sodium loss through urine, or natriuresis, while fasting or on a VLCD, peaks after two to four days on this reduced caloric intake and declines spontaneously thereafter, even if starvation is continued (Kolanowski, 1977). The addition of carbohydrates to a fasting condition

immediately induces sodium and water retention (Bloom, 1962). The reason for enhancement in renal sodium excretion at the onset of fasting and for the antinatriuretic effect of carbohydrate refeeding remains unclear. Thus carbohydrate content of a hypocaloric diet may effect sodium balance in obese individuals and consequently may influence blood pressure. Aerobic exercise conditioning enhances weight loss by minimizing more lean tissue loss and maximizing total fat loss (McArdle, Katch and Katch, 1981). Physical training among hypertensive patients has also been demonstrated to achieve modest reduction in both systolic and diastolic pressures (Boyer, 1970).

Success and safety in the treatment of obesity is related to the quality and quantity of nutrients consumed. Carbohydrate content may be of specific importance regarding sodium balance and therefore blood pressure. It is the purpose of this study to identify the effectiveness of varying carbohydrate content of a VLCD combined with physical activity on blood pressure and sodium balance.

Methods

The study involved twelve obese young normotensive women volunteers (age 23-36, mean wt ± SD = 79.1 ± 9.2 kg) without other known health problems. Each subject was prescribed an individualized weight maintenance mixed diet

(20% protein, 45% carbohydrate, 35% fat) for one week to establish baseline values. A treadmill graded exercise test using a modified Balke protocol was performed with each subject to calculate individual $\dot{V}O_2max$. Subjects were randomly assigned to one of two treatment groups: a high carbohydrate (HC) hypocaloric diet group (n = 5) and a low carbohydrate (LC) hypocaloric diet group (n = 7) for a 28-day daily treatment period. The HC group consumed a daily liquid diet consisting of 530 kcal, 33 g protein, 3 g fat, 94 g carbohydrate and 1555 mg/day Na. The LC group consumed a daily liquid formula diet of 530 kcal, 33 g protein, 25 g fat, 44 g carbohydrate and 1504 mg/day Na. All subjects were told not to consume more than two diet saccharin sweetened drinks per day as well as no boullion or other substances high in Na content. During the treatment period both groups participated in the same exercise program consisting of brisk walking and jogging at an intensity corresponding to their 60% $\dot{V}O_2max$. Subjects worked out three times per week for 30-45 minutes under the supervision of the experimenters. The exercise sessions continued one week post dietary treatment period. Subjects were instructed to follow a 1000 kcal diet (20% protein, 45% carbohydrate, 35% fat) for one week following the treatment period.

Blood pressure (BP) readings were determined weekly by a mercury sphygomomanometer. Measurements were made in a thermol neutral environment (21-25°C) at the same time each week in the morning (8-10 a.m.) after a 12-hour fast. Participants were asked to rest quietly in a supine position for 30 minutes before a measurement was taken. They were then asked to sit, after which an immediate reading was taken. Consecutive blood pressure readings followed 2, 4, 6 and 8 minutes of quiet sitting. All blood pressures were performed on the left arm each week and measured by the same experimenter. Patients were specifically questioned regarding lightheadedness, dizziness or weakness caused after quickly rising from a bed or a chair.

Blood samples were drawn weekly after an overnight fast for determination of sodium (Na). Serum was isolated from whole blood and frozen to be analyzed at the end of the study. Serum values for Na were determined by means of an atomic absorption spectrometer (Perkin Elmer Model, Varian AA-175 series). Each sample was analyzed three times.

Twenty-four hour urine samples were delivered before 8 a.m. daily and measured for volume and sodium concentration. Small daily aliquotes of each sample were frozen daily and stored to be analyzed at the end of the study. Na balance was calculated cumulatively by subtracting the daily NA

excretion from the daily Na intake over the total 28-day treatment period. Urine Na values were determined by means of an atomic absorption spectrometer (Perkin Elmer Model, Varian AA-175 series).

The results were analyzed by two-factor analysis of variance (ANOVA) with repeated measures on one factor using the General Linear Model procedure. The alpha level was set at .05 and the Tukey procedure was used to determine statistically significant differences between means. Insignificant variation was first detected by ANOVA. Correlation analysis were performed on changes in group means during the experimental period to determine relationships between variables.

Results

Weight Loss. Table 1 gives the group means for weight loss during the experimental period. The mean weight loss for the HC group was 6.7 kg (8.8%) while the mean for the LC group was 8.0 kg (9.8%) of initial body weight. Weight loss from baseline was significant throughout the dietary treatment for both groups. Both groups changed over time but the LC group lost the weight more quickly than the HC group. Non-significant increases were exhibited in both groups in the post treatment week.

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Insert Table 1 about here.

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Blood Pressure. The means for systolic, diastolic mean arterial blood pressure (MAP) pressure are presented in Table 2. The mean decrease in systolic blood pressure for the HC group was 5.2 mmHg (4.5%) and 4.3 mmHg (3.8%) for the LC group. The mean decrease in diastolic blood pressure was 4 mmHg (5.2%) for the HC group and 2.3 (3.1%) for the LC group. Mean arterial blood pressure decreases were 4.4 mmHg (4.9%) for the HC group, while the mean for the LC group was 2.1 mmHg (2.4%). For both groups, decreases in blood pressure from baseline were not significant throughout the entire diet period. Both groups returned to near baseline values post-treatment week. Group means for postural blood pressure changes during pre-diet and week 4 of diet are given in Figure 1. Neither group had significant changes from baseline values.

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Insert Tables 2 Figure 1 about here.

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Sodium. Sodium in serum did not significantly change in either group throughout the experimental period, but the change for both groups did vary significantly over time

(Table 1). There was a 19.5% net decrease in Na excretion for the HC group and a 18.9% net decrease in serum Na for the LC group from week 1-diet values to post-diet values. It is interesting to note that mean Na excretion in the HC group continued to decrease at the completion of the diet in the week of post dietary treatment (213.2 mg/L), while in the LC group it remained the same (29.7 mg/L).

A separate analysis of the first 7 days of the experiment to determine significant difference between treatments is show in Tables 3 and 4. Daily Na balance showed no significant difference. The first two days of the diet resulted in large negative Na balances. As the treatment continued, marked reductions in urinary excretion of Na was shown by a positive balance in both groups.

Urinary sodium balance on the HC diet (4814 ± 1150 mg) did not differ significantly from the LC diet (7794 ± 856 mg) over the 28 day period. Sodium balance was negative during week 1 for the LC group (-259.8 mg) and positive for the HC group (298.9 mg.). After the first week of dietary treatment the LC group maintained a higher positive balance. The change in Na balance on an average per day basis is shown in Figure 2 for both diets.

Discussion

A comparison of results of this research to other studies shows similar Na and BP changes with VLCD diets (12, 1). Most investigations show Na balance determined by 24 hour urine collection to be more positive with subjects consuming diets higher in CHO content. Our results, however, parallel two studies cited in that subjects on low CHO diets exhibited a more positive Na balance after 28 days.

The LC group resulted in a larger weight loss during the first week of the diet (mean loss = 2.8 kg.) than the HC group (mean loss = 1.8 kg). A suggested explanation of this difference may be due to the greater Na loss exhibited by the LC group at the onset of the diet, resulting in greater water loss. The LC group showed more total weight loss during the diet than the HC group. A possible explanation accounting for the greater weight loss among the LC group is that the LC group was randomly composed of highly obese subjects who had a greater percentage of body fat and were able to lose it at a faster rate.

During post treatment, both groups consumed a 1000 kcal/day mixed diet. The HC group gained 0.2 kg and the LC group 0.8 kg. This may be attributed to water storage due to glycogen repletion (14).

The slight systolic blood pressure changes occurring during treatment are in accordance with other research of obese, non-hypertensive women (9). The rate of reduction in BP during weight loss has not been correlated with the initial obesity, but rather with the initial BP. All subjects in this study had normal blood pressure values, which is probably the reason greater systolic and diastolic changes were not seen. Both groups showed slight decreases in systolic and diastolic blood pressure, which returned to baseline once the diet was terminated. Systolic blood pressure responded with a decrease greater than the diastolic in both the LC and HC groups. The exaggerated postural decline in systolic blood pressure seen in carbohydrate free diets (1,3) was not evident by measurement or by verbal questioning with subjects in this study. Thus, the 44 gms of carbohydrate in the LC diet may have been enough to prevent postural hypotension.

