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MANIPULATION OF MUSCLE GLYCOGEN CONCENTRATIONS USING HIGH AND LOW CARBOHYDRATE DIETS AND EXERCISE

U S ARMY RESEARCH INSTITUTE
OF
ENVIRONMENTAL MEDICINE
Natick, Massachusetts

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The Military Nutrition Division of the U.S. Army Research Institute of Environmental Medicine (USARIEM) provided dietary support for a study conducted by the Military Ergonomics Division of USARIEM entitled, "The Influence of Muscle Glycogen Levels on Shivering and Temperature Regulation During Cold Water Immersion". This study was designed to investigate the effect of muscle glycogen levels on body temperature homeostasis in man acutely exposed to cold, with alterations in muscle glycogen levels experimentally induced by exercise and dietary manipulation. over

Between August 1986-January 1987, 10 male soldiers from the Natick Research, Development, and Engineering Center (NRD&EC) volunteered as test subjects for two 5-day tests. During Phase 1 (Glycogen Depletion Phase), muscle glycogen levels were experimentally depleted through prolonged daily submaximal exercise bouts and provision of an average of 3039 kcal in the form of a low carbohydrate (115 g) mixed diet. During Phase 2 (Carbohydrate Loading Phase), the test subjects performed no formal exercises, were provided an average of

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3238 kcal and were provided a high carbohydrate (515 g) mixed diet in an attempt to increase muscle glycogen concentrations above normal levels. Each phase was separated by a one week rest period and the order of the two phases was varied randomly among test subjects with 7 of the 10 subjects undergoing the Glycogen Depletion Phase first.

The results of muscle biopsies taken from each test subject after each phase indicated that the exercise and dietary manipulation were effective in depleting muscle glycogen concentrations as well as repleting levels above what would be expected as normal concentrations in untrained subjects. The mean muscle glycogen level after the Glycogen Depletion Phase was 41.87 $\pm$ 5.98 mmol glycogen/kg wet weight of the muscle (mean $\pm$ SD). After the Carbohydrate Loading Phase, the mean muscle glycogen level was 126.95 $\pm$ 10.6 mmol glycogen/kg wet weight. Normal muscle glycogen concentrations range between 80-90 mmol/kg wet weight and 120-130 mmol/kg wet weight in untrained and trained individuals respectively.

The results of the dietary efforts supported the findings of other investigators that muscle glycogen levels can be increased by consumption of a high carbohydrate diet (in conjunction with a reduction of physical exercise), without necessarily having to stimulate the muscle for supercompensation via a depletion phase immediately preceding the loading phase as has been recommended for glycogen loading in the past. A series of practical high and low carbohydrate diets were developed using foods that can be easily obtained from commercial "supermarket" sources. These diets require minimal preparation and can be effectively utilized in metabolic ward studies or by athletes preparing for endurance events requiring replete muscle glycogen levels prior to competion.

HUMAN RESEARCH and DISCLAIMER STATEMENTS

Human Subjects participated in this study after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

MANIPULATION OF MUSCLE GLYCOGEN CONCENTRATIONS USING HIGH AND LOW CARBOHYDRATE DIETS AND EXERCISE

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FOREWORD

The data for this report were obtained during a study conducted 11 Aug 1986 to 29 Jan 1987 by the Military Ergonomics Division of the U.S. Army Research Institute of Environmental Medicine (USARIEM) under the protocol "The Influence of Muscle Glycogen Level on Shivering and Temperature Regulation During Cold Water Immersion." The metabolic results of this study will be published in other appropriate reports by the principal investigator, Dr. Andrew Young. The Military Nutrition Division assisted Military Ergonomics by designing menus, preparing test subject meals and recording food and nutrient intakes. Considerable effort went into designing palatable diets that would effectively control the amount of dietary carbohydrate offered to the test subjects. The purpose of this report is to document the effectiveness of these diets in altering muscle glycogen levels when accompanied by an appropriate exercise regimen. It is hoped that the menus published in this report may be useful in subsequent metabolic studies requiring high or low carbohydrate diets.

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ABSTRACT

The Military Nutrition Division of the U.S. Army Research Institute of Environmental Medicine (USARIEM) provided dietary support for a study conducted by the Military Ergonomics Division of USARIEM entitled, "The Influence of Muscle Glycogen Level on Shivering and Temperature Regulation During Cold Water Immersion." This study was designed to investigate the effect of muscle glycogen levels on body temperature homeostasis in man acutely exposed to cold, with alterations in muscle glycogen levels experimentally induced by exercise and dietary manipulation.

Between August 1986-January 1987, 10 male soldiers from the Natick Research, Development, and Engineering Center (NRD&EC) volunteered as test subjects for two 5-day tests. During Phase 1 (Glycogen Depletion Phase), muscle glycogen levels were experimentally depleted through prolonged daily submaximal exercise bouts and provision of an average of 3039 kcal in the form of a low carbohydrate (115 g) mixed diet. During Phase 2 (Carbohydrate Loading Phase), the test subjects performed no formal exercises, were provided an average of 3238 kcal and were provided a high carbohydrate (515 g) mixed diet in an attempt to increase muscle glycogen concentrations above normal levels. Each phase was separated by a one week rest period and the order of the two phases was varied randomly among test subjects with 7 of the 10 subjects undergoing the Glycogen Depletion Phase first.

The results of muscle biopsies taken from each test subject after each phase indicated that the exercise and dietary manipulations were effective in depleting muscle glycogen concentrations as well as repleting levels above what would be expected as normal concentrations in untrained subjects. The mean

muscle glycogen level after the Glycogen Depletion Phase was 41.87 $\pm$ 5.98 mmol glycogen/kg wet weight of the muscle (mean $\pm$ SD). After the Carbohydrate Loading Phase, the mean muscle glycogen level was 126.95 $\pm$ 10.6 mmol glycogen/kg wet weight. Normal muscle glycogen concentrations range between 80-90 mmol/kg wet weight and 120-130 mmol/kg wet weight in untrained and trained individuals, respectively.

The results of the dietary efforts supported the findings of other investigators that muscle glycogen levels can be increased by consumption of a high carbohydrate diet (in conjunction with a reduction of physical exercise), without necessarily having to stimulate the muscle for supercompensation via a depletion phase immediately preceding the loading phase as has been recommended for glycogen loading in the past. A series of practical high and low carbohydrate diets were developed using foods that can be easily obtained from commercial "supermarket" sources. These diets require minimal preparation and can be effectively utilized in metabolic ward studies or by athletes preparing for endurance events requiring replete muscle glycogen levels prior to competition.

INTRODUCTION

Military operations are often conducted under cold weather conditions thus increasing the risk of accidental hypothermia for exposed personnel. Military troops at significant risk for hypothermia include: troops operating in severely cold regions such as the Arctic; troops operating in mild or moderately cold conditions who are also exposed to wet weather, river, or swamp operations; and military divers working in cold water. If the diet of these individuals is inadequate to offset the high energy expenditure required in their jobs, they may experience a reduced resistance to hypothermia since muscle metabolism is dependent on an adequate supply of energy substrate, and metabolic heat production increases through shivering. The overall purpose of this investigation was to study the role of muscle glycogen levels on body temperature regulation during cold stress. Since dietary and physical activity factors influence levels of muscle glycogen (1,2,4-7,9-11), it is important to know the effects of altered muscle glycogen on body temperature regulation during cold stress.

The dietary portion of the study dealt with altering muscle glycogen levels by altering the percent carbohydrate in the diet. The beneficial effects of dietary carbohydrates on muscle glycogen during exercise have been studied since the early 1900's when Zuntz (1901), Krogh and Lindhard (1920), Embden and Habs (1927), and Christensen and Hansen (1939) began to incorporate various types of carbohydrates into the diets of athletes (2,6). In the 1960's Bergstrom and Hultman tested a more exact relationship between diet and work performance. By developing and utilizing the technique of muscle biopsy to measure glycogen stores in muscle, they were able to determine that glycogen stores were the limiting factor in activities of high intensity and long duration (12). Since then, the role of diet and substrate utilization during exercise has been studied extensively. The technique of carbohydrate loading to increase muscle glycogen concentrations (glycogen supercompensation) is well known among researchers (1-7,9-19).

Muscle glycogen is the body's chief source of energy for prolonged exercise at relatively high intensity (65-85% VO_2 max.) Neither fat nor blood glucose is a primary energy source at high exercise intensities, thus muscle glycogen is the most readily available and easily metabolized fuel for exercise. Muscle glycogen stores are therefore a limiting factor for exercise at these intensities and are commonly depleted after 80-120 minutes of exercise (1). During continuous moderate exercise, ($\leq$60% of maximum work capacity or VO_2 max), energy is derived mainly from the breakdown of body stores of fat and carbohydrate. In the early stages of submaximal exercise, about 50-60% of the energy requirement is supplied by the glycogen stored in the exercising muscles and the liver (where it is hydrolyzed to glucose and transported to the muscles via blood.) As exercise continues and glycogen stores are reduced, an increasingly greater percentage of energy is supplied through fat metabolism (3,11). The liver normally contains about 270 mmol of glycogen/kg wet weight and muscle glycogen concentration is 80-90 mmol/kg wet weight and 120-130 mmol/kg wet weight in untrained and trained individuals, respectively (1). Thus less than 2000 calories are normally available from body stores of glycogen. However, the quantities of liver and muscle glycogen stores are in part dependent upon the fitness level of an individual with perhaps 20-50% higher concentrations in trained versus untrained individuals (2). The rate of glycogen utilization and subsequent depletion is also dependent upon the trained state of the individual with better trained individuals utilizing more fat than glycogen during exercise (14). Daily training workouts can deplete an individual's muscle glycogen reserves to less than 40-60 mmol glycogen/kg wet muscle weight (19). Daily training workouts and a diet deficient in carbohydrate can deplete muscle and liver glycogen and subsequently affect performance in intense, short-term exercise as well as in prolonged, submaximal endurance activities.

Mixed diets providing 50-70% carbohydrates have been shown to be sufficient for glycogen resynthesis (5). Others (1,4,5,8,19) recommend a diet of at least 70% carbohydrate, 525 g carbohydrate from a 3000 kcal mixed diet, or a minimum of 250-525 g carbohydrate from a 2500-4000 kcal diet (6). However, even when diets are high in carbohydrates (70%), muscle glycogen is not rapidly restored to pre-exercise levels. While muscle glycogen stores can be partially repleted within 24 hours when a 70% carbohydrate diet is consumed (4,9), at least 48 hours are required to completely restore initial muscle glycogen levels after prolonged, exhaustive exercise. Some individuals may require more than 5 days to re-establish muscle glycogen levels if their diet contains only moderate amounts of carbohydrate. In addition, at least 2 days of rest or light exercise and a high carbohydrate intake must be provided to re-establish the pre-exercise muscle glycogen levels (3).

