THE EFFECTS OF VARYING PROTEIN/CARBOHYDRATE RATIO OF A HYPOCALORIC DIET ON BODY COMPOSITION AND MUSCULAR FUNCTION IN BODY BUILDERS

by

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(ABSTRACT)

The effects of two hypocaloric diets on body weight (BW), percent body fat (%BF), lean body mass (LBM) and static muscular endurance were studied in college aged experienced male weightlifters for 7 days. Nineteen (X age = 20.6) volunteers were randomly assigned to one of three groups: control (n=5), High Protein/Moderate Carbohydrate - HP/MC (n=7) or Moderate Protein/High Carbohydrate - MP/HC (n=7). The two hypocaloric groups consumed 18 kcal/kg body weight for 7 days. The HP/MC group's diet contained 1.6 g/kg body weight/day of protein while the MP/HC group consumed 0.8 g/kg body weight/day of protein. Fat content of both diets was approximately equal so that carbohydrate content varied inversely with protein content. The control group was asked to follow a weight maintenance diet. All groups followed a similar supervised weight training regimen approximately 2 hours per day, six of the seven days of the study. Analysis of variance revealed that weight loss for the control group was not significant over the seven day experiment but that the two experimental groups showed a similar significant decrease in body weight of 3.6 kg for the HP/MC group and 4.0 kg for the MP/HC group. %BF of all subjects was significantly lower over the 7 d study using both skinfold measurements and hydrostatic weighing but there was no significant difference between the groups. LBM losses calculated from skinfold measurements were seen over time for all subjects and a significant interaction showed the 2 experimental groups to lose significantly more LBM over the 7 d study. LBM determined from hydrostatic weighing produced losses as well, but no differences were noted between the groups. All groups experienced quadricep endurance decrements over the 7 d study, but did not differ from each other. No significant changes were found for bicep endurance. It was concluded that neither the HP/MC diet nor the MP/HC diet was effective for maintaining LBM or quadricep endurance. However, both diets did produce significant losses in BW and %BF over the week long study.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter I

INTRODUCTION

The increasing popularity of physical fitness has brought about a new awareness of what constitutes good health. Regular aerobic exercise, expanded knowledge of adequate nutrition principles, and decreasing use of cigarettes and alcohol are the most frequent and beneficial changes seen. World class athletes have become role models for the rest of the population and these practices are part of their everyday routine. Unfortunately, many of these athletes disregard these practices when the concern for winning becomes too great.

Wrestlers, weight lifters, and body builders are examples of the types of athletes who are required to meet weight classes or achieve maximal lean body mass prior to a competition. To obtain these goals a combination of diet and exercise is utilized, sometimes to a point where the athletes feel tired, irritable, and listless. This is often due to the diet that is followed. It is often high in protein, low in carbohydrate and fat, and low in calories. The purpose of this type diet is to increase lean body mass (muscle) while decreasing body fat so that muscle definition, muscle size, muscle strength and muscular endurance are increased (Spitler, Diaz, Horvath and Wright, 1980).

Limited research has been done on protein and carbohydrate intake and caloric restriction for athletes involved in anaerobic activities such as wrestling, weight lifting and body building. Without documented evidence no one can be certain as to the effectiveness of these dietary practices and whether or not they actually help the athlete achieve his/her intended goals of increased muscle function, and modified body composition.

Statement of the Problem

Body builders are notorious for experimenting with their diets in order to determine the one leading to the most body fat lost in the shortest amount of time (Lemon, 1985). Four to six weeks prior to the competition many body builders undergo a phase of dieting where they eat large amounts of protein, small amounts of fat and carbohydrates and very few calories (Katch et al, 1980; Rozenek and Stone, 1984; and Spitler et al, 1980). Whether these diets are necessary to actually achieve the overall goals of increased muscle size and definition and decreased body fat is not known (Katch et al, 1980; and Spitler et al, 1980). The purpose of this study was to examine the effects of dietary protein and carbohydrate intake on body composition and muscular function for body builders on a 7 day hypocaloric diet.