It was seen in the first week of the diet that the LC group lost more NA than the HC group. The changes observed in Na balance throughout the experiment however, showed the LC group tended to cumulatively retain more Na. Although non-significant in this investigation and others (15,11, 12) it is in disagreement to results as reported by some authors (13). Recent studies of obese individuals under total

starvation conditions showed evidence that electrolytic excretions per day are subject to wide individual variations (14). Another reason for the wide conflict among reports is the fact that some of the individual studies have been performed over short intervals and in small heterogeneous groups receiving inaccurately defined diets (12). Different techniques of estimating at Na status largely responsible for contrasting results in the literature (ie. net excretion, cumulative balance, balance).

Reisin et al. (1978) reported that over a period of six months, mean Na excretion was slightly, but not significantly higher in their diet groups on a weight-reduction program than those on no diet. Subjects on a weight-reduction program not receiving antihypertensive-drug therapy showed 3801.9 mg/24 hr Na; patients on a weight reduction program receiving concommitant regular antihypertensive-drug therapy 4248.1 mg/24 hr Na; and patients not on dietary program receiving regular antihypertensive-drug therapy 3560.4 mg/24 hr. Na. There was no control of the Na intake and the subjects were encouraged to freely eat salt-pickled vegetables and other low-calorie foods (13).

Subjects on 1,000-calorie formula diets, studied by Rabast, Kasper and Schonborn, (1978) demonstrated higher Na

excretions in urine over an average of at least 32 days of carbohydrate restricted treatment (1970 g/day of carbohydrate vs 25 g/day of carbohydrate, with 90 mg/day of Na in both diets). This difference, however, was not statistically significant. Total mean values for Na excretion were not presented.

Another group of obese subjects studied by Rabast et al. in 1981 (12) showed sodium excretion calculated cumulatively during the first seven days was significantly greater on a low carbohydrate diet (40 g/day carbohydrate) whereas, after 28 days of treatment, the total amount of Na excretion was highest on the high carbohydrate diet (225 g/day carbohydrate). Sodium intake of approximately 127 mg/day was equally included across all diet treatments throughout the experimental period. Cumulative sodium loss obtained on the high carbohydrate diet after seven days (2622 mg) were significantly lower than on the lower carbohydrate diets (5140.5 mg and 4572.4 mg).

Our results showed comparative cumulative Na excretion values (10,586 mg) in the HC group over the first seven days (94 g/day carbohydrates, 530 kcal) and the LC group (10,784 mg; 44 g/day carbohydrate, 530 kcal). After 28 days the total Na excreted in the high carbohydrate treatment was 38725 mg and 34317 mg in the low carbohydrate treatment.

This was an 11% difference between groups. Rabast (12) showed a 12% difference between dietary groups after 28 days.

A positive urine sodium daily balance of 358.8 mg was also demonstrated with supplemented Optifast diets (472 kcal and 2300 mg/day Na) (1). Our study substantiated the Optifast result of a positive sodium balance, but showed a lower average Na balance of 171 mg/day (52% difference in mg from the Optifast study).

Several reasons may explain the insignificant difference between the two treatments. One possibility is the fact that both diets contained the minimum amount of carbohydrate content that prevented extensive amounts of natriuresis. Both diets contained 44 g carbohydrate as a base (Cambridge diet base). Consequently this amount of carbohydrate may have had a sparing effect on electrolytic loss in the LC group since carbohydrates have been shown to have a sodium-sparing effect (11,14). Subject variation in the elimination of daily water and electrolytes may be another possible explanation for the difference in Na values between studies (11,14).

Exercise training may have also had an effect on Na excretion. It has been found that insulin increases sodium retention in the distal tubuli, and that lower insulin

values are found after exercise training. Consequently, both groups may have had diminished sodium retention because of exercise training (1). It should be noted that our study did not account for any possible Na loss due to sweating, which is a limitation.

In summary, the two diets used in this study were not sufficiently different in carbohydrate content to result in varying degrees of sodium excretion. Because normotensive subjects were used, blood pressure was not significantly affected by either diet.

References

1. Amatruda, J.M., R.G. Brodous and D.H. Lockwood. Very low-calorie diets: efficacy, cardiac, arrhythmias, nitrogen sparing, mineral depletion, and hormone and substrate levels. J. Obesity, Wt Regulation, 3:3-13, 1984

2. Bjorntorp, P. Effects of exercise on hypertension in obesity. Recent Advances in Obesity Research III: Proceedings of the 3rd International Congress on Obesity. Editors Bjorntorp, Cairella and Howard. John Libbey, London, 1981.

3. Bortz, W.M., A. Wroldson, P. Morris, and B. Issekutz Jr. Fat, carbohydrate, salt and weight loss. Amer. J. Clin. Nutri. 20:1104-1112, 1967.

4. DeHaven, J., R. Sherwin, R. Hendler and P. Felig. Nitrogen and sodium balance and sympathetic-nervous system activity in obese subjects treated with a low-calorie protein or mixed diet. N. Engl. J. of Med. 302:477-482, 1980.

5. Eliahou, H.E., A. Iaina, T. Goan, J. Shochat and M. Modan. Body weight reduction necessary to attain normotension in the overweight hypertensive patient. Inter. J. Obesity. 5:157-163, 1981.

6. Howard, A.N. The historical development, efficacy and safety of very-low-calorie diets. Inter J. Obesity. 5:195-208, 1981.

7. Iaina, A., D. Goldfarb, T. Gaon, J. Shochat, and H.E. Eliahou. Low-energy diet and the essential hypertension patient. Recent Advances in Obesity Research III. Editors Bjorntorp, Cairella, Howard. John Libbey, London, 1981.

8. Kolanowski, J. Associations between sodium retention and carbohydrate metabolism. Recent Advances in Obesity Research III: Proceedings of the 3rd International Congress on Obesity. Editors Bjorntorp, Cairella and Howard. John Libbey, London, 1981.

9. Lewis, S.B., J.D. Wallin, J.P. Kane, J.E. Gerich. Effect of diet composition and metabolic adaptations to hypocaloric nutrition: comparison of high carbohydrate and high fat isocaloric diets. Amer. J. Clin. Nutri. 30:160-170, 1977.

10. Mancini, M., G. Di Biase, F. Contaldo, A. Fischetti. Medical complications of severe obesity: importance of treatment by very-low-calorie diets: intermediate and long-term effects. Inter. J. of Obesity. 5:341-352, 1981.

11. Rabast, U., H. Kasper, and J. Schonborn. Comparative studies in obese subjects fed carbohydrate-restricted and high carbohydrate 1,000-calorie formula diets. Nutr. Metab. 22:269-277, 1978.

12. Rabast U., K.H. Vornberger, M. Ehl. Loss of weight, sodium and water in obese persons consuming a high-or-low carbohydrate diet. Am. Nutr. Metab. 25:341-349, 1981.

13. Reisin, E., R. Abel, M. Modan, D.S. Silverberg, H.E. Eliahou, and B. Modan. Effect of weight loss without salt restriction on the reduction of blood pressure in overweight hypertensive patients. N. Engl. J. Med. 298:1=6, 1978.

14. Runcie, J. Urinary sodium and potassium excretion in fasting obese subjects. Br. Med. J. ii:22-25, 1971.

15. Spencer, H., I. Lewin, J. Samachson and J. Laszlo. Changes in metabolism in obese persons during starvation. Amer. J. of Med. 40:27-37, 1966.

16. Yang, M. and T. Van Itallie. Composition of weight loss during short term weight reduction. J. Clin. Invest. 58:722-730, 1976.

17. Young, C.M., S.S. Scanlan, H. Sooklm, and L. Lutwak. Effect on body composition and other parameters in obese young men of carbohydrate level of reduction diet. Amer. J. Clin. Nutri. 24:290-296, 1971.

Table 1. Group Means for Weight, Urinary Sodium Balance[+] and Serum Sodium

Week of Treatment	Weight (kg)		Serum Na (mg/L)		Urinary Na (mg/day)	
	LC	HC	HC	LC	HC	LC
Pre-diet	76.0+3.4	81.3+3.8	------	------	-----	-----
1	74.2+3.6*	76.6+3.6*	3079.8+84.9	3058.0+66.9	298.9+286.1	-259.8+317.0
2	72.7+3.8*	76.6+3.6*	2740.0+222.6	2721.5+119.9	1861.5+245.8	3838.9+159.9*
3	71.3+3.7*	74.7+3.6*	2542.0+51.3*	2632.3+75.7	807.4+445.5	1609.3+219.4
4	69.3+3.7*	73.3+3.5*	2478.4+137.0*	2477.4+81.2*	1847.0+3804.7	2606.0+397.7*
Post-diet	69.5+3.7*	74.1+3.7*	2265.2+152.9*	2447.7+33.22*	-----	-----

Values are means = SEM; HC = high carbohydrate group (n = 5); LC = low carbohydrate group (n = 7)

*Significantly different ($p < .05$) from baseline value.