Carbohydrate loading, or glycogen supercompensation, has been practiced for decades by endurance athletes who are attempting to increase muscle glycogen levels and thus increase physical endurance during prolonged aerobic training or competition. Glycogen supercompensation has been shown to increase glycogen concentrations (often to twice pre-existing levels) and therefore prolong exercise time to exhaustion (4). According to Costill and Miller (4), a high carbohydrate diet will not increase muscle glycogen stores above normal levels unless the diet is preceded by a large muscle glycogen depletion. If muscle glycogen stores are first depleted by exhaustive exercise, a diet rich in carbohydrate will return muscle glycogen to pre-exercise levels within 24 hours, and if continued for 2 more days, will elevate muscle glycogen to twice preexisting concentrations.

The classic procedure for achieving the supercompensation effect has been to reduce the muscle's glycogen content with prolonged steady-rate exercise about 6 days prior to the competitive event. Because glycogen supercompensation occurs only in exercised muscles, the individual must exercise those muscles that will be used in the event. The individual should maintain a low-carbohydrate (approximately 100 g), high protein, high fat diet for several days to further deplete glycogen stores. During this time, moderate exercise is continued. Then for at least 2-3 days the individual should consume a high carbohydrate (400-600 g) diet. The traditional muscle glycogen regimen would stimulate the depleted muscle to supercompensate or load up on muscle glycogen during the 3-4 days of the high carbohydrate diet. A moderate intake of protein and fat is needed to provide essential vitamins and minerals. Adequate fluids must also be consumed since 3 grams of water are stored with every 1 gram of glycogen (3).

This report will not encompass the metabolic results of this investigation, but will document the effectiveness of the diets in providing a deficit or surfeit of carbohydrate to the exercising or resting musculature.

METHOD

Test Subjects

Ten untrained male soldiers served as the test subjects for this study. Before experimental testing began, all subjects were fully informed of the nature of the study and the requirements for participation. Each subject was familiarized with all experimental procedures, was fully informed of his right to withdraw from the study at any time without prejudice, and signed the Volunteer Agreement of Participation.

Test Facility

Experimental testing by the Military Ergonomics Division of USARIEM was conducted at USARIEM. The NRD&EC Climatic Chamber Facility served as the designated site for all exercise sessions as well as the dormitory for the test subjects. All test subjects' meals and snacks were prepared and served to them in the kitchen facilities located in the Arctic Chamber of the Climatic Chamber Facility.

Study Design

Ten male test subjects were studied during two independent test phases (glycogen depleted and glycogen loaded) in a cross over design. Each test subject completed a cold-water stress test at the end of each phase. The order of presentation of the two phases was randomized among the subjects with 3 of the 10 (subjects 7,8,9) being tested under the glycogen loaded state first. During Phase 1 (Glycogen Depletion Phase), the test subjects were fed a low carbohydrate (15%), high fat (65%), high protein (20%) diet consisting of approximately 3039 kcal. The food was divided in 3 meals and 2 snacks each day for the 3 1/3 days of dietary manipulation. During the 3 days of Phase 1 the test subjects performed daily bouts of heavy exercise. For each of the 3 days, the subjects performed three 90 minute exercise sessions separated by 2 hour rest periods. Each of the 3 daily sessions included a different mode of exercise so as to achieve glycogen depletion in several different major muscle groups. Exercise modes included treadmill running, cycle ergometry, and rowing ergometry. All exercises were performed at an intensity eliciting a heart rate corresponding to approximately 75% of the individual's maximal heart rate which was determined during treadmill running. Each 90 minute session consisted of 3 repeats of 20 minute exercise and 10 minute rest periods. A minimum of 12 hours of recovery was allowed between completion of the last exercise session and the muscle biopsy and cold water stress test.

In Phase 2 (Carbohydrate Loading Phase), the test subjects engaged in no formal exercise, and were encouraged to refrain from heavy energy expenditure (i.e., long walks, physical training, etc.) During the 3 1/3 days of dietary manipulation they were fed a mixed diet consisting of approximately 3238 kcal each day with carbohydrates providing an average of 63%, fat 24%, and protein 13% of the daily calories. A variety of high carbohydrate food and beverage items were used to provide both simple sugars and complex carbohydrates in order to satisfy individual food preferences and encourage dietary compliance. Emphasis was placed on the provision of complex carbohydrates to provide more nutritionally dense foods and beverages and fewer "empty" calories. At the end of the 3 days the subjects underwent the same cold water stress test and muscle biopsy procedure.

The biopsy procedure of Bergstrom (7) was used to obtain samples of the vastus lateralis muscle which were frozen in liquid nitrogen until analysis for glycogen concentration (8). The results of the biopsies for each test subject can be seen in Table 7; the group mean and standard deviation contain the results for subjects #7 & #8 despite their noncompliance during Phase 1.

Menu Design

Prototype menus were provided by another research institute for the first 2 test subjects (#3 & #4), (Appendices A & B). A Registered Dietitian from USARIEM redesigned the menus for the remaining 8 test subjects (#5-12) while taking into account individual preferences and variety. A low carbohydrate 3 1/3 day menu cycle (Appendix C) was developed for the Glycogen Depletion Phase (Phase 1) of the study and a high carbohydrate 3 1/3 day menu cycle (Appendix D) was designed for use during the Carbohydrate Loading Phase (Phase 2). The low carbohydrate menus were designed to provide approximately 3000 calories each day with 15-20% (100-120 g) of those calories provided by carbohydrates, 15-20% from protein, and 65% from fat. The menus were designed to provide 3 meals and 2 snacks each day throughout the phase. The high carbohydrate menus were designed to provide approximately 3200 calories each day with 60-70% (450-550 g) of the total daily calories provided through carbohydrates, 10-15% from protein, and 20-30% from fat. During Phase 2, 3 meals and 3 snacks were provided each day. The 200 calorie difference between the two sets of menus was designed to insure palatability while remaining within the dietary constraints during the high fat, low carbohydrate phase.

Each test subject (with the exception of subjects #3 & #4) was personally interviewed by the Registered Dietitian one week prior to his participation. At this time, any food allergies or intolerances were identified as well as individual food likes and dislikes. To promote dietary compliance, (i.e., adequate consumption of carbohydrates during the loading phase, and adequate total caloric consumption during the depletion phase), menus were then modified by the Registered Dietitian to incorporate any necessary changes. If for any reason a test subject was unwilling to consume certain food(s) during a particular meal, a nutritionally equivalent food was substituted (Appendix F).

Food Consumption Data

The cycle menus developed for each dietary phase were utilized by the dietary data collectors responsible for the preparation and service of test subject meals. All foods were prepared and served in accordance with the gram weight and descriptive specifications of the particular meal for the particular test day and phase.

Each food and beverage item was weighed on a digital food balance (Sartorius, accurate ± 1.0 gram). Those foods that required cooking were weighed after preparation in order to provide the proper gram weight of each item to each test subject. The quantity of each food and beverage item served to each test subject was recorded by the dietary data collector on Ration Record forms (Appendix E) during meal preparation. Any additional items served (i.e., diet cola, unsweetened Kool-Aid) during a meal were weighed at that time and recorded by the dietary data collector and/or test subjects (each of whom was briefed on the use of the food balance).

All leftover food and/or beverage items were weighed and the remaining portion weight recorded on the respective test subject's Ration Record form for that particular meal. The difference between the served gram weight and returned gram weight was determined by the dietary data collector and used as the final gram weight consumed.

Each in-between meal snack was weighed, recorded, and left by the dietary data collector for the test subject's consumption between or after exercise bouts during Phase 1 (Glycogen Depletion Phase) and at the test subject's discretion during Phase 2 (Carbohydrate Loading Phase). Leftover portions from evening snacks were weighed and recorded by each test subject. Test subjects were instructed to consume only food items prepared for them during the 3 1/3 day dietary phases.

Nutrient Data Base

The University of Massachusetts Nutrient Data Bank was used to compute the nutrient composition of each food item used during the study. Any missing nutrient information on commercial products was obtained from food packaging labels and entered into the data base.

The actual consumption (gram weight) of each food/beverage item for each meal/day/phase was entered into each test subject's personal computer file. The calories provided, as well as the grams and percent of calories from carbohydrate, protein, and fat, were determined for each food and beverage item. Analysis of the total daily caloric consumption, the grams and percent of calories from carbohydrate, protein, and fat were determined for each test subject, for each meal, and for each day of both phases.

RESULTS

Total Calories

The mean total caloric intake during the Depletion Phase (Phase 1) was 2860 kcal. A comparison of the actual caloric intakes of the test subjects in this phase can be seen in Table 1 and Figure 1. Subjects #3 and #4 were given 2 servings of peanuts (80 g, 480 calories) each day to boost their total daily caloric intake as the original prototype menus (Appendix A) provided for an insufficient quantity. Because test subject #4 consumed an excess of peanuts on day 3 his caloric intake was boosted to 3826 calories on that day, influencing his and the overall mean caloric intake. During this phase, test subjects #7 & #8 were found to be noncompliant to the test diet but to what extent is unknown. Because individual preferences were incorporated into the test menus in an effort to enhance dietary compliance, the calories offered to each test subject varied slightly. Although approximately the same number of calories were provided to each test subject, variations in food consumption caused differences in caloric intake.

During the Carbohydrate Loading Phase (Phase 2) the mean caloric intake of all test subjects was 3244 calories. A comparison of the actual individual caloric intakes can be seen in Table 2 & Figure 1. Again, due to small differences in individual menu designs and the total caloric consumption of each test subject, caloric intakes differed slightly.

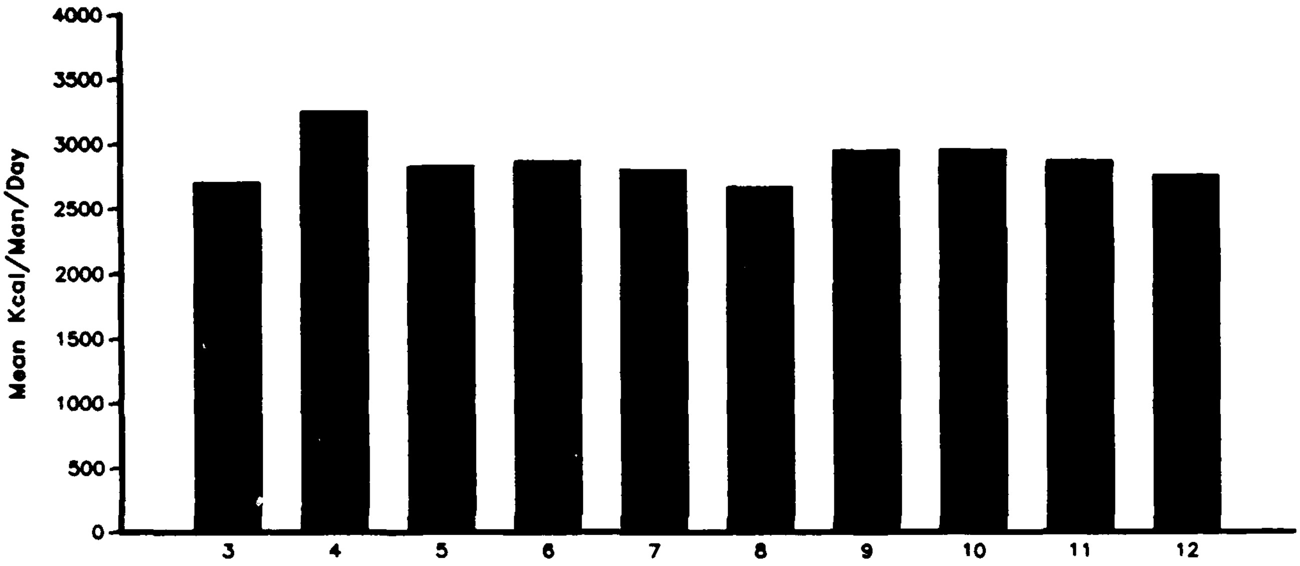
The distribution of calories from carbohydrate, protein, and fat can be seen for each test subject for each phase in Tables 1-6 and Figure 2. During Phase 1, the mean carbohydrate intake was 16.5%, protein 19.9%, and fat 64.8%.