Research Hypotheses

The following null hypotheses were tested in this study:

1. HO: There is no significant difference between body builders who consume 0.8 g/kg/day of protein and body builders who consume 1.6 g/kg/day of protein (with constant fat and varying carbohydrate ratios) in percent body fat estimated by skinfold and hydrostatic weighing on a 7 day hypocaloric diet.
2. HO: There is no significant difference between body builders who consume 0.8 g/kg/day of protein and body builders who consume 1.6 g/kg/day of protein (with constant fat and varying carbohydrate ratios) in static muscular endurance as measured by the Cybex for biceps and quadriceps on a 7 day hypocaloric diet.

Significance of the Study

While few people contest the need for protein in an athlete's diet, conflicts do arise over the actual amount required. (Lemon, 1985; Rozenek and Stone, 1984). The studies conducted have reported conflicting results, one suggested that additional protein did increase muscular performance (Widerman and Hagan, 1982), while others reported no statistically significant differences in muscle function for those subjects consuming diets high in protein (Rasch and Pierson, 1962; Rasch, Hamby, and Burns, 1969). Nutritionists believe that the additional protein consumed is stored as adipose tissue if the caloric intake is sufficient or, as in the case of body builders, is used as an inefficient source of energy when a caloric deficit occurs (Rozenek and Stone, 1984). Most researchers have examined protein intakes of 2-3 times the RDA (Rasch and Pierson, 1962; Rasch, Hamby, and Burns, 1969) however, many body builders consume as much as 80% of their calories in the form of protein (Spitler, Diaz, Horvath, and Wright, 1980).

Since there are few documented studies on the effects of protein and carohydrate intake on body composition and muscular function, a study examining these parameters would be of great value to those athletes who are involved in body building. Not only could this study possibly provide guidelines for those athletes to follow, but the study could aid in determining whether or not these diets actually increase or decrease muscular endurance during training and competition therefore affecting the performance.

Delimitations

The following delimitations were made:

1. The subjects were male body builders between the ages of 18-26.
2. Dietary intake was controlled by providing a liquid formula diet.
3. Dietary protein was varied for the two experimental treatments. Group 2 (High Protein/Moderate Carbohydrate) received 1.6 g/kg/day while Group 3 (Moderate Protein/High Carbohydrate) received 0.8 g/kg/day.
4. Dietary carbohydrate was varied for the two experimental groups. Group 2 (High Protein/Moderate Protein) received approximately 50% and Group 3 (Moderate Protein/High Carbohydrate) received approximately 70%.
5. The dependent criterion scores were: change in percent body fat by skinfold measurements, change in percent body fat by hydrostatic weighing and change in static muscular endurance in percent by endurance ratio.
6. The length of the hypocaloric treatment condition was 7 days.

Limitations

The following limitations of the study were noted:

1. Although diet was specifically provided and prescribed subjects may have consumed additional food or less than the allotted diet.
2. Subjects were asked to have not been using anabolic steroids in the past 3 months, however steroid usage was not tested.
3. Subjects were asked not to participate in any additional exercise programs but they may have continued to exercise on their own.

Definitions and Symbols

1. Body Composition: The major components of the body which include muscle, fat and bone (McArdle, Katch and Katch, 1981).
2. Percent Body Fat (%BF): The percentage of the total body composition which includes essential and nonessential lipid stores (Brooks and Fahey, 1984).
3. Lean Body Mass (LBM): All the nonfat tissues including skeleton, water muscle, connective tissue, organ tissue and teeth (Brooks & Fahey, 1984).
4. Body Builder: A body builder who has been weight training 3 to 7 days a week for the past two years.
5. Static Muscular Endurance: The ability to perform a physical activity or resist muscular fatigue for 10 repeated isometric contractions.