[+] Urinary sodium balance was calculated by subtracting daily Na excretion from daily dietary Na intake (1555 mg/day Na for HC; and 1504 mg/day Na for LC).

Table 2. Statistical Summary of Analysis of Variance

		WT	BP SYS	BP DIA	BP MAP		NA URINE		NA SERUM
Source	df	MS	MS	MS	MS	df	MS	df	MS
Group**	1	320.22	7.34	19.91	24.43	1	26779955.88	1	31289.16
Error 1	10	490.05	128.11	125.92	104.82	10	37489408.43	10	22874.90
Time	5	94.18*	35.41	49.30	37.07	3	90368843.0*	4	879577.75*
Group*Time	5	1.08*	28.18	4.94	8.86	3	6759372.3	4	23005.98
Error 2	50	.42	24.45	29.40	20.43	30	3220726.2	40	78958.2

** Group tested by subject, (group)
* $p < .05$
df = degrees of freedom
MS = Mean square
SYS = Systolic Blood Pressure
DIA = Diastolic Blood Pressure
MAP = Mean Arterial Pressure

Table 3. Group Means for Urinary Sodium Balance* for Days 1-7 Diet Treatment

Day of Treatment	HC	LC
1	-980±196.0	-990±415.1
2	-635±365.2	-343±236.2
3	207±500.5	123±298.7
4	728±214.1	383±141.0
5	176±339.7	-23±260.8
6	248±205.1	130±353.6
7	556±119.5	212±275.6

Values are means ± SEM; HC = high carbohydrate group (n = 5); LC = low carbohydrate group (n = 7)

*Urinary sodium balance was calculated by subtracting the daily Na intake (1555 mg/day Na for HC; 1504 mg/day Na for LC) from the daily Na excretion.

Table 4. Statistical Summary of Analysis of Variance Urinary Na Balance:+ Treatment Days 1-7

Source**	df	MS
Group**	1	214384.7
Error 1	10	304245.6
Time	6	3199515.3*
Group*Time	6	153750.69
Error 2	60	586918.9

**Group tested using Error 1; Time and Group*Time tested using Error 2

*p < 0.05

df = Degrees of Freedom

MS = Mean Square

*Urinary Na balance was calculated by subtracting daily urinary Na excretion from daily Na intake (1555 mg/day Na for HC; 1504 mg/day Na for LC group).

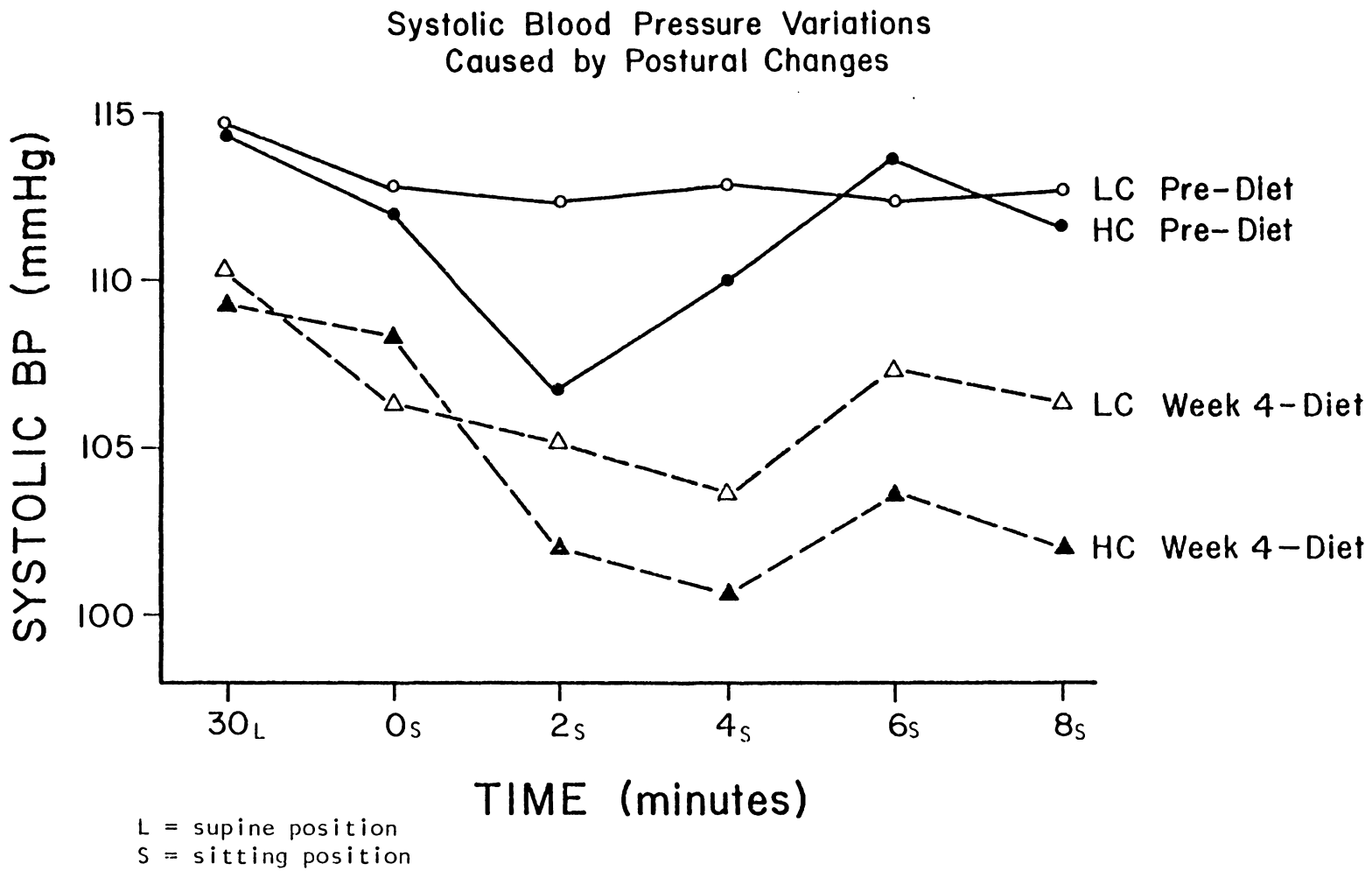
Systolic Blood Pressure Variations
Caused by Postural Changes
SYSTOLIC BP (mmHg)
115
110
105
100
30L
0S
2S
4S
6S
8S
TIME (minutes)
LC Pre-Diet
HC Pre-Diet
LC Week 4-Diet
HC Week 4-Diet
L = supine position
S = sitting position