FIGURE 1

GLYCOGEN STUDY

Kcalories

PHASE I
(Depletion)



PHASE II
(Loading)

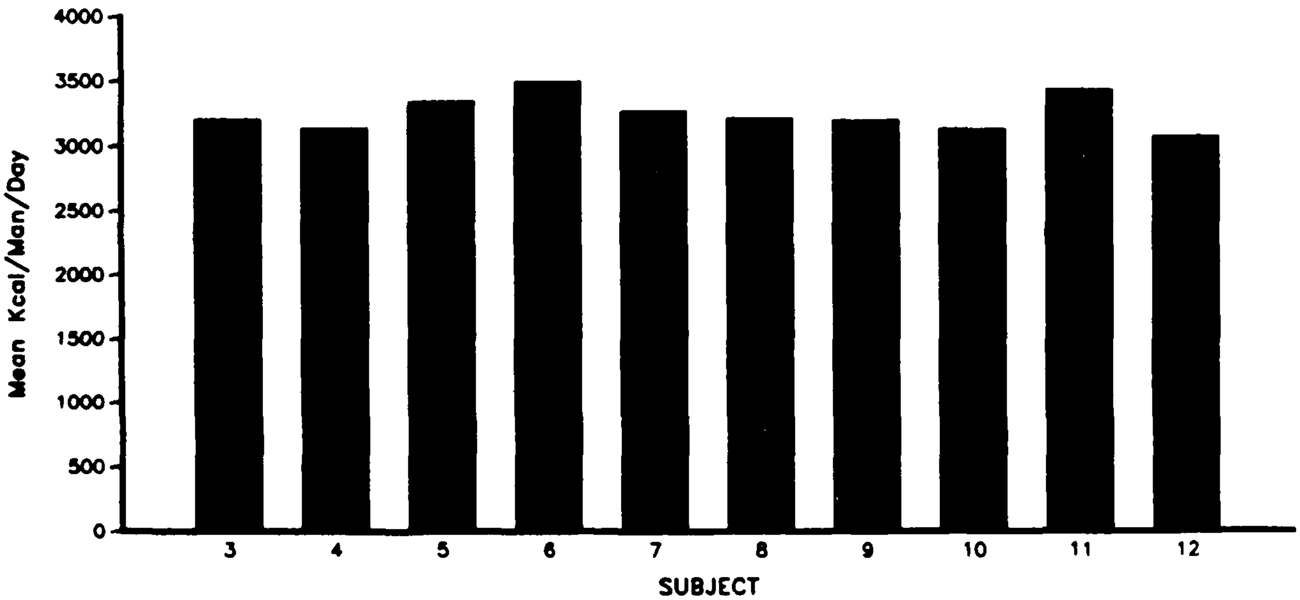


FIGURE 2

GLYCOGEN STUDY

Distribution of Kilocalories

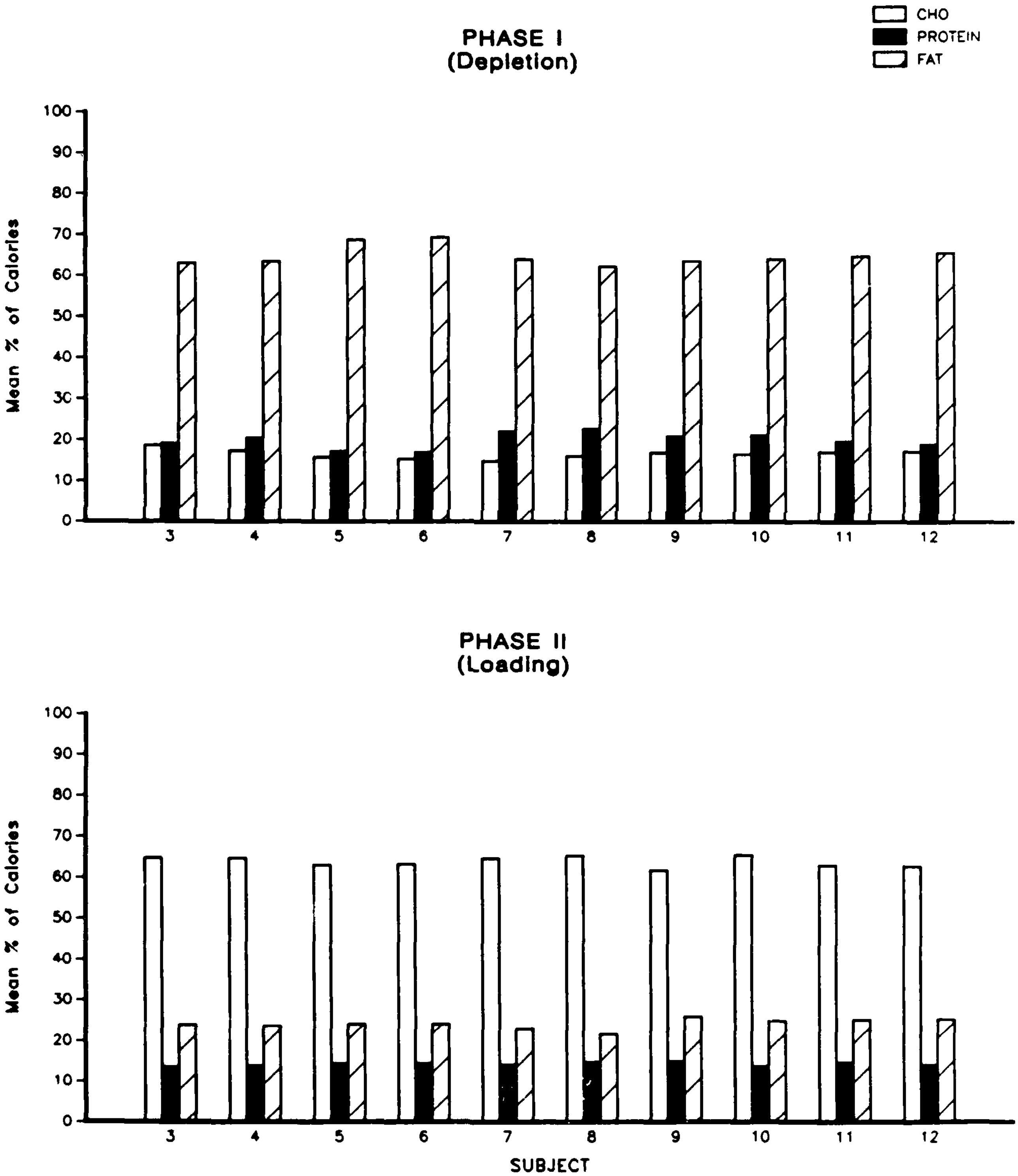


TABLE 1
PHASE ONE CARBOHYDRATE INTAKE

PHASE	SUBJECT	TEST DATE		CALORIES	CHO (GM)	% CHO CALORIES
1	3	2		3067.4	133.6	17.4
1	3	3		2492.3	115.8	18.6
1	3	4		2537.3	125.7	19.8
			MEAN	2699.0	125.0	18.6
1	4	2		3020.0	134.6	17.8
1	4	3		3826.5	152.3	15.9
1	4	4		2889.9	132.4	18.3
			MEAN	3245.4	139.7	17.3
1	5	2		2771.5	122.5	17.7
1	5	3		2818.3	104.9	14.9
1	5	4		2889.7	105.3	14.6
			MEAN	2826.5	110.9	15.7
1	6	2		2903.8	124.9	17.2
1	6	3		2802.2	102.7	14.7
1	6	4		2886.0	102.1	14.1
			MEAN	2864.0	109.9	15.3
1	7	6		2984.3	121.8	16.3
1	7	7		2844.6	96.3	13.5
1	7	8		2564.4	96.3	15.0
			MEAN	2797.7	104.6	14.9
1	8	6		2867.1	119.6	16.7
1	8	7		2811.8	107.4	15.3
1	8	8		2304.2	93.9	16.3
			MEAN	2661.0	106.9	16.1
1	9	6		2888.6	135.6	18.8
1	9	7		2983.0	115.1	15.4
1	9	8		2964.6	124.0	16.7
			MEAN	2945.4	124.9	16.9
1	10	2		2880.2	131.5	18.3
1	10	3		3004.3	112.9	15.0
1	10	4		2967.0	121.1	16.3
			MEAN	2950.5	121.8	16.5
1	11	2		2765.9	128.1	18.2
1	11	3		2950.2	114.5	15.5
1	11	4		2870.5	125.4	17.5
			MEAN	2862.2	122.0	17.2
1	12	2		2574.2	128.2	19.9
1	12	3		3183.6	115.3	14.5
1	12	4		2493.8	108.1	17.3
			MEAN	2750.5	117.2	17.2
			GROUP MEAN	2860.2	118.3	16.5

TABLE 2
PHASE TWO CARBOHYDRATE INTAKE

PHASE	SUBJECT	TEST DATE	CALORIES	CHO (GM)	% CHO CALORIES
2	3	6	3050.8	457.0	59.9
2	3	7	3250.2	516.6	63.6
2	3	8	3300.9	583.8	70.7
		MEAN	3200.6	519.1	64.7
2	4	6	2936.2	454.7	61.9
2	4	7	3187.7	501.3	62.9
2	4	8	3272.1	566.9	69.3
		MEAN	3132.0	507.6	64.7
2	5	6	3374.0	494.0	58.6
2	5	7	3410.5	529.1	62.1
2	5	8	3223.5	551.3	68.4
		MEAN	3336.0	524.8	63.0
2	6	6	3436.1	494.0	57.5
2	6	7	3440.7	534.5	62.1
2	6	8	3585.1	628.9	70.2
		MEAN	3487.3	552.4	63.2
2	7	2	3232.1	483.8	59.9
2	7	3	3449.9	547.0	63.4
2	7	4	3115.0	551.5	70.8
		MEAN	3265.6	527.4	64.7
2	8	2	3133.1	478.1	61.0
2	8	3	3302.0	538.1	65.2
2	8	4	3184.0	558.6	70.2
		MEAN	3206.3	524.9	65.4
2	9	2	2938.3	424.1	57.7
2	9	3	3282.7	484.5	59.0
2	9	4	3353.5	576.0	68.7
		MEAN	3191.5	494.8	61.8
2	10	6	3046.4	445.1	58.4
2	10	7	3117.9	487.1	62.5
2	10	8	3210.2	559.8	69.7
		MEAN	3124.8	497.3	63.5
2	11	6	3340.9	496.7	59.5
2	11	7	3492.1	548.7	62.9
2	11	8	3451.1	575.5	66.7
		MEAN	3428.0	540.3	63.0
2	12	6	2523.4	392.2	62.2
2	12	7	3382.6	514.3	60.8
2	12	8	3301.4	540.6	65.5
		MEAN	3069.1	482.3	62.8
		GROUP MEAN	3244.1	517.1	63.7