6. Endurance Ratio: The ratio calculated by dividing the total area of the last two trials by the total area of the first two trials. The percentage change from beginning to end is calculated as the endurance ratio (Davies, 1984).
7. Hydrostatic Weighing: The procedure of weighing subjects underwater to determine body density using weight in air, weight underwater, water density, and residual lung volume.
8. Residual Lung Volume (RLV): The volume of gas remaining in the lungs at the end of a maximal expiration (Brooks and Fahey, 1984).
9. Skinfold Measurements: The sum (in millimeters) of subcutaneous fat at the chest, abdomen, and thigh.
10. High Protein/Moderate Carbohydrate (HP/MC): Those subjects who consumed diets of 1.6 g/kg/day of protein, 50% carbohydrate and 15% fat totalling between 1200 and 1750 kilocalories per day (based on 18 kcal/kg/day).
11. Moderate Protein/High Carbohydrate (MP/HC): Those subjects who consumed diets of 0.8 g/kg/day of protein, 70% carbohydrate and 13% fat totalling between 1200 and 1750 kilocalories per day (based on 18 kcal/kg/day).

12. Exercise: Resistance weight training program which was identical for all treatment conditions. It was supervised by the investigators and consisted of weight lifting at 60-80% of 1RM for 3 sets, 10 repititions, six days a week and alternating triceps, shoulders and chest with biceps, back and legs.

13. Five Repetition Maximum (5RM): The maximum amount of weight that can lifted for five repititions.

Basic Assumptions

The following basic assumptions were made:

1. It was assumed that for the static endurance tests the subjects performed with maximal effort.
2. It was assumed that the workouts included the prescribed amount of exercise at the proper intensity.
3. It was assumed that maximal expirations were given to achieve the correct residual volume.
4. It was assumed that maximal stability was achieved during each trial for the hydrostatic weighing procedures.

Summary

There has been a limited amount of research conducted on protein and carbohydrate intake during a hypocaloric diet and their effects on body composition and muscular function for body builders. Therefore, it would be advantageous to determine some dietary guidelines that would aid these athletes in nutrient intake during training and competition. The most common diet followed is one containing high protein, low carbohydrate and few calories. The aim of this diet is to increase lean body mass while decreasing percent body fat. These athletes believe that the added protein will increase muscle size, strength, and definition thus increasing their chances of winning a competition. However, often times too much muscle mass and glycogen is lost which negatively affects perfomance. Athletes will continue to adhere to these dietary practices without evidence of the efficacy until controlled research has determined the optimal diet for performance.

Chapter II

REVIEW OF LITERATURE

The heightened awareness of the importance of the diet prior to competitive athletic events has become a major issue in recent years. This chapter contains a review of the literature concerning caloric restriction, protein and carbohydrate intake, muscular function and a general overview of the body composition of body builders. The literature review will be divided into six sections: 1) Caloric Restriction and Body Composition Changes, 2) Caloric Restriction and Muscular Function Changes, 3) Protein and Carbohydrate Intake and Body Composition Changes, 4) Protein and Carbohydrate Intake and Muscular Function Changes, 5) Testing and Validation of Body Composition, and 6) Body Composition of Body Builders.

Caloric Restriction and Body Composition Changes

Diets which reduce the number of calories consumed per day can produce significant weight loss, however the composition of the weight loss will vary depending on how severe the restriction is. Stored glycogen and water will be the first constituents lost in order to compensate for the caloric restriction. Stored fat will be the next tissue used for energy and finally protein will be broken down and used. Since body builders often use caloric restriction as a means of achieving desired weight loss prior to competition, it is important that they understand how it affects body composition. The following studies have examined caloric restriction and its effect on body composition.

In 1969, Oscai and Holloszy examined exercising and sedentary rats that were placed on hypocaloric diets. After 18 weeks of a swimming program the sedentary food restricted rats lost 38% lean tissue and 62% fat while the exercising rats lost 22% lean tissue and 78% fat. A group of sedentary non food restricted rats gained 87% fat. The authors concluded that 1) the exercise protected the rats against losing significant amounts of lean tissue, and 2) weight loss due to caloric restriction may be one third or more lean body mass (LBM). These are important considerations for body builders who are trying to lose fat but not lean body mass. This study showed how important exercise was in decreasing LBM loss during caloric restriction.