FIGURE 1

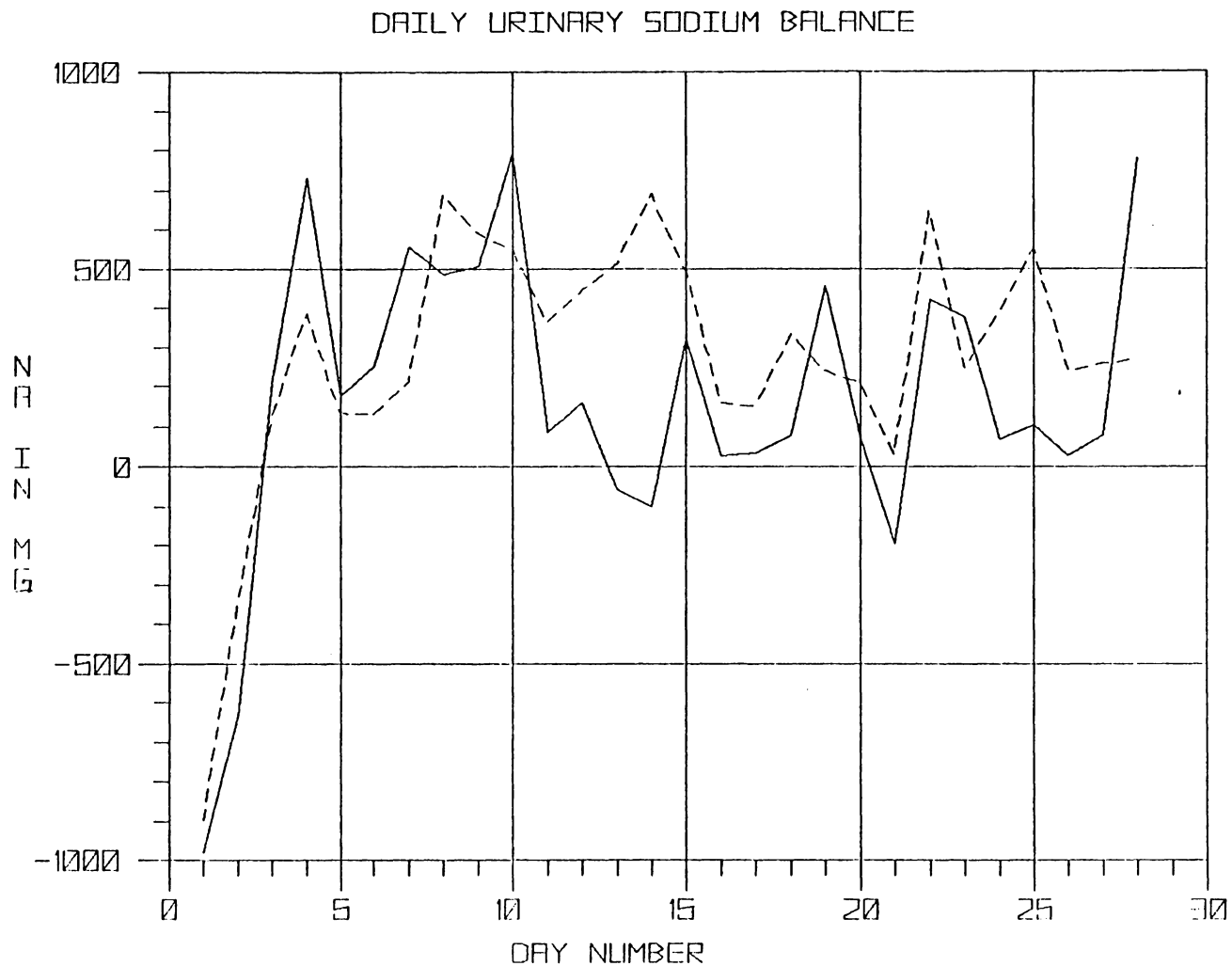
DAILY URINARY SODIUM BALANCE
1000
500
0
-500
-1000
NA IN MG
0
5
10
15
20
25
30
DAY NUMBER

FIGURE 2

Figure Captions

Fig. 1. Changes in daily group means for urinary sodium balance during the 28-day diet. Urinary sodium balance was calculated by subtracting daily Na excretion from daily Na intake (1555 mg/day Na for Hc; 1504 mg/day Na for LC).

Fig. 2 Significant changes in mean systolic blood pressure resulting from postural changes (supine to sitting during pre-diet and week 4 of diet.

Chapter IV

SUMMARY

Successful treatment of obesity and its medical complications have been accomplished using a combination of strict caloric reduction and regular aerobic exercise. Weight loss and accompanying fat reduction may normalize elevated blood pressure. A reduction in mean arterial pressure occurs in about half the patients who lose weight, with systolic pressure responding more readily than diastolic. Exercise alone has also been shown to reduce blood pressure in the hypertensive individual.

Affecting this reduction may also be the loss of sodium caused by underfeeding and elimination of dietary carbohydrate. The mechanism which determines sodium balance is not clear, but is is known that the inclusion of carbohydrate in the diet (a minimum of 40 g) has a retaining effect on sodium. Unchecked excess sodium excretion leads to electrolyte imbalance.

Recent investigations have studied the initial effect carbohydrate content of the diet (VLCD) has on electrolytic balance. Researchers are in agreement that sodium loss is decreased when more carbohydrates are included in dietary treatment. In the study undertaken, twelve obese, normotensive young women volunteers were randomly assigned

to one of two dietary treatment groups: a high carbohydrate hypocaloric diet and a low carbohydrate hypocaloric diet. Both groups participated in an aerobic exercise program three times a week for 30-45 minutes, walking or jogging at an intensity corresponding to 60% of their VO_2max. The treatment period was 28-days and was followed by a week when both groups consumed a 1000 kcal mixed diet and continued the exercise program. Twenty-four hour urine collection was made daily so that Na excretion could be determined. Blood pressure measurements were performed weekly and sodium in serum was determined from the blood samples drawn each week. These measurements were also taken the weeks prior to and after the treatment period.

Analysis of the data revealed that there was a significant difference in weight loss between groups across time. Na balance between groups was different, though not significant. The LC group retained the most Na across time. The difference in sodium loss with HC losing more Na than LC by the end of the experiment was significant in both groups. Serum Na revealed no significant difference between groups but was significantly decreased across time. Blood pressure decreases throughout the treatment were small and non-significant.

Postural changes in BP remained small and non-significant. The lack of significant difference in Na balance between groups may be due to carbohydrate intake in both diets being greater than 40 gm. Further studies using more drastic carbohydrate differences are need to substantiate this hypothesis.

It can be concluded from the data that the inclusion of carbohydrates in a very-low calorie dietary treatment resulted in less Na loss after 4 days. Examination of changes on different postural positions did not reveal evidence of hypotension reported by subjects of carbohydrate free protein diets. Overweight normotensive individuals did not reduce blood pressure values below normal levels.

Research Implications

Current estimates place the number of obese or overweight Americans anywhere between 40 to 80 million. One of the leading causes of morbidity and mortality in the obese are hypertension and associated cardiovascular diseases. Because such a large portion of the American population is at risk, therapies which can permanently reduce body weight are needed.

Weight control offers a potential tool in the control of hypertension which is low in cost and free of side effects. If medication is necessary, it is possible at a

lower dose. Though criticism has been raised for the initial weight loss as being misleading, it is a normal physiological response to a low carbohydrate diet and a decreased food intake. It has the psychological advantage of motivating the dieter to continue the diet. Very low-calorie diets produce this result and thus eliminate the frustration brought about by a diet that results in minute weight changes. Research seems to indicate that lowering the percent of carbohydrate present in the diet tends to facilitate weight loss, but more study is needed in this area.

Exercise is an added benefit to the weight loss regime because it increases the negative caloric balance and helps spare the breakdown of lean body mass. Because the state of being overweight produces psychological stress, physical exercise can provide an outlet for this release. Additionally, exercise may help limit the decrease in metabolic rate.

Recommendations for Future Study

Though this study provided enlightenment in several areas, it left several inquiries unanswered regarding the joint effect of diet and exercise. The necessary amount of carbohydrate needed to ensure effective and safe treatment on a VLCD is still unknown. Answers to questions pertaining

to mechanisms involved in Na retention and excretion also remain unclear. In this study and similar investigations by others, the subjects being examined had normal cardiac functions. Whether these diets are safe on older subjects or for those with complicating illness, such as diabetes mellitus and hypertension remains to be seen. The following recommendations for further study are suggested to compliment the results of this investigation:

1. Inclusion of a larger sample of subjects will help in minimizing individual variability in sodium determination.
2. Further study should be carried out with mildly hypertensive individuals using no medication and with no other medical complications.
3. A control group on the same dietary carbohydrate treatment, but participating in no exercise program and using a longer treatment period may give further insight into the effect exercise may have on the variables.
4. Investigation of the effect of diet treatment of lesser carbohydrate content (<45 g carbohydrate content) is needed.
5. Alter the specific fat content (saturated or unsaturated) and maintain a constant carbohydrate ratio.

6. Compare blood pressure, Na and weight loss changes in studies involving men.

Bibliography

Amatruda, J.M., Brodus, R.G., Lockwood, D.H. (1984). Very-low-calorie diets: efficacy, cardiac arrythmias, nitrogen sparing, mineral depletion, and hormone and substrate levels. Journal of Obesity and Weight Regulation, 3,3-13.

Atkinson, R.L., Kaiser, D.I. (1981). Non physician supervision of a very-low-calorie diet. Results in over 200 cases. International Journal of Obesity, 5,237-241.

Benoit, F.L., Martin, R.L., Watten, R.H. (1965). Changes in body composition during weight reduction in obesity. balance studies comparing effects of fasting and a ketogenic diet. Annals of Internal Medicine, 63, 604-612.

Bier, D.M., Young, V.R. (1983). Exercise and blood pressure: nutritional considerations. Annals of Internal Medicine, 98(Part 2), 864-869.

Bjorntorp, P. (1982). Hypertension and exercise. Hypertension, 4(Suppl. III) III-56.

Bloom, W.L. (1962). Inhibition of salt excretion by carbohydrate. Archives of Internal Medicine, 109, 80-86.

Bortz, W.M., Wroldson, A., Morris, P. and Issekut, B. Jr. (1967). Fat, carbohydrate, salt, and weight loss. American Journal of Clinical Nutrition, 20, 1104-1112.