TABLE 3
PHASE ONE PROTEIN INTAKE

PHASE	SUBJECT	TEST DATE	CALORIES	PRO (GM)	% PRO CALORIES
1	3	2	3067.4	148.3	19.3
1	3	3	2492.3	112.2	18.0
1	3	4	2537.3	128.3	20.2
		MEAN	2699.0	129.6	19.1
1	4	2	3020.0	150.8	20.0
1	4	3	3826.5	198.7	20.8
1	4	4	2889.9	148.7	20.6
		MEAN	3245.4	166.0	20.4
1	5	2	2771.5	127.4	18.4
1	5	3	2818.3	117.0	16.6
1	5	4	2889.7	120.8	16.7
		MEAN	2826.5	121.7	17.2
1	6	2	2903.8	126.9	17.5
1	6	3	2802.2	115.9	16.5
1	6	4	2886.0	120.5	16.7
		MEAN	2864.0	121.1	16.9
1	7	6	2984.3	150.8	20.2
1	7	7	2844.6	139.4	19.6
1	7	8	2564.4	170.2	26.5
		MEAN	2797.7	153.4	22.1
1	8	6	2867.1	149.6	20.9
1	8	7	2811.8	142.5	20.3
1	8	8	2304.2	155.1	26.9
		MEAN	2661.0	149.0	22.7
1	9	6	2888.6	144.4	20.0
1	9	7	2983.0	137.7	18.5
1	9	8	2964.6	179.4	24.2
		MEAN	2945.4	153.8	20.9
1	10	2	2880.2	148.3	20.6
1	10	3	3004.3	138.6	18.5
1	10	4	2967.0	179.2	24.2
		MEAN	2950.5	155.3	21.1
1	11	2	2765.9	143.3	20.7
1	11	3	2950.2	128.7	17.5
1	11	4	2870.5	151.6	21.1
		MEAN	2862.2	141.2	19.7
1	12	2	2574.2	130.6	20.3
1	12	3	3183.6	143.2	18.0
1	12	4	2493.8	117.3	18.8
		MEAN	2750.5	130.3	19.0
		GROUP MEAN	2860.2	142.8	19.9

TABLE 4
PHASE TWO PROTEIN INTAKE

PHASE	SUBJECT	TEST DATE	CALORIES	PRO (GM)	% PRO CALORIES
2	3	6	3050.8	121.2	15.9
2	3	7	3250.2	113.7	14.0
2	3	8	3300.9	88.8	10.8
		MEAN	3200.6	107.9	13.5
2	4	6	2936.2	117.7	16.0
2	4	7	3187.7	113.0	14.2
2	4	8	3272.1	92.2	11.3
		MEAN	3132.0	107.6	13.8
2	5	6	3374.0	138.7	16.4
2	5	7	3410.5	134.2	15.7
2	5	8	3223.5	90.4	11.2
		MEAN	3336.0	121.1	14.4
2	6	6	3436.1	140.1	16.3
2	6	7	3440.7	134.8	15.7
2	6	8	3585.1	101.0	11.3
		MEAN	3487.3	125.3	14.4
2	7	2	3232.1	136.8	16.9
2	7	3	3449.9	118.8	13.8
2	7	4	3115.0	92.5	11.9
		MEAN	3265.7	116.0	14.2
2	8	2	3133.1	134.7	17.2
2	8	3	3302.0	128.3	15.5
2	8	4	3184.0	93.5	11.7
		MEAN	3206.3	118.8	14.8
2	9	2	2938.3	126.9	17.3
2	9	3	3282.7	132.3	16.1
2	9	4	3353.5	94.9	11.3
		MEAN	3191.5	118.0	14.9
2	10	6	3046.4	120.6	15.8
2	10	7	3117.9	102.1	13.1
2	10	8	3210.2	93.9	11.7
		MEAN	3124.3	105.5	13.5
2	11	6	3340.9	127.2	15.2
2	11	7	3492.1	130.2	14.9
2	11	8	3451.1	117.3	13.6
		MEAN	3428.0	124.9	14.5
2	12	6	2523.4	79.3	12.6
2	12	7	3382.6	131.9	15.6
2	12	8	3301.4	113.1	13.7
		MEAN	3069.1	108.1	13.9
		GROUP MEAN	3244.1	115.4	14.2

TABLE 5
PHASE ONE FAT INTAKE

PHASE	SUBJECT	TEST DATE	CALORIES	FAT (GM)	% FAT CALORIES
1	3	2	3067.4	218.4	64.1
1	3	3	2492.3	177.8	64.2
1	3	4	2537.3	171.7	60.9
		MEAN	2699.0	189.3	63.0
1	4	2	3020.0	212.2	63.3
1	4	3	3826.5	276.6	65.1
1	4	4	2889.9	199.0	62.0
		MEAN	3245.4	229.2	63.4
1	5	2	2771.5	201.2	65.3
1	5	3	2818.3	220.4	70.4
1	5	4	2889.7	226.2	70.5
		MEAN	2826.5	215.9	68.7
1	6	2	2903.8	216.3	67.0
1	6	3	2802.2	219.0	70.3
1	6	4	2886.0	226.1	70.5
		MEAN	2864.0	220.4	69.2
1	7	6	2984.3	216.5	65.3
1	7	7	2844.6	214.8	67.9
1	7	8	2564.4	167.8	58.9
		MEAN	2797.7	199.7	64.0
1	8	6	2867.1	204.1	64.1
1	8	7	2811.8	204.6	65.5
1	8	8	2304.2	146.1	57.1
		MEAN	2661.0	184.9	62.2
1	9	6	2888.6	202.0	62.9
1	9	7	2983.0	225.1	67.9
1	9	8	2964.6	197.8	60.0
		MEAN	2945.4	208.3	63.6
1	10	2	2880.2	201.9	63.1
1	10	3	3004.3	228.1	68.3
1	10	4	2967.0	200.1	60.7
		MEAN	2950.5	210.0	64.0
1	11	2	2765.9	193.5	63.0
1	11	3	2950.2	225.0	68.6
1	11	4	2870.5	199.3	62.5
		MEAN	2862.2	205.9	64.7
1	12	2	2574.2	177.6	62.1
1	12	3	3183.6	244.6	69.2
1	12	4	2493.8	180.9	65.3
		MEAN	2750.5	201.0	65.5
		GROUP MEAN	2860.2	206.5	64.8

TABLE 6
PHASE TWO FAT INTAKE

PHASE	SUBJECT	TEST DATE		CALORIES	FAT (GM)	% FAT CALORIES
2	3	6		3050.8	90.3	26.7
2	3	7		3250.2	88.4	24.5
2	3	8		3300.9	75.2	20.5
			MEAN	3200.6	84.6	23.9
2	4	6		2936.2	80.3	24.6
2	4	7		3187.7	88.0	24.8
2	4	8		3272.1	77.4	21.3
			MEAN	3132.0	81.9	23.5
2	5	6		3374.0	97.8	26.1
2	5	7		3410.5	91.4	24.1
2	5	8		3223.5	78.4	21.9
			MEAN	3336.0	89.2	24.0
2	6	6		3436.1	104.7	27.4
2	6	7		3440.7	91.9	24.0
2	6	8		3585.1	82.0	20.6
			MEAN	3487.3	92.8	24.0
2	7	2		3232.1	86.8	24.2
2	7	3		3449.9	95.1	24.8
2	7	4		3115.0	68.1	19.7
			MEAN	3265.6	83.3	22.9
2	8	2		3133.1	80.0	23.0
2	8	3		3302.0	78.5	21.4
2	8	4		3184.0	72.4	20.5
			MEAN	3206.3	76.9	21.6
2	9	2		2938.3	91.2	27.9
2	9	3		3282.7	99.0	27.1
2	9	4		3353.5	83.1	22.3
			MEAN	3191.5	91.1	25.7
2	10	6		3046.4	90.6	26.8
2	10	7		3117.9	91.7	26.5
2	10	8		3210.2	74.5	20.9
			MEAN	3124.8	85.6	24.7
2	11	6		3340.9	103.8	28.0
2	11	7		3492.1	94.1	24.3
2	11	8		3451.1	85.8	22.4
			MEAN	3428.0	94.5	24.9
2	12	6		2523.4	76.6	27.3
2	12	7		3382.6	95.5	25.4
2	12	8		3301.4	82.6	22.5
			MEAN	3069.1	84.9	25.0
			GROUP MEAN	3244.1	86.5	24.6

In Phase 2, the mean carbohydrate intake contributed 63.7% of the mean total daily calories consumed, protein 14.2%, and fat 24.0%.

Carbohydrate Intake

Phase 1

The combined effects of carbohydrate intake and physical activity regimens on glycogen concentration are reflected in the muscle samples obtained by the biopsies of the vastus lateralis muscle (Table 7). When test subjects were engaged in prolonged, submaximal (75% VO_2 max) aerobic activity to promote muscle glycogen depletion, dietary carbohydrate intake was kept low. The mean dietary carbohydrate intake for all test subjects was 118.3 g or 16.5% of the total daily calories (Table 1, Figure 3). Low carbohydrate intake in conjunction with the submaximal aerobic activity markedly depleted muscle glycogen levels to a mean of 41.87 $\pm$ 5.98 mmol glycogen/kg wet muscle weight during this phase. During this phase of the study, a maximum of 12-15 hours rest was allowed between test days, thus both insufficient carbohydrates and glycogen repletion time were allowed. The muscle biopsy results for 2 subjects (#7 & #8) were higher than the other test subjects because they did not comply with the test diet rules. The group mean and standard deviation of muscle glycogen concentrations would have been lower if the data for subjects #7 & #8 had been excluded.

Phase 2

In the carbohydrate loading phase, the mean carbohydrate intake of the test subjects was 517 g, which contributed 63.7% of their total mean caloric intake. Daily carbohydrate intake can be seen in Table 2 & Figure 3. The amount of carbohydrate provided during this study and the sedentary activity program were apparently adequate to increase muscle glycogen concentrations (126 $\pm$ 10.6 mmol glycogen/kg wet muscle weight) to levels which were significantly ($p < 0.01$) greater than would be expected in untrained individuals (Table 7). The values during the Carbohydrate Loading Phase were 57.8% higher than normal values (80-90 mmol/kg wet muscle weight) for untrained individuals and within the normal range for trained individuals.