Bosello, O., Armellini, F., Cigolini, M., Miccilo, R., Montresor, S., Scuro, L.A. (1981). Semistarvation and physical exercise in the treatment of obesity. Serno Symposium No. 28, "Obesity; Pathogenesis and treatment." Edited by G. Enzi, G. Grepaldi, G. Pozza and A.E. Renold. Academia Press, London and New York.

Boyer, J.L., Kasch, F.W. (1970). Exercise therapy in hypertensive men. Journal American Medical Association, 211, 1668-71.

Dahl, L., Silver, L., and Christie, R. (1958). Role of salt in the fall of blood pressure accompanying reduction of obesity. New England Journal of Medicine, 258, 1186-1197.

DeHaven, J., Sherwin, R., Hendler, R., Felig, P. (1980). Nitrogen and sodium balance and sympathetic-nervous-system activity in obese subjects treated with a low-calorie protein or mixed diet. New England Journal of Medicine, 302, p 447-482.

Dustan, H.P. (1984). Mechanisms in obesity-related high blood pressure. Alabama Journal Medicine Science, 2, 18.

Dustan, H.P. (1983). Mechanisms of hypertension associated with obesity. Annuals of Internal Medicine, 98(Part 2), 860-864.

Ekblom, B., Astrand, P., Saltin, B., Stenberg, J., Walkstrom, B. (1968). Effect of training on circulatory response to exercise. Journal of Applied Physiology, 24, 518-528.

Eliahou, H.E., Iaina, A., Gaon, T., Schochat, J., Modan, M. (1981). Body weight reduction necessary to attain normotension in the overweight hypertensive patient. International Journal of Obesity, 5, Suppl. 1, 157-163.

Frohlich, E.D. (1983). Mechanisms contributing to high blood pressure. Annuals of internal medicine, 98(Part 2), 709-714.

Hamwi, G.J., Mitchell, M.C., Wieland, R.G., Kruger, F.A., Schachner, S.S. (1967). Sodium and potassium metabolism during starvation. American Journal of Clinical Nutrition, 20, 897-902.

Havlik, R.J., Hubert, H.B., Fadsitz, R.R., and Feinleib, M. (1983). Weight and hypertension. Annuals of Internal Medicine, 98(Part 2), 855-859.

Hickey, N., Daly, L., Bourke, G., and Mulcahy, R. (1981). Outpatient treatment of obesity with a very-low-calorie formula diet. International Journal of Obesity, 5,227-230.

Hodges, R.E., REbello, T. (1983). Carbohydrates and blood pressure. Annuals of Internal Medicine, 98(Part 2), 838-841.

Howard, A.N. (1981). The historical development, efficacy and safety of very-low-calorie diets. International Journal of Obesity, 5, 195-208.

Iacono, J.M., Marshall, W.M., Daugherty, R.M., Wheeler, A., Maken, J.F., Canary, J.J. (1975). Reduction in blood pressure associated with high polyunsaturated fat diets that reduced blood cholesterol in man. Preventive Medicine, 4, 426-43.

Iaina, A., Goldfarb, D., Gaon, T., Schochat, J., Eliahou, H.E. (1981). Low-energy diets and the essential hypertension patient. Recent Advances in Obesity Research III. Proceedings of the 3rd International Congress on Obesity. Editors: Bjorntorp, Cairella, Howard. John Libby, London, 19-24.

Kaplan, N.M. (1983). Hypertension: prevalence, risks and effect of therapy. Annuals of Internal Medicine, 98(Part 2), 5, 705-709.

Kolanowski, J. (1981). Association between sodium retention and carbohydrate metabolism. Recent Advances in Obesity Research III. Proceedings of the 3rd International Congress on Obesity. +John Libbey London, 25-30.

Lewis, S.B., Wallin, J.D., Kane, J.P., Gerich, J.E. (1977). Effect of diet composition on metabolic adaptations to hypocaloric nutrition; comparison of high carbohydrate and high fat isocaloric diets. The American Journal of Clinical Nutrition, 30, 160-170.

Luft, F.C., Rankin, L.I. Bloch, R. et al. (1979). Cardiovascular and humoral responses to extremes of sodium intake in normal black and white men. Circulation, 60, 697-706.

Mancini, M.D., Biase, G., Contaldo, F., Fischetti, A., Grasso, L., Mathioli, P. (1981). Medical complications of severe obesity: important treatment by very-low-calorie diets: intermediate and long-term effects. International Journal of Obesity, 5, 341-352.

Rabast, U., Vornberger, K.H., Ehl, M. (1981). Loss of weight, sodium and water in obese persons consuming a high or low carbohydrate diet. Annuals of Nutrition, 25, 341-349.

Rabast, U., Schonborn, J., Kasper, H. (1979). Dietetic treatment of obesity with low and high-carbohydrate diets: comparative studies and clinical results. International Journal of Obesity, 3, 201-211.

Rabast, U., Kasper, H., Schononborn, J. (1978). Comparative studies in obese subjects fed carbohydrate-restricted and high carbohydrate 1,000-calorie formula diets. Nutrition and Metabolism, 22, 269-277.

Ramsay, L.E., Ramsey, M.H., Hettiarachchi, J., Davies, D.L. and Winchester, J. (1978). Weight reduction in blood pressure clinic. British Medical Journal, 2, 1-6.

Rao, R.H., Rao, V.B., Srikanka, S.G. (1981). Effects of polyunsaturate-rich vegetable oils on blood pressure in essential hypertension. Clinical Experiments in Hypertension, 3, 27-38.

Reisin, E., Abel, R., Modan, M., Silverberg, D.S., Eliahou, H.E., Modan, B. (1978). Effect of weight loss without salt restriction on the reduction of blood pressure in overweight hypertensive patients. The New England Journal of Medicine, 298:1, 1-6.

Seal, D.R., Hagberg, J.M. (1984). The effect of exercise training on human hypertension: a review. Medicine and Science in Sports and Exercise, 16, 207-215.

Sims, E.A.H. (1981). Hypertension and Obesity: mechanisms and management. Recent Advances in Obesity Research III. Proceedings of the 3rd International Congress on Obesity. Editors: Bjorntorp, Cairella, Howard. John Libbey, London, 10-18.

Sims, E.A.H. (1981). Mechanisms of hypertension in the syndromes of obesity. International Journal of Obesity, 5, Suppl. 1, 9-18.

Smith-Barbaro, P.A., Pucak, G.J. (1983). Dietary Fat and Blood Pressure. Annals of Internal Medicine, 98(Part 2), 828-831.

Smith-Barbaro, P., Quinn, M.R., Fisher, H., Hegsted, D.M. (1981). The effect of fat and salt on blood pressure, renal, and aortic prostaglandins. Nutrition Res. 1, 277-87.

Spencer, H., Lewin, I., Samachson, J. (1966). Changes in metabolism in obese persons during starvation. American Journal of Medicine, 40, 27-37.

Stamler, R., Stamler, J., Redlinger, W.T., Algera, G., Roberts, R.H. (1978). Weight and blood pressure: findings in hyptertension screening of 1 million Americans. Journal of the American Medical Association, 240, 1607-10.

Winder, W.W., Hickson, R.C., Hagberg, R.C., Ehsani, A.A. and McLane, J.A. (1979). Training-induced changes in normal and metabolic responses to submaximal exercise. Journal of Applied Physiology, 46, 766-771.

Young, J.B., Mullen, D., and Landsberg, L. (1978) Caloric restriction lowers blood pressure in the spontaneously hypertensive rat. Metabolism, 27, No. 12, 1711-1714.

Appendix A

DETAILED METHODOLOGY

DETAILED METHODOLOGY

Introduction

In order to meet the objectives, this investigation required daily collection and analysis of sodium loss per day, weekly assessment of blood pressure throughout the six-week period of the study, and daily weight measurements. The six-week experimental period consisted of the following phases:

1. one week of pretreatment period in which the subjects consumed a weight maintenance diet without exercise,
2. four-week treatment period during which each participant consumed one of the two dietary treatments and participated in an exercise program,
3. one-week post-treatment period where each subject consumed a 1000 kcal diet in addition to their exercise program.

Subject Screening and selection

Subjects were recruited through an announcement placed in the Virginia Tech Spectrum. Fourteen participants were selected for inclusion of the study. Selection criteria included the following:

1. age between 18 and 36 years,

2. generally healthy without any known health problems such as diabetes, gout, heart disease, hypertension or orthopedic problems,
3. body fat greater than 30%,
4. willingness to adhere to all aspects of experimental protocol,
5. $50.00 deposit for adherence to experimental protocol during the entire length of time: money was to be returned upon completion of the study.