Table 7

MUSCLE GLYCOGEN CONTENT OF VASTUS LATERALIS MUSCLE BIOPSIES[1]

Test Subject	Muscle Glycogen (mmol glycogen/kg wet weight muscle)	
	Phase 1 (Glycogen Depletion)	Phase 2 (Carbohydrate Loading)
3	32.1	182.8
4	40.0	184.2
5	21.5	139.8
6	25.3	93.6
7*	83.0	103.6
8*	69.7	107.1
9	44.1	92.8
10	43.4	113.3
11	33.3	117.3
12	26.3	135.0
Mean	41.8	126.0
SD	5.9	±10.6

[1]Mean values ± SD are shown for both phases. These two means were significantly different, $p < 0.01$.

*Subjects did not comply with test diet during the Glycogen Depletion Phase (Phase 1).

DISCUSSION

The purpose of this report is to document the effectiveness of controlling the amount of dietary carbohydrate to alter muscle glycogen levels. During the classical glycogen supercompensation process, the type of carbohydrate (simple or complex) fed during the glycogen loading phase does not seem to affect the glycogen levels during the first 24 hours of refeeding. However, during the next 24 hours, glycogen restoration is significantly greater with a diet high in complex carbohydrates (3). During the carbohydrate loading phase of this study, the test subjects were provided with a variety of foods and beverages high in carbohydrates in the form of simple sugars (i.e., sucrose, fructose, lactose) and complex carbohydrates (i.e., starches, dietary fiber). Emphasis was placed on the provision of complex carbohydrates to help insure nutritional adequacy. Foods high in simple sugars were added to the diet to increase overall palatability and acceptability (Appendices C & D).

Unpleasant side-effects such as fatigue, nausea, dizziness, irritability, hunger, etc. may be experienced because of the marked ketosis associated with a low carbohydrate, high fat diet (4, 11). Therefore, the classical glycogen loading method is recommended only for those individuals who are engaged in competitive endurance events, and should be limited to no more than 2-3 times per year. During Phase 1, an average of 118 grams of dietary carbohydrate was provided to supply the necessary 100 grams glucose/day required for neurological function (11), to minimize the symptoms of severe carbohydrate restriction, and to avoid drawing on amino acid reserves. The 15% carbohydrate diet provided the minimal amount of glucose necessary to maintain the proper functioning of the central nervous system, spare the break down of muscle protein, and preserve normal fat metabolism, yet this amount of dietary carbohydrate was insufficient for optimal glycogen resynthesis as demonstrated by muscle glycogen concentrations (Table 8).

The side-effects of ketosis induced by a low carbohydrate intake can be avoided by following a modified glycogen loading regimen. Although researchers (2,4,10) have indicated that the depletion phase is essential to stimulate the supercompensation effect of glycogen loading, others (2,3) report that a normal mixed diet containing 50-70% of calories from carbohydrate can produce the same high level of muscle glycogen storage without previous glycogen depletion. Maintaining a carbohydrate-rich diet for several days will enhance the body's carbohydrate stores to a level almost twice that obtained with a normal, well-balanced diet (3). In the present study, there was no stimulus for supercompensation of muscle glycogen because the Carbohydrate Loading Phase did not immediately follow the Glycogen Depletion Phase and in fact preceded it for some subjects. The results of this study confirm the findings of other researchers that adequate muscle glycogen levels can be achieved when a high carbohydrate mixed diet is provided without previously depleting muscle glycogen stores, but reducing physical activity. The current emphasis for increasing muscle glycogen stores is now placed upon reducing the intensity and duration of training to minimize daily burn-off of both muscle and liver glycogen stores while increasing the percent of carbohydrate in the diet. The high carbohydrate diet provided to the test subjects, along with their light activity schedule, was apparently sufficient to elevate glycogen levels above normal concentrations without the stimulus for supercompensation provided by a depletion phase.

Table 8

CARBOHYDRATE INTAKE AND MUSCLE GLYCOGEN CONCENTRATION

PHASE ONE

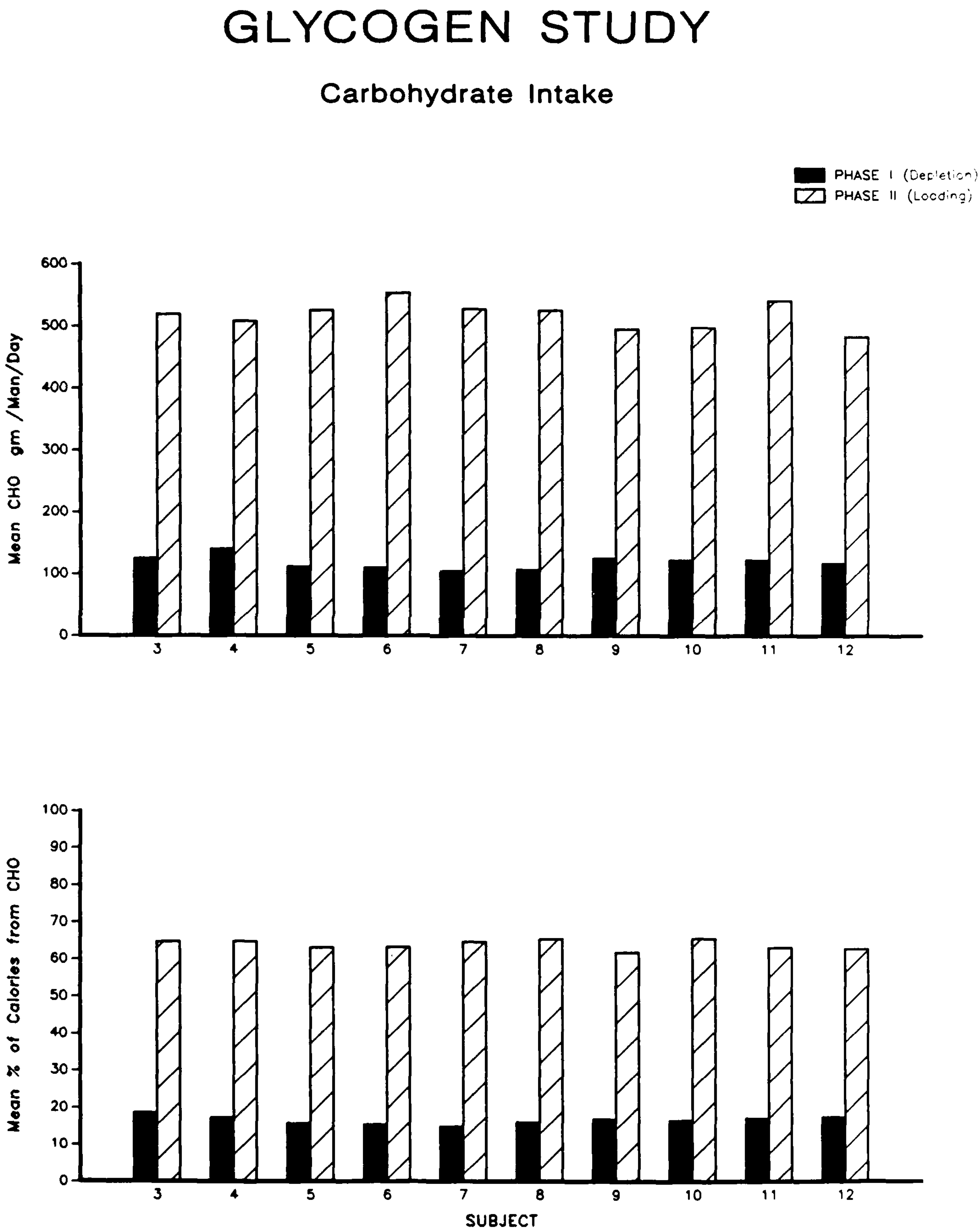
Subject Number	Carbohydrate Intake (g)	mmol glycogen/kg wet weight muscle
3	125.0	32.1
4	139.7	40.0
5	110.9	21.5
6	109.0	25.3
7*	104.8	83.0
8*	106.9	69.7
9	124.9	44.1
10	121.8	43.4
11	122.0	33.3
12	117.2	26.3

PHASE TWO

Subject Number	Carbohydrate Intake (g)	mmol glycogen/kg wet weight muscle
3	519.1	182.8
4	507.6	184.2
5	524.8	139.8
6	552.4	93.6
7	527.4	103.6
8	524.9	107.1
9	494.8	92.8
10	497.3	113.3
11	540.3	117.3
12	482.3	135.0

*Subjects noncompliant to test diet during the Glycogen Depletion Phase (Phase 1).

FIGURE 3


GLYCOGEN STUDY
Carbohydrate Intake
PHASE I (Depletion)
PHASE II (Loading)
600
500
400
300
200
100
0
Mean CHO gm /Man/Day
3
4
5
6
7
8
9
10
11
12
100
90
80
70
60
50
40
30
20
10
0
Mean % of Calories from CHO
SUBJECT

SUMMARY

As part of a larger study in which shivering thermogenesis and the rate of body cooling during cold water immersion were studied in men with high and low muscle glycogen levels, the Military Nutrition Division of USARIEM planned and prepared meals to control the carbohydrate intakes of 10 military test subjects. Personalized test menus were developed for each test subject (with the exception of subjects #3 & #4) for both phases of this study.

In Phase 1 (Glycogen Depletion Phase), a low carbohydrate (115 g) diet along with prolonged daily submaximal exercise served to decrease muscle glycogen concentrations to below normal levels. During Phase 2 (Carbohydrate Loading Phase) a high carbohydrate (515 g) diet was sufficient to increase muscle glycogen levels to above normal levels in untrained subjects without the stimulus of an initial glycogen depletion phase. In this study the Carbohydrate Loading Phase did not immediately follow the Glycogen Depletion Phase; a one week or more rest period was scheduled between phases. In addition, 3 of the 10 test subjects participated in the Loading Phase first, followed by the Depletion Phase. This randomized protocol was chosen in view of the scientific literature (2,3) which states that enhanced muscle glycogen concentrations can be achieved through a high carbohydrate diet (low-moderate exercise) without previous depletion phase.

Several menu cycles were developed that were effective in providing high or low carbohydrate diets utilizing commercially available foods that were familiar and palatable to the test subjects. These diets could be utilized in future metabolic studies requiring diets that are effective in promoting changes in muscle glycogen concentrations.

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APPENDIX A

Original Low Carbohydrate Meal Plan Utilized For Test Subjects 3 & 4

Breakfast	Amount	Kcal	Pro(g)	Fat(g)	CHO(g)
Egg, scrambled	50 g	79.0	6.0	5.6	0.6
Butter	5 g	65.9	0.1	7.5	0.0
Coffee, regular	180 g	3.0	0.0	0.0	0.5
Cream, half-half	11 g	28.6	0.7	2.5	0.9
Bagel	66 g	85.0	3.5	0.5	17.0
Cream Cheese	15 g	53.0	1.1	5.2	0.4
Subtotals:		314.5	11.5	21.3	19.5
Lunch					
Cream Mushroom Soup	197 g	196.0	2.0	12.0	14.0
Lettuce Salad	50 g	19.8	1.5	0.3	3.1
Italian Salad Drsg	28 g	392.5	0.5	40.5	8.5
Tuna Salad	78 g	205.2	17.0	14.8	0.5
Saltine Crackers	12 g	44.1	0.9	1.2	7.4
Cole Slaw	73 g	182.0	2.5	16.4	7.9
Coffee, regular	180 g	3.0	0.0	0.0	0.5
Cheddar Cheese	15 g	121.0	7.5	9.9	0.4
Subtotals:		1166.7	31.9	95.2	42.9
Dinner					
Tenderloin, broiled	100 g	259.5	30.2	14.5	0.0
Baked Potato	155 g	85.7	2.5	0.1	19.3
Sour Cream	15 g	64.2	0.9	6.3	1.3
Asparagus, frozen	100 g	24.0	3.2	0.2	4.1
Butter	5 g	65.9	0.1	7.5	0.0
Chocolate Ice Cream	100 g	333.3	3.8	12.0	24.6
Subtotals:		832.7	40.7	40.6	49.3
Day Totals:		2198	84.2	157.2	111.7
% of Calories:			15.3	64.4	20.3

APPENDIX B

Original High Carbohydrate Meal Plan Utilized For Test Subjects 3 & 4

DAY 1

Breakfast	Amount	Kcal	Pro(g)	Fat(g)	CHO(g)
Orange Juice	124 g	55.8	0.8	0.1	13.4
Bran Muffin	89 g	244.1	5.5	8.5	41.0[A
Grape Jelly	15 g	41.0	0.0	0.0	10.6
Corn Flakes Cereal	28 g	80.0	2.0	0.0	18.0
Milk, Whole	244 g	150.0	8.0	8.1	11.4
Sugar	4 g	15.4	0.0	0.0	3.9
Subtotals:		586.3	16.4	16.7	98.4
Lunch					
Sliced Ham on Rye Bread	60 g	216.6	14.5	6.8	24.9
Lettuce Salad	50 g	6.6	0.5	0.1	1.0
French Lite Salad Drsg	28 g	37.6	0.0	1.6	6.0
Cream Tomato Soup	200 g	106.8	1.9	1.9	20.4
Melba Toast Crackers	4 pc	70.0	2.0	0.0	12.0
Subtotals:		437.6	19.0	10.5	64.4
Afternoon Snack					
Protein Free Pudding	90 g	131.8	0.4	3.7	24.8
Apple Juice	124 g	58.3	0.1	0.1	14.5
Subtotals:		190.0	0.5	3.8	39.3
Dinner					
Poached Haddock	150 g	118.5	27.5	0.2	0.0
White Rice	30 g	221.4	4.4	0.2	48.7
Stewed Tomatoes	1 pc	26.0	0.9	0.1	6.5
Angel Food Cake	34 g	176.2	3.8	0.1	40.4
Fresh Fruit	1 pc	40.0	0.0	0.0	10.0
Subtotals:		582.1	36.7	0.6	105.6
Evening Snack					
Peanut Butter/Jelly Sndwch	1	317.2	12.1	15.6	34.1
Pineapple Chunks	100 g	60.0	0.4	0.1	15.7
Subtotals:		377.2	12.5	15.7	49.8
Day Totals:		2173.3	85.2	47.5	357.6
% of Calories:			15.7	19.7	65.8

APPENDIX B

Original High Carbohydrate Meal Plan Utilized For Test Subjects 3 & 4

DAY 2

Breakfast	Amount	Kcal	Pro(g)	Fat(g)	CHO(g)
Bagel	66 g	170.0	7.0	1.0	34.0
Cream Cheese	15 g	53.0	1.1	5.3	0.4
Grape Jelly	15 g	82.0	0.0	0.0	21.1
Orange Juice	124 g	55.8	0.8	0.1	13.4
Grapefruit	.5	35.7	0.6	0.1	8.1
Honey	15 g	45.6	0.0	0.0	12.3
Subtotals:		442.1	9.7	6.5	89.4
Morning Snack					
Fruited Yogurt	240 g	263.0	10.0	3.0	49.0
Honey	15 g	45.6	0.0	0.0	12.3
Apple Juice	124 g	58.3	0.0	0.1	14.4
Subtotals:		366.9	10.1	3.1	75.8
Lunch					
Turkey Breast	90 g	141.3	26.9	2.9	0.0
Lettuce Salad	50 g	6.6	0.5	0.1	1.0
Italian Lite Salad Drsg	28 g	59.0	0.0	5.5	2.7
Wheat Bread	21 g	104.0	4.5	1.3	20.4
Fresh Fruit	1 pc	40.0	0.0	0.0	10.0
Cranberry Juice	126 g	73.3	0.0	0.0	18.8
Subtotals:		424.2	32.0	9.8	52.9
Dinner					
Spaghetti/Mtbls/Sce		487.3	22.9	23.1	44.7
Broccoli, frozen	1 sk	29.0	3.0	0.3	5.3
Garlic Bread	33 g	116.0	2.6	4.9	15.3
Vegetable Soup	150 g	67.0	2.0	1.0	11.0
Melba Toast Crackers	4 pc	70.0	2.0	0.0	12.0
Fresh Fruit	1 pc	40.0	0.0	0.0	10.0
Subtotals:		809.3	32.6	29.4	98.4
Evening Snack					
Protein Free Pudding	90 g	131.8	0.4	3.7	24.8
Apple Juice	124 g	58.3	0.1	0.1	14.5
Subtotals:		190.0	0.5	3.8	39.3
Day Totals:		2232.6	84.9	52.7	355.9
% of Calories:			15.2	21.2	63.7

APPENDIX B

Original High Carbohydrate Meal Plan Utilized For Test Subjects 3 & 4

DAY 3

Breakfast	Amount	Kcal	Pro(g)	Fat(g)	CHO(g)
Pancakes	96 g	327.6	7.9	1.6	69.6
Maple Syrup	28 g	141.2	0.0	0.0	36.4
Orange Juice	124 g	55.8	0.8	0.1	13.4
Milk, Whole	244 g	150.0	8.0	8.1	11.4
Subtotals:		674.6	16.8	9.8	130.8
Lunch					
Roast Beef on Wheat	60 g	217.0	23.2	5.0	20.4
Chef Salad-Base	175 g	27.3	1.7	0.3	4.8
Italian Lite Salad Drsg	28 g	29.5	0.0	2.7	1.4
Tomato	42 g	8.0	0.4	0.1	1.8
Milk, Low-fat	246 g	119.0	9.7	2.8	13.6
Subtotals:		400.8	35.1	11.1	49.1
Afternoon Snack					
Fruited Yogurt	240 g	263.0	10.0	3.0	49.0
Dinner					
Chicken Noodle Soup	205 g	106.0	2.0	1.0	20.0
Saltine Crackers	12 g	44.2	0.9	1.2	7.4
Vegetable Sandwich Pocket	1	407.2	16.5	13.0	55.8
Apple Crisp	149 g	279.2	2.2	10.4	46.5
Water	210 g	0.0	0.0	0.0	0.0
Subtotals:		836.6	21.7	25.7	129.7
Evening Snack					
Peach Slices, Ice pack	60 g	45.0	0.6	0.1	11.6
Day Totals:		2220.0	84.2	49.7	363.1
% of Calories:			15.2	20.2	65.4

APPENDIX C

PHASE ONE   LOW CARBOHYDRATE DIET -- SAMPLE MENUS DEVELOPED BY USARIEM

DAY	MEAL	SIX CODE	FOOD NAME	AMT (gm)	KCAL	PRO (gm)	FAT (gm)	CHO (gm)
1	DINNER	003100	BEEF BROILED HIP SIRLOIN	227.0	544.8	67.6	28.4	0.0
1	DINNER	811403	POTATO FRENCH FRIED FZN NO SA	85.0	188.7	2.9	7.4	28.8
1	DINNER	811252	LETTUCE	75.0	9.8	0.8	0.1	1.6
1	DINNER	811529	TOMATO,RED,RIPE,RAW	50.0	9.5	0.4	0.1	2.2
1	DINNER	022861	CATSUP	30.0	31.8	0.6	0.1	7.6
1	DINNER	809326	WATERMELON	160.0	51.2	1.0	0.7	11.5
1	DINNER	KOOL'	KOOLAID UNSWEETENED	246.0	2.5	0.0	0.0	0.0
1	SNACK	014950	ROASTED PEANUTS	30.0	174.6	7.9	14.6	6.2
1	SNACK	004090	COKE DIET	354.0	0.0	0.0	0.0	0.4
Day Totals:					1012.8	81.2	51.5	58.3
% of Calories:						32.1	45.7	23.0
2	BREAKFAST	863007	BREAD WHEAT COMM.	22.0	56.1	2.1	0.9	10.3
2	BREAKFAST	812692	PEANUT BUTTER SALTED	30.0	177.3	8.5	15.3	4.8
2	BREAKFAST	810124	BACON-COOKED	36.0	207.4	11.0	17.7	0.2
2	BREAKFAST	801001	BUTTER REGULAR	10.0	71.7	0.1	8.1	0.0
2	BREAKFAST	801079	MILK LOWFAT 2%	244.0	121.2	8.1	4.7	11.7
2	BREAKFAST	COFFEE	COFFEE BREWED-NO CAFFEINE	180.0	3.6	0.0	0.0	0.5
2	BREAKFAST	801049	HALF AND HALF CREAM	22.0	28.6	0.7	2.5	0.9
			Subtotals:		713.1	30.3	54.9	28.2
2	LUNCH	806416	SOUP-CREAM OF CHICKEN	394.0	189.1	5.6	11.9	15.0
2	LUNCH	805277	CHICKEN CANNED IN BROTH	120.0	198.0	26.1	9.5	0.0
2	LUNCH	804025	MAYO SOYBEAN	36.0	258.0	0.4	28.6	1.0
2	LUNCH	801009	CHEDDAR CHEESE	60.0	241.8	14.9	19.9	0.8
2	LUNCH	009160	SALTINES	12.0	51.4	1.1	1.2	8.8
2	LUNCH	811252	LETTUCE	75.0	9.8	0.8	0.1	1.6
2	LUNCH	804539	SALAD DRESSING-BLUE CHEESE	45.0	226.8	2.2	23.5	3.3
2	LUNCH	KOOL'	KOOLAID UNSWEETENED	246.0	2.5	0.0	0.0	0.0
2	LUNCH	809200	ORANGE,ALL VARIETIES	139.0	65.3	1.3	0.2	16.3
2	SNACK	014950	ROASTED PEANUTS	30.0	174.6	7.9	14.6	6.2
2	SNACK	004090	COKE DIET	354.0	0.0	0.0	0.0	0.4
			Subtotals:		1321.1	62.6	103.0	42.4
2	DINNER	805064	CHICKEN BREAST ROAST	157.0	259.0	48.7	5.6	0.0
2	DINNER	811061	GREEN BEANS BLD FZN NO SALT	100.0	26.0	1.4	0.1	6.1
2	DINNER	811252	LETTUCE	75.0	9.8	0.8	0.1	1.6
2	DINNER	811529	TOMATO,RED,RIPE,RAW	100.0	19.0	0.9	0.2	4.3
2	DINNER	801001	BUTTER REGULAR	10.0	71.7	0.1	8.1	0.0
2	DINNER	804025	MAYO SOYBEAN	25.0	179.2	0.3	19.9	0.7
2	DINNER	ICECHO	ICE CREAM CHOCOLATE	100.0	208.0	2.4	11.0	24.9
2	DINNER	KOOL'	KOOLAID UNSWEETENED	246.0	2.5	0.0	0.0	0.0
2	SNACK	014950	ROASTED PEANUTS	30.0	174.6	7.9	14.6	6.2
2	SNACK	004090	COKE DIET	354.0	0.0	0.0	0.0	0.4
			Subtotals:		949.8	62.3	59.7	44.2
Day Totals:					3080.1	152.8	224.1	125.7
% of Calories:						19.8	65.5	16.3