All subjects were given a physical examination by the supervising physician to verify good health prior to participation in the study.

Instructional Procedures

Prior to the beginning of the study, a general meeting was held to inform all participants of the details and precise procedures to be undertaken involving the diets and exercise protocols and the tests to be conducted. Each participant was instructed at this time to follow a weight maintenance diet for one week prior to the experimental period. All initial measurements were taken during the week before the experimental period and included a treadmill test to determine VO_2max for calculation of exercise prescription, body weight, and blood pressure readings to establish baseline data. Upon the seven day completion of

the maintenance period, the two diet and exercise protocols were started and continued for a total of 28 days. The two treatments consisted of one group consuming a high carbohydrate hypocaloric diet (530 kcal), and the other group consuming a low carbohydrate hypocaloric diet (530 kcal) with both groups participating simultaneously in an exercise program. Subjects were asked to maintain a daily 24-hour urine collection so that sodium loss could be measured. Following the experimental period, each participant was instructed on a 1000 calorie diet (20% protein, 45% carbohydrate, 35% fat) to be followed for at least one week after the treatment period. The exercise program was continued during the refeeding week. Measurements of blood pressure, weight and sodium loss were assessed throughout the experimental period and one week following termination of the diet.

Diet Protocol

The sole source of nutrition for the 28-day experimental period was a liquid formula diet. The daily diet of the high carbohydrate group was composed of the following mixture: diet base (Cambridge Plan International) consisting of 330 kcal, 33g protein, 3g fat, 44g carbohydrate; the additional 200 kcal came from 50g of a carbohydrate from a carbohydrate source (Polycose, Ross Labs).

The daily diet of the low carbohydrate group was composed of the following mixture: diet base (Cambridge Plan International) consisting of 330 kcal, 33g protein, 3g fat, 44g carbohydrate; the additional 200 kcal came from 22.2g fat from a calorie source (Microlipid, Organon).

The diet base (Cambridge Plan International) contained 1500mg sodium/day, and the carbohydrate source (Polycose, Ross Labs) contained 55mg/day and the fat source (Microlipid, Organon) contained 4mg/day.

Exercise Protocol

Both groups participated in a supervised exercise session three times per week for the 28 days of diet and one week post treatment. Each individual was given a graded exercise test on a motor driven treadmill (Quinton) to determine $\dot{V}O_2max$. A modified Balke Protocol was used with increments equivalent to 2 METS (7.0 ml 0 per kg per min). Speed began and remained constant at 3.0 mph (4.8 km per hr) throughout the test. Every two minutes the grade was increased 5% and was continued until subject reached exhaustion. Gas analysis was done on an applied electrochemistry S-3A oxygen analyzer and CD-3A carbon dioxide analyzer with expired air measured by a Hewlett-Packard 47303A digital pneumotach. Determination of individual exercise prescriptions were made to correspond to

60% of the $\dot{V}O_2max$. Sessions were held three times per week throughout the dietary treatment and one week post treatment.

Sodium Determination

Urine. Sodium concentration was measured daily during the 28 days of the treatment period. Determination of values was made utilizing the following equipment.

1. Atomic Absorption Spectrometer (Perkin-Elmer Varian AA - 175 Series)
   a. Flame: air/acetylene (oxidizing - fuel lean),
   b. Mode: Absorption with automatic 3-second integration,
   c. Hollow Cathode Lamp: Perkin-Elmer Intensitron Lamp
      Element: Na K
      Maximum Current: 12 mA
2. 1 quart size container per subject,
3. 1 gallon size container per subject.

The following procedure was used:

1. 24-hour urine collections were taken daily with the smaller size containers used for routine excretions and the 1 gallon container for the total daily output to be turned in to experimenters by 8:00 each morning,

2. 2 ml HCL was added to each daily sample as a preservative,
3. 2 ml of each daily sample were frozen analyzed at a later date.

The following materials were utilized in the assays:

1. distilled deionized water,
2. precision micro pipettes,
3. 100 ml columetric flasks,
4. plastic tubes with tops.

Details of Urine Dilution:

1. 100 ul of urine was pipetted into each tube.
2. Each tube was mixed with 100 ml of distilled deionized water in a volumetric flask.
3. All tubes were capped and inverted to mix.
4. A portion of this dilution was poured into smaller containers for easier analysis.
5. Each sample was analyzed three times on an AA unit.
6. Values of the standards and unknown samples were entered into a programmed calculator and values for the Na concentration were determined from the computed linear regression.

The following equation was used:

1. ug/ml x Dilution Factor (DF) = ug/ml urine

2. mg/ml urine x total ml of urine in ml/day = mg Na excreted/day
3. ug Na excreted/day x 1000 = ug Na/day
4. Na concentration per day

Serum

Blood samples were drawn after an overnight fast during the experimental period. Each whole blood sample was centrifuged within 30 minutes. The serum was separated and frozen until the end of the study. The following materials were utilized in the assays:

1. distilled, deionized water
2. precision micro pipettes
3. 100 ml volumetric flask
4. plastic tubes with tops

Details of Serum Dilution

1. 50 ul of serum was pipetted into each tube.
2. Each tube was mixed with 100 ml of distilled, deionized water.
3. All tubes were capped and inverted.
4. A portion of the dilution was poured into smaller containers for easier analysis.
5. Each sample was analyzed three times on an AA unit.

6. Values of the standards and unknown standards were entered into a programmed calculator and values for Na concentration were determined from the computed linear regression.

The following equation was used:

Na concentration x DF = Na in mg/liter (DF = 2000)

Blood Pressure Determination by Blood Pressure Cuff

Measurements were taken at the end of each week of the experimental period with the following equipment being utilized:

1. blood pressure cuff
2. stethescope

The following procedures were used:

1. Subjects were instructed to abstain from their prescribed diet and beverages except water, twelve hours prior to test and to refrain from physical activity until termination of test.
2. For thirty minutes the patient was reclined on a cot in the supine position and relaxed.
3. A blood pressure reading was taken in the supine position.
4. The subject was then instructed to sit, at which time an immediate reading was taken.

5. Blood pressure readings were subsequently taken every two minutes for a total of 8 minutes.

The following calculation was used to determine mean arterial pressure (MAP):

$$MAP = DBP + (1/3) \times (SPB-DBP)$$

Weight Measurement

Assessment was made in kilograms to the nearest tenth every morning before 8 a.m.

Research Design and Statistical Procedures

The research design of this study was a two factor design with repeated measures on one factor. The two independent variables were the dietary treatments of a low carbohydrate hypocaloric diet and a high carbohydrate hypocaloric diet and time. The dependent measures were weight, Na balance in urine and serum, systolic, diastolic and mean arterial blood pressure changes. These parameters, except Na, were observed during the six-week period of the study.

Subjects were randomly assigned to one of the two treatment groups. Original make up of each group contained seven subjects per group. Due to health problems, two of the participants were forced to discontinue their participation. All data from these subjects were not included in the statistical analysis.

All data were statistically 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 employed to determine statistically significant differences between group means.

Statistical analysis revealed that weight decreased significantly from baseline in both groups throughout the experimental period and in the post-treatment week. Values for blood pressure were not significant throughout the entire treatment period. Values for Na both in serum and in urine showed no significant change in either groups, but was significant over time. Blood pressure changes affected by postural changes, showed no significant difference in either group for the experimental period. A negative, low correlation between weight and diastolic blood pressure was found in the HC group, while a low, positive weight and diastolic blood pressure was found in the LC group. The LC group also showed evidence of a positive correlation between systolic blood pressure and weight.

ANOVA - Na (Serum)

Source	SS	df	MS	F	P
Group	31289.160	1	31289.160	1.37	0.2693
Error 1 Subject (Group)	228749.04	10	22874.904	----	----
Time	3518311.7209	4	879577.75	11.14	0.0001
Group*Time	92023.9209	4	23005.98	11.14	.8819
Error 2 Sn(Group)* Time	3158328.046	40	78958.2	----	----

ANOVA - Na (Urine: Cumulative Balance)*

Source	SS	df	MS	F	P
Group	2677955.878	1	26779955.878	0.71	0.4178
Error 1 Subject (Group)	374894084.273	10	38489408.427	----	----
Time	271106431.925	3	90368843.0	28.85	0.001
Group*Time	20278117.194	3	6759372.3	2.10	0.1213
Error 2 Sn(Group)* Time	96621787.125	30	3220726.2	----	----

*Cumulative urine balance was calculated by subtracting the daily Na excretion from daily Na intake (1555 mg/day Na, HC Group; 1504 mg/day, LC Group).