APPENDIX C

PHASE ONE LOW CARBOHYDRATE DIET -- SAMPLE MENUS DEVELOPED BY USARIEM

DAY	MEAL	SIX CODE	FOOD NAME	AMT (gm)	KCAL	PRO (gm)	FAT (gm)	CHO (gm)
3	BREAKFAST	863007	BREAD WHEAT COMM.	22.0	56.1	2.1	0.9	10.3
3	BREAKFAST	801132	SCRAMBLED EGG	100.0	148.0	9.3	11.1	2.1
3	BREAKFAST	810124	BACON-COOKED	36.0	207.4	11.0	17.7	0.2
3	BREAKFAST	801001	BUTTER REGULAR	15.0	107.5	0.1	12.2	0.0
3	BREAKFAST	801079	MILK LOWFAT 2%	244.0	121.2	8.1	4.7	11.7
3	BREAKFAST	COFFEE	COFFEE BREWED-NO CAFFEINE	180.0	3.6	0.0	0.0	0.5
3	BREAKFAST	801049	HALF AND HALF CREAM	22.0	28.6	0.7	2.5	0.9
			Subtotals:		719.7	31.1	54.7	25.5
3	LUNCH	020050	HAM BOILED	100.0	234.0	19.0	17.0	0.0
3	LUNCH	013730	MUSTARD YELLOW	30.0	22.5	1.4	1.3	1.9
3	LUNCH	801009	CHEDDAR CHEESE	120.0	483.6	29.9	39.8	1.5
3	LUNCH	811252	LETTUCE	75.0	9.8	0.8	0.1	1.6
3	LUNCH	811529	TOMATO,RED,RIPE,RAW	100.0	19.0	0.9	0.2	4.3
3	LUNCH	009160	SALTINES	12.0	51.4	1.1	1.2	8.8
3	LUNCH	804025	MAYO SOYBEAN	36.0	258.0	0.4	28.6	1.0
3	LUNCH	809200	ORANGE,ALL VARIETIES	140.0	65.8	1.3	0.2	16.4
3	LUNCH	KOOL'	KOOLAID UNSWEETENED	246.0	2.5	0.0	0.0	0.0
3	SNACK	014950	ROASTED PEANUTS	30.0	174.6	7.9	14.6	6.2
3	SNACK	004090	COKE DIET	354.0	0.0	0.0	0.0	0.4
			Subtotals:		1321.1	62.6	103.0	42.2
3	DINNER	003701	BEEF-HAMBURG MED WELL	142.0	406.1	34.4	28.8	0.0
3	DINNER	811061	GREEN BEANS BLD FZN NO SALT	100.0	26.0	1.4	0.1	6.1
3	DINNER	811252	LETTUCE	75.0	9.8	0.8	0.1	1.6
3	DINNER	804114	SALAD DRESSING ITALIAN	27.0	126.2	0.2	13.0	2.8
3	DINNER	022861	CATSUP	15.0	15.9	0.3	0.1	3.8
3	DINNER	LOCPUD	PUDDING CHOCOLATE LOCAL	130.0	99.6	5.0	3.0	13.9
3	DINNER	801053	CREAM HEAVY	45.0	155.2	0.9	16.6	1.3
3	DINNER	004090	COKE DIET	354.0	0.0	0.0	0.0	0.4
3	SNACK	014950	ROASTED PEANUTS	30.0	174.6	7.9	14.6	6.2
3	SNACK	KOOL'	KOOLAID UNSWEETENED	246.0	2.5	0.0	0.0	0.0
			Subtotals:		1015.8	50.7	76.5	36.1
Day Totals:					3056.6	144.4	234.1	103.8
% of Calories:						18.9	68.9	13.6

APPENDIX C

PHASE ONE LOW CARBOHYDRATE DIET -- SAMPLE MENUS DEVELOPED BY USARIEM

DAY	MEAL	SIX CODE	FOOD NAME	AMT (gm)	KCAL	PRO (gm)	FAT (gm)	CHO (gm)
4	BREAKFAST	U25331	BAGEL	33.0	97.7	3.6	0.8	18.5
4	BREAKFAST	801132	SCRAMBLED EGG	100.0	148.0	9.3	11.1	2.1
4	BREAKFAST	810124	BACON-COOKED	36.0	207.4	11.0	17.7	0.2
4	BREAKFAST	801017	CREAM CHEESE	15.0	52.3	1.1	5.2	0.4
4	BREAKFAST	801001	BUTTER REGULAR	5.0	35.9	0.0	4.1	0.0
4	BREAKFAST	801079	MILK LOWFAT 2%	244.0	121.2	8.1	4.7	11.7
4	BREAKFAST	COFFEE	COFFEE BREWED-NO CAFFEINE	180.0	3.6	0.0	0.0	0.5
4	BREAKFAST	801049	HALF AND HALF CREAM	22.0	28.6	0.7	2.5	0.9
			Subtotals:		666.0	33.2	43.6	33.6
4	LUNCH	023252	TUNA IN WATER	120.0	152.4	33.6	1.0	0.0
4	LUNCH	804025	MAYO SOYBEAN	36.0	258.0	0.4	28.6	1.0
4	LUNCH	801009	CHEDDAR CHEESE	60.0	241.8	14.9	19.9	0.8
4	LUNCH	809160	SALTINES	12.0	51.4	1.1	1.2	8.8
4	LUNCH	811252	LETTUCE	75.0	9.8	0.8	0.1	1.6
4	LUNCH	804114	SALAD DRESSING ITALIAN	54.0	252.3	0.4	26.1	5.5
4	LUNCH	809326	WATERMELON	160.0	51.2	1.0	0.7	11.5
4	LUNCH	KOOL'	KOOLAID UNSWEETENED	246.0	2.5	0.0	0.0	0.0
4	SNACK	014950	ROASTED PEANUTS	30.0	174.6	7.9	14.6	6.2
4	SNACK	004090	COKE DIET	354.0	0.0	0.0	0.0	0.4
			Subtotals:		1194.0	60.0	92.1	35.7
4	DINNER	003100	BEEF BROILED HIP SIRLOIN	227.0	544.8	67.6	28.4	0.0
4	DINNER	811061	GREEN BEANS BLD FZN NO SALT	100.0	26.0	1.4	0.1	6.1
4	DINNER	811252	LETTUCE	75.0	9.8	0.8	0.1	1.6
4	DINNER	811529	TOMATO,RED,RIPE,RAW	100.0	19.0	0.9	0.2	4.3
4	DINNER	022861	CATSUP	30.0	31.8	0.6	0.1	7.6
4	DINNER	804114	SALAD DRESSING ITALIAN	54.0	252.3	0.4	26.1	5.5
4	DINNER	809236	PEACH	139.0	59.8	1.0	0.1	15.4
4	DINNER	KOOL'	KOOLAID UNSWEETENED	246.0	2.5	0.0	0.0	0.0
4	SNACK	014950	ROASTED PEANUTS	30.0	174.6	7.9	14.6	6.2
4	SNACK	004090	COKE DIET	354.0	0.0	0.0	0.0	0.4
			Subtotals:		1120.5	80.5	69.8	47.2
Day Totals:					2980.5	173.7	205.6	116.5
% of Calories:						23.3	62.1	15.6

APPENDIX D

PHASE TWO HIGH CARBOHYDRATE DIET -- SAMPLE MENUS DEVELOPED BY USARIEM

DAY	MEAL	SIX CODE	FOOD NAME	AMT (gm)	KCAL	PRO (gm)	FAT (gm)	CHO (gm)
1	DINNER	807022	FRANKFURTER BEEF	90.0	289.8	10.2	26.5	2.2
1	DINNER	863041	ROLL HAMBURGER/HOTDOG	84.0	240.2	7.2	4.4	42.2
1	DINNER	001580	BEANS W/O PORK	200.0	240.0	12.6	1.0	46.0
1	DINNER	811403	POTATO FRENCH FRIED FZN NO SA	85.0	188.7	2.9	7.4	28.8
1	DINNER	022861	CATSUP	30.0	31.8	0.6	0.1	7.6
1	DINNER	012620	LEMONADE	368.0	161.9	0.4	0.0	42.0
1	DINNER	013730	MUSTARD YELLOW	30.0	22.5	1.4	1.3	1.9
1	DINNER	801064	ICE MILK VANILLA	131.0	183.6	5.2	5.6	29.0
1	SNACK	809003	APPLE W SKIN	138.0	81.4	0.3	0.5	21.0
1	SNACK	FIGNUT	COOKIE FIG NEWTON	42.0	147.9	1.5	3.0	29.6
Day Totals:					1587.9	42.2	49.8	250.2
% of Calories:						10.6	28.2	63.0
2	BREAKFAST	PANCAK	PANCAKES	200.0	436.0	13.7	16.1	58.4
2	BREAKFAST	020520	SYRUP MAPLE FLAVORED	78.0	196.6	0.0	0.0	50.7
2	BREAKFAST	801001	BUTTER REGULAR	10.0	71.7	0.1	8.1	0.0
2	BREAKFAST	801079	MILK LOWFAT 2%	244.0	121.2	8.1	4.7	11.7
2	SNACK	809200	ORANGE,ALL VARIETIES	140.0	65.8	1.3	0.2	16.4
			Subtotals:		891.3	23.2	29.1	137.3
2	LUNCH	807043	BEEF LUNCHMEAT SLICE	85.0	104.5	18.6	2.7	0.3
2	LUNCH	863040	ROLL FRENCH NO FAT	50.0	137.0	4.3	0.4	28.3
2	LUNCH	013730	MUSTARD YELLOW	15.0	11.2	0.7	0.7	1.0
2	LUNCH	804025	MAYO SOYBEAN	28.0	200.7	0.3	22.2	0.8
2	LUNCH	811529	TOMATO,RED,RIPE,RAW	100.0	19.0	0.9	0.2	4.3
2	LUNCH	811252	LETTUCE	50.0	6.5	0.5	0.1	1.0
2	LUNCH	811411	POTATO CHIPS	28.0	146.4	1.8	9.9	14.5
2	LUNCH	012520	LEMONADE	368.0	161.9	0.4	0.0	42.0
2	SNACK	FRTYOG	YOGURT WITH FRUIT	227.0	231.5	9.9	2.5	43.2
2	SNACK	012520	LEMONADE	368.0	161.9	0.4	0.0	42.0
			Subtotals:		1180.8	37.8	38.6	177.3
2	DINNER	805064	CHICKEN BREAST ROAST	157.0	259.0	48.7	5.6	0.0
2	DINNER	809081	CRANBERRY SAUCE	70.0	105.7	0.1	0.1	27.2
2	DINNER	811674	POTATO BAKED	150.0	163.5	3.5	0.2	37.8
2	DINNER	801001	BUTTER REGULAR	15.0	107.5	0.1	12.2	0.0
2	DINNER	811168	CORN,YELLOW,BOILED,WO/SALT	100.0	108.0	3.3	1.3	25.1
2	DINNER	811252	LETTUCE	150.0	19.5	1.5	0.3	3.1
2	DINNER	804021	SALAD DRESSING ITALIAN LOWCAL	30.0	31.6	0.0	2.9	1.5
2	DINNER	HPOPSI	POPSICLE FRUIT	182.0	149.2	0.0	0.0	35.3
2	DINNER	801079	MILK LOWFAT 2%	244.0	121.2	8.1	4.7	11.7
2	SNACK	809252	PEARS	166.0	97.9	0.6	0.7	25.1
2	SNACK	HPOPSI	POPSICLE FRUIT	182.0	149.2	0.0	0.0	35.3
			Subtotals:		1312.5	66.1	27.9	202.2
Day Totals:					3384.6	127.1	95.5	516.8
% of Calories:						15.0	25.4	61.1

APPENDIX D

PHASE TWO HIGH CARBOHYDRATE DIET -- SAMPLES MENUS DEVELOPED BY USARIEM

DAY	MEAL	SIX CODE	FOOD NAME	AMT (gm)	KCAL	PRO (gm)	FAT (gm)	CHO (gm)
3	BREAKFAST	809080	JUICE CRANBERRY COCKTAIL	253.0	146.7	0.1	0.1	37.6
3	BREAKFAST	808020	CEREAL CORN FLAKES KELLOGGS	28.0	108.9	2.3	0.1	24.1
3	BREAKFAST	801079	MILK LOWFAT 2%	244.0	121.2	8.1	4.7	11.7
3	BREAKFAST	PPEMUF	ENGLISH MUFFIN CIN-RAISIN	56.0	148.4	4.9	2.0	27.7
3	BREAKFAST	011491	JELLY	15.0	40.9	0.0	0.0	10.6
3	BREAKFAST	022300	SUGAR GRANULATED	6.0	23.1	0.0	0.0	6.0
3	SNACK	FRTYOG	YOGURT WITH FRUIT	227.0	231.5	9.9	2.5	43.2
			Subtotals:		820.8	25.3	9.3	160.9
3	LUNCH	020050	HAM BOILED	100.0	234.0	19.0	17.0	0.0
3	LUNCH	863040	ROLL FRENCH NO FAT	50.0	137.0	4.3	0.4	28.3
3	LUNCH	013730	MUSTARD YELLOW	15.0	11.2	0.7	0.7	1.0
3	LUNCH	811252	LETTUCE	50.0	6.5	0.5	0.1	1.0
3	LUNCH	811411	POTATO CHIPS	28.0	146.4	1.8	9.9	14.5
3	LUNCH	801079	MILK LOWFAT 2%	244.0	121.2	8.1	4.7	11.7
3	LUNCH	809003	APPLE W SKIN	138.0	81.4	0.3	0.5	21.0
3	SNACK	809268	PINEAPPLE CANNED IN JUICE	250.0	150.0	1.0	0.2	39.3
3	SNACK	012520	LEMONADE	368.0	161.9	0.4	0.0	42.0
			Subtotals:		1180.8	37.8	38.6	177.3
3	DINNER	011000	HADDOCK FRIED	100.0	165.0	19.6	6.4	5.8
3	DINNER	811674	POTATO BAKED	150.0	163.5	3.5	0.2	37.8
3	DINNER	801001	BUTTER REGULAR	15.0	107.5	0.1	12.2	0.0
3	DINNER	811061	GREEN BEANS BLD FZN NO SALT	100.0	26.0	1.4	0.1	6.1
3	DINNER	LOCPUD	PUDDING CHOCOLATE LOCAL	260.0	199.2	10.0	6.0	27.9
3	DINNER	012520	LEMONADE	368.0	161.9	0.4	0.0	42.0
3	SNACK	812692	PEANUT BUTTER SALTED	30.0	177.3	8.5	15.3	4.8
3	SNACK	011491	JELLY	15.0	40.9	0.0	0.0	10.6
3	SNACK	004460	BREAD FRENCH	50.0	140.0	4.8	1.9	25.3
3	SNACK	801079	MILK LOWFAT 2%	244.0	121.2	8.1	4.7	11.7
			Subtotals:		1302.7	56.3	46.8	172.0
Day Totals:					3173.2	117.8	89.6	491.7
% of Calories:						14.8	25.4	62.0

APPENDIX D

PHASE TWO HIGH CARBOHYDRATE DIET -- SAMPLE MENUS DEVELOPED BY USARIEM

DAY	MEAL	SIX CODE	FOOD NAME	AMT (gm)	KCAL	PRO (gm)	FAT (gm)	CHO (gm)
4	BREAKFAST	U25331	BAGEL	66.0	195.4	7.2	1.7	37.1
4	BREAKFAST	812692	PEANUT BUTTER SALTED	30.0	177.3	8.5	15.3	4.8
4	BREAKFAST	011491	JELLY	15.0	40.9	0.0	0.0	10.6
4	BREAKFAST	809206	JUICE ORANGE	249.0	112.1	1.7	0.5	25.9
4	BREAKFAST	809040	BANANA	114.0	104.9	1.2	0.5	26.7
4	SNACK	FIGNUT	COOKIE FIG NEWTON	84.0	295.8	3.0	5.9	59.2
4	SNACK	809016	APPLE JUICE CANNED	248.0	116.6	0.1	0.3	29.0
			Subtotals:		1042.9	21.8	24.3	193.2
4	LUNCH	807079	TURKEY LOAF(BR MEAT)	90.0	99.0	20.3	1.4	0.0
4	LUNCH	863040	ROLL FRENCH NO FAT	50.0	137.0	4.3	0.4	28.3
4	LUNCH	811252	LETTUCE	50.0	6.5	0.5	0.1	1.0
4	LUNCH	013730	MUSTARD YELLOW	15.0	11.2	0.7	0.7	1.0
4	LUNCH	804025	MAYO SOYBEAN	28.0	200.7	0.3	22.2	0.8
4	LUNCH	006190	CARROTS RAW	100.0	42.0	1.1	0.2	9.7
4	LUNCH	801079	MILK LOWFAT 2%	244.0	121.2	8.1	4.7	11.7
4	LUNCH	809236	PEACH	87.0	37.4	0.6	0.1	9.7
4	SNACK	006090	JELLY BEANS	56.0	205.5	0.0	0.3	52.1
4	SNACK	012520	LEMONADE	368.0	161.9	0.4	0.0	42.0
			Subtotals:		1022.5	36.3	30.0	158.2
4	DINNER	013000	MACARONI TENDER	180.0	199.8	6.1	0.7	41.4
4	DINNER	SAUCES	SAUCE SPAGHETTI +MEAT	200.0	140.8	5.2	3.5	21.1
4	DINNER	801032	CHEESE PARMESAN GRATED	8.0	36.5	3.3	2.4	0.3
4	DINNER	004460	BREAD FRENCH	25.0	70.0	2.4	1.0	12.6
4	DINNER	801001	BUTTER REGULAR	5.0	35.9	0.0	4.1	0.0
4	DINNER	802020	GARLIC POWDER	3.0	10.0	0.5	0.0	2.2
4	DINNER	806468	SOUP VEGETARIAN VEGETABLE	241.0	72.3	2.1	1.9	12.0
4	DINNER	811168	CORN,YELLOW,BOILED,WO/SALT	100.0	108.0	3.3	1.3	25.1
4	DINNER	801001	BUTTER REGULAR	5.0	35.9	0.0	4.1	0.0
4	DINNER	809326	WATERMELON	160.0	51.2	1.0	0.7	11.5
4	DINNER	801079	MILK LOWFAT 2%	244.0	121.2	8.1	4.7	11.7
4	DINNER	HFUDGS	FUDGSICLE	73.0	105.1	3.0	0.3	24.4
4	SNACK	HPOPSI	POPSICLE FRUIT	128.0	105.0	0.0	0.0	24.8
			Subtotals:		1091.5	35.1	24.6	187.1
Day Totals:					3156.9	93.2	78.9	538.5
% of Calories:						11.8	22.5	68.0

APPENDIX E

RATION RECORD

NAME: ____________________ DATA COLLECTOR # __________

SUBJECT #: ____________________ DATA ENTERER # __________

JULIAN DATE: 85 ____________________

MEAL: (CIRCLE ONE) RATION TYPE: (CIRCLE ONE)

BREAKFAST - B A B T

DINNER - D

FOOD TYPE	DESCRIPTION	CODE #	REASON NOT EATEN CODE	PORTION SERVED	PORTION RETURNED	RATING CODE
ENTREE						
VEGETABLE						
STARCH						
FRUIT						
BREAD						
SPREAD						
DESSERT						
BEVERAGE						
OTHER						

NATICK Form 613 (ONE-TIME)
1 Jul 85

APPENDIX F

SUBSTITUTIONS TO LOW CARBOHYDRATE DIET MENUS

LUNCH ITEMS
Orange
Grapefruit
Baked Liver
Baked Haddock
Cheddar Cheese
Baked Potato
Green Beans, frozen
Jello, unsweetened
Iced Tea, unsweetened

DINNER ITEMS
Orange
Grapefruit
Frankfurters
Roast Beef, deli
Turkey Breast, deli
Thousand Island Salad Dressing
Jello, unsweetened
Whipped Cream

SUBSTITUTIONS TO HIGH CARBOHYDRATE DIET MENUS

BREAKFAST ITEMS
Corn Chex Cereal
English Muffin, plain

LUNCH ITEMS
Orange
Raisins
Coke
Corn, kernels
Potato Chips
Jelly Beans

DINNER ITEMS
Coke
Raspberry Sherbet

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