Summary ANOVA - Weight

Source	SS	df	MS	F	P
Group	320.2154	1	320.2154	.65	0.4377
Error 1 Subject (Group)	4900.5361	10	490.0536	----	----
Time	470.9027	5	94.1805	222.33	0.0001
Group*Time	5.3827	5	1.0765	2.54	0.0399
Error 1 Sn(Group)* Time	21.1799	50	0.4236	----	----

Summary ANOVA - BP (Systolic)

Source	SS	df	MS	F	P
Group	7.3397	1	7.3397	1.06	0.8157
Error 1 Subject (Group)	1281.1048	10	128.1105	----	----
Time	177.5556	5	35.5112	1.45	0.2222
Group*Time	140.8889	5	28.1779	1.15	0.3457
Error 2 Sn(Group)* Time	1222.6667	50	24.4533	----	----

Summary ANOVA - BP (Diastolic)

Source	SS	df	MS	F	P
Group	19.9111	1	19.9111	0.16	0.6992
Error 1 Subject (Group)	1259.2000	10	125.9200	----	----
Time	246.4952	5	49.2990	1.68	0.1575
Group*Time	24.7175	5	4.9435	0.17	0.9732
Error 2 Sn(Group)* Time	1470.1714	50	29.4034	----	----

Summary ANOVA - BP (Mean Arterial Pressure)

Source	SS	df	MS	F	P
Group	24.4260	1	24.4260	.23	0.6397
Error 1 Subject (Group)	1048.1577	10	104.8158	----	----
Time	185.3545	5	37.0709	1.81	0.1270
Group*Time	44.3123	5	8.8625	0.43	0.8228
Error 2 Sn(Group)* Time	1021.4714	50	20.4294	----	----

Correlation Coefficients--HC Group

	SYS	DIA	MAP	WT	NA
SYS	1.000	.36936*	----	.04891	.24471
DIA	.36936*	1.000	----	-.44629*	.32520
MAP	----	----	1.000	.38255	----
WT	.04891	-.44629*	.38255	1.000	.06698
NA	.24471	.32520	----	.06698	1.000

Correlation Coefficients--LC Group

	SYS	DIA	MAP	WT	NA
SYS	1.000	.55875*	----	.61581*	-.06786
DIA	.55875*	1.000	----	.44640*	.11412
MAP	----	----	1.000	.56706	----
WT	.61581*	.44640*	.56706	1.000	.11170
NA	-.06786	.11412	----	.11170	1.000

SYS = systolic blood pressure
DIA = diastolic blood pressure
MAP = mean arterial pressure
* = $p < .05$

Summary of Analysis of Variance
Blood Pressure: Postural Changes

Source	df	MS
Group**	1	331.85*
Error 1	10	690.33
Posture	5	329.02
Time	5	492.64
Posture x Time	25	20.164
Group x Posture	5	47.72
Group x Time	5	190.90
Group x Posture x Time	25	11.914*
Error 2	350	26.679

**Group tested using Error 1 (group). Remaining factors and interactions tested using Error 2.

*$p < 0.05$

df = Degrees of Freedom

MS = Mean Square

Group Means for Systolic Blood Pressure: Postural Changes

Week of Treatment	Supine		Sitting									
	30 min		0 min		2 min		4 min		6 min		8 min	
	HC	LC	HC	LC	HC	LC	HC	LC	HC	LC	HC	LC
Pre-diet	114.4 ±1.2	114.6 ±3.1	112.0 ±2.1	112.9 ±2.5	106.8 ±3.2	112.3 ±2.2	110.0 ±1.2	112.9 ±2.7	113.6 ±1.7	112.3 ±2.1	111.6 ±2.2	113.7 ±1.9
Week 1 diet	111.6 ±2.9	111.4 ±3.6	109.2 ±4.7	111.4 ±3.6	106.8 ±1.9	114.6 ±2.5	106.4 ±2.5	109.4 ±1.4	103.6 ±1.3	111.1 ±2.9	104.4 ±2.1	111.1 ±2.5
Week 2 diet	114.8 ±3.1	107.1 ±2.0	112.4 ±1.0	105.7 ±2.8	106.8 ±1.4	104.0 ±2.4	103.6 ±1.5	102.8 ±3.1	106.0 ±1.4	101.4 ±2.8	104.4 ±1.5	102.2 ±3.1
Week 3 diet	110.0 ±1.8	110.3 ±2.2	106.0 ±2.5	108.9 ±2.9	106.0 ±2.8	107.1 ±1.7	102.4 ±1.9	106.0 ±2.8	105.2 ±2.8	105.7 ±4.1	104.4 ±3.7	104.8 ±3.9
Week 4 diet	109.2 ±1.5	110.3 ±3.2	108.4 ±1.7	106.3 ±2.2	102.0 ±1.8	105.1 ±2.0	100.8 ±2.6	103.7 ±1.9	103.6 ±1.8	107.4 ±2.9	102.0 ±2.1	106.2 ±2.5
Post-diet	112.2 ±2.6	113.4 ±1.7	110.8 ±2.3	112.9 ±1.6	106.4 ±3.2	111.7 ±2.6	102.0 ±1.9	111.1 ±3.7	108.0 ±2.8	112.9 ±3.5	102.0 ±2.8	110.6 ±2.8

Appendix B

INDIVIDUAL SUBJECT DATA

Individual Subject Data

NA* Excretion -- High Carbohydrate Subjects

Day of Treatment	Sub 1	Sub 2	Sub 3	Sub 4	Sub 5
1	2818.2	2657.0	2800.8	2635.3	1765.2
2	1264.5	3163.8	1595.2	2037.3	2887.7
3	3177.7	560.4	911.8	468.2	1624.5
4	764.3	951.3	1194.8	34.3	1194.0
5	906.0	705.1	2161.5	870.2	2250.2
6	1175.3	1141.6	2067.5	1312.2	839.7
7	1400.0	695.1	943.7	1097.2	859.0
8	1316.7	816.4	399.0	1052.1	1772.2
9	1474.7	1295.5	887.2	482.1	1107.4
10	673.9	631.4	535.8	997.5	974.5
11	1371.2	1096.2	1206.6	1309.6	2367.0
12	2072.5	819.2	1323.0	2082.8	682.6
13	1990.5	1677.4	1475.9	1358.9	1581.8
14	1076.9	1392.9	2175.0	1652.5	1988.7
15	1247.0	1002.5	806.0	548.0	2576.9
16	1576.7	755.5	842.1	1503.4	2964.2
17	1843.9	913.9	1669.7	1797.0	1383.8
18	1790.2	1043.4	1296.8	2151.9	113.4
19	1553.9	795.9	686.1	1326.0	1143.8
20	992.4	1131.6	2880.0	1058.5	1431.3
21	1909.2	1295.0	1984.0	1373.7	2197.4
22	1486.7	786.6	876.1	1135.3	1388.6
23	997.2	455.6	1745.1	1169.8	1537.5
24	1118.5	1129.5	1213.0	1429.0	2539.7
25	1643.5	1368.7	1821.0	1082.5	1334.3
26	2342.0	941.5	2134.5	830.9	2395.0
27	1671.4	854.5	2426.5	1326.5	1108.6
28	757.1	1271.0	908.0	338.6	615.7

* 24-hour urine collection

Na* Excretion--Low Carbohydrate Subjects

Day of Treatment	Sub 6	Sub 7	Sub 8	Sub 9	Sub 10	Sub 11	Sub 12
1	1413.8	1924.3	1531.5	2256.3	4317.8	1535.1	1841.2
2	2557.1	2679.6	1726.5	1975.3	1780.0	1171.2	1039.1
3	2773.2	542.1	1067.0	415.0	1648.1	1514.2	2711.1
4	1509.7	903.5	811.2	1185.8	732.8	978.1	1725.3
5	2530.8	2049.6	729.8	947.7	1205.3	821.4	1294.8
6	1724.3	828.0	823.1	643.0	941.3	3324.4	1338.2
7	1094.7	360.5	1423.0	429.2	1955.5	2317.8	1466.4
8	829.1	957.9	819.5	502.2	604.3	889.1	1088.7
9	708.0	466.5	966.3	1911.3	892.0	585.2	867.8
10	1056.2	911.2	753.4	1272.0	1594.2	324.0	761.4
11	1841.3	284.3	982.8	1103.2	1555.0	744.5	1468.9
12	1044.7	1285.6	1153.4	558.2	1514.0	1284.8	632.4
13	998.0	829.9	1060.2	168.0	1531.4	1047.6	1311.8
14	456.2	1202.9	836.9	975.8	899.0	1199.2	133.3
15	822.8	777.6	1036.8	920.8	1242.6	1506.2	783.7
16	1089.6	1107.2	1016.8	1236.1	1351.9	1674.4	1219.1
17	995.7	608.3	1097.6	1020.0	1986.2	1361.9	2403.5
18	1493.2	1499.9	1022.4	1069.9	1164.6	1164.8	791.1
19	907.9	1532.1	110.2	1328.9	1302.1	847.6	1839.7
20	1889.2	1786.0	1189.2	1062.9	1147.7	863.2	1126.4
21	905.0	2062.9	1008.5	714.6	2224.6	1216.8	2181.3
22	2678.8	487.2	1188.7	597.0	476.4	840.1	717.6
23	1201.4	1014.5	1220.0	973.7	1643.2	932.3	1819.1
24	2023.7	698.0	919.2	1455.4	980.2	901.2	840.3
25	1001.7	386.5	727.5	893.9	1655.3	715.3	1280.4
26	1345.8	1659.5	575.3	1210.9	1355.0	1104.0	1583.3
27	2146.1	1246.9	764.5	1046.8	1259.1	1160.9	1107.7
28	2270.4	1250.4	709.0	686.9	1765.3	853.9	1110.6

* 24-hour urine collection

Individual Subject Data - High Carbohydrate Group

Subject - 1

Week of Treatment	WT (kg)	Na-Serum (mg/l)	SYS (mmHg)	DIA (mmHg)	MAP (mmHg)
1	67.0	----	118	78	91.3
2	65.1	3158	110	80	90.0
3	62.5	2388	126	82	97.6
4	61.3	2576	104	74	84.0
5	59.2	2568	110	72	84.7
6	59.1	2272	110	70	83.3

Subject - 2

Week of Treatment	WT (kg)	Na-Serum (mg/l)	SYS (mmHg)	DIA (mmHg)	MAP (mmHg)
1	71.7	----	114	88	96.7
2	69.1	3151	122	78	92.7
3	67.8	2530	108	64	78.7
4	66.1	2504	112	72	85.3
5	64.7	2220	104	82	89.3
6	65.9	2202	116	84	94.7

Subject - 3

Week of Treatment	WT (kg)	Na-Serum (mg/l)	SYS (mmHg)	DIA (mmHg)	MAP (mmHg)
1	83.7	----	112	76	88.0
2	82.1	3197	112	70	84.0
3	81.0	2512	112	68	82.7
4	79.9	2698	108	66	80.0
5	77.5	2760	112	74	86.7
6	77.7	2530	112	66	81.3

Subject - 4

Week of Treatment	WT (kg)	Na-Serum (mg/l)	SYS (mmHg)	DIA (mmHg)	MAP (mmHg)
1	84.2	----	112	70	84.0
2	83.3	3151	104	70	81.3
3	81.7	3614	112	70	84.0
4	79.8	2550	114	64	80.7
5	78.2	2094	108	64	78.7
6	78.0	1730	116	74	88.0

Subject - 5

Week of Treatment	WT (kg)	Na-Serum (mg/l)	SYS (mmHg)	DIA (mmHg)	MAP (mmHg)
1	73.5	----	116	76	89.3
2	71.4	1780	110	74	86.0
3	70.4	2742	116	78	90.7
4	68.6	2656	112	78	89.3
5	66.8	2382	112	76	88.0
6	66.8	2592	104	74	83.3

Individual Data Sheet -- Low Carbohydrate Group

Subject - 6

Week of Treatment	WT (kg)	Na-Serum (mg/l)	SYS (mmHg)	DIA (mmHg)	MAP (mmHg)
1	86.4	----	116	72	86.7
2	83.1	2992	116	72	86.7
3	80.3	2992	112	56	74.7
4	78.3	2876	108	60	76.0
5	77.4	2216	108	68	81.3
6	78.2	2406	118	80	92.7

Subject - 7

Week of Treatment	WT (kg)	Na-Serum (mg/l)	SYS (mmHg)	DIA (mmHg)	MAP (mmHg)
1	92.6	----	130	86	100.7
2	88.7	3151	126	74	91.3
3	87.3	2572	112	76	88.0
4	85.9	2438	122	78	92.7
5	84.1	2392	128	84	98.7
6	84.3	2626	118	78	91.3

Subject - 8

Week of Treatment	WT (kg)	Na-Serum (mg/l)	SYS (mmHg)	DIA (mmHg)	MAP (mmHg)
1	75.0	----	106	78	87.3
2	72.8	3130	108	82	90.7
3	70.5	2606	112	74	86.7
4	69.5	2788	106	66	79.3
5	67.8	2416	108	78	88.3
6	68.4	2442	110	76	87.3

Subject - 9

Week of Treatment	WT (kg)	Na-Serum (mg/l)	SYS (mmHg)	DIA (mmHg)	MAP (mmHg)
1	86.0	----	116	76	86.0
2	84.2	3128	120	78	92.0
3	82.3	2452	108	80	89.3
4	81.1	2526	108	78	88.0
5	79.6	2458	110	70	83.3
6	82.0	2484	118	72	87.3

Subject - 10

Week of Treatment	WT (kg)	Na-Serum (mg/l)	SYS (mmHg)	DIA (mmHg)	MAP (mmHg)
1	90.9	----	112	80	90.7
2	87.2	3141	106	68	80.3
3	85.0	2304	112	80	90.7
4	82.1	2416	112	74	83.3
5	79.9	2886	100	68	78.7
6	82.4	2430	112	78	89.3

Subject - 11

Week of Treatment	WT (kg)	Na-Serum (mg/l)	SYS (mmHg)	DIA (mmHg)	MAP (mmHg)
1	70.2	----	116	74	84.7
2	67.7	3174	106	70	82.0
3	66.4	3151	100	66	77.3
4	64.1	2856	110	66	80.7
5	63.2	2364	110	66	80.7
6	62.5	2374	110	72	84.7

Subject - 12

Week of Treatment	WT (kg)	Na-Serum (mg/l)	SYS (mmHg)	DIA (mmHg)	MAP (mmHg)
1	68.0	----	106	58	74.0
2	65.5	2680	98	66	76.4
3	63.8	2974	100	66	77.3
4	62.0	2526	104	66	78.7
5	61.0	2610	108	74	85.3
6	61.2	2372	108	68	81.3

Tukey Procedure for Body Weight

	LC Group	HC Group
Differences Between Weekly Means	Q	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

Q = 4.20
df = 50
*p<.05

Tukey Procedure for Sodium Balance

Within Groups and Between Time	LC Group	HC Group
Differences Between Weekly Means	Q*	Q*
Week 1 diet and week 2 diet	5.84*	2.23
Week 1 diet and week 3 diet	2.66	.72
Week 1 diet and week 4 diet	4.09*	2.21
Week 2 diet and Week 3 diet	3.18	1.50
Week 2 diet and week 4 diet	1.76	0.02
Week 3 diet and week 4 diet	1.42	1.48

Between Groups	
Differences Between Weekly Means	Q
Week 1 LC and Week 1 HC	0.859
Week 2 LC and Week 2 HC	3.046*
Week 3 LC and Week 3 HC	1.235
Week 4 LC and Week 4 HC	1.169

*Q = 3.85 Q = 2.89
df = 30 df = 30
*p<.05 p<.05

Tukey Procedure for Serum Sodium

Within Groups and Between Time	LC Group	HC Group
Differences Between Weekly Means	Q*	Q*
Week 1 diet and week 2 diet	2.704	3.167
Week 1 diet and week 3 diet	4.279*	4.011
Week 1 diet and week 4 diet	4.789*	5.467*
Week 1 diet and Week 5 diet	6.484*	5.746*
Week 2 diet and week 3 diet	1.576	0.844
Week 2 diet and week 4 diet	2.085	2.300
Week 2 diet and week 5 diet	3.780	2.579
Week 3 diet and week 4 diet	0.509	1.456
Week 3 diet and week 5 diet	2.204	1.735
Week 4 diet and week 5 diet	1.695	0.279

Between Groups	
Differences Between Weekly Means	Q
Week 1 LC and Week 1 HC	0.1276
Week 2 LC and Week 2 HC	0.1118
Week 3 LC and Week 2 HC	0.6687
Week 4 LC and Week 4 HC	0.0036
Week 5 LC and Week 5 HC	1.1106

*Q = 4.04 Q = 2.86
df = 40 df = 40
*p<.05 p<.05

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 under water 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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