A case study by Widerman and Hagan (1982) looked at measurements similar to Oscai and Holloszy (LBM and % BF) during a wrestling season. The subject decreased his caloric intake from approximately 2000 cal/day to 1200 cal/day over a period of 53 days. Initial measures included weight: 54.88 kg, % BF = 4.8 and LBM (kg) 52.24. Three weeks later values were WT: 53.25 kg, % BF = 3.8% and LBM = 51.22 kg. (Of the 1.63 kg lost, 1.02 kg was LBM). The final measurements were WT = 50.59 kg, % BF = 1.1% and LBM = 50.03 kg. (Of the 2.66 kg lost, 1.19 kg was LBM). Overall the subject lost 4.29 kg, 3.7% percent body fat and 2.21 kg LBM. During the entire study daily training took place which consisted of running, wrestling and weight lifting.

Weight loss, lean body mass and fat mass were also analyzed by Pavlou, Steffee, Lerman and Burrows (1985) using exercising and non-exercising groups on hypocaloric diets. The exercise regimen used was an 8 week aerobics program held 3 times a week at 70-85% maximum heart rate. The groups all consumed approximately 800 Kcal/day. The researchers found that the weight loss between the exercising and non-exercising groups was not significantly different (11.8±0.6 kg vs. 9.2±0.3 kg) however LBM loss and fat mass were significantly different between the groups. The exercising group's lean body mass dropped 0.6 kg while the lean body mass of the non-exercising group was reduced 3.3 kg. Body fat loss was higher for the exercising group (11.2±1.5 kg) than for the non-exercising group (5.2±1.6 kg). The authors concluded that aerobic exercise in addition to a hypocaloric diet helped to maintain lean body mass.

In a study similar to Pavlou et al., Hagan, Upton, Wong and Whittam (1986) examined the effects of aerobic exercise and/or hypocaloric dieting on body composition. For 12 weeks a 1200 kcal/day diet was followed and a 5 day/week (30 min) exercise session was conducted. Results for the males (n=48) showed a weight loss of 11.4 kg for diet and exercise (DE) versus 8.4 kg for diet (D) alone. Fat weight decreased 7.9 kg with DE and 5.9 kg for D. Finally fat free weight loss was 3.5 kg for DE and 2.5 kg for D. The results for the women (n=48) were similar but less dramatic. All changes were significantly greater with DE as compared to D alone, thus it was concluded that diet/exercise is more effective for losing weight and fat than diet alone however, fat free weight loss was also greater for the DE group.

The studies by Oscai and Holloszy (1969) and Pavlou et al. (1985) found that exercising during a period of caloric restriction helped to reduce the amount of lean tissue lost. However, the exercise did not prevent lean tissue loss. Hagan et al. (1986) found the opposite to be true. Subjects on hypocaloric diets who continued to exercise during caloric restriction lost significant amounts of lean body mass. Three of the four studies looked at aerobic exercise (Oscai and Holloszy, Pavlou et al., and Hagan et al.). It is possible that the type and intensity of the exercise plays an important role in the amount of lean tissue lost.

Caloric Restriction and Muscular Function Changes

Diets low in calories can also affect the muscles' ability to perform a given activity. If the caloric intake is too low, stored glycogen will be used to provide energy thus depleting the muscles and liver of their stores and potentially impairing performance. If an anaerobic exercise (high intensity) is being executed, glycogen will be used even more rapidly since it is the only nutrient providing energy to the muscle anaerobically. During less intense exercise the adipose stores will be used to provide energy (McArdle et al., 1981). The following studies examine the effects of caloric restriction on muscular function.

Taylor, Buskirk, Brozek, Anderson, and Grande (1957) studied the effects of two diets on work performance in young men. One group (n=6) ate 580 kcal/day for 12 days and the other group (n=13) consumed 1010 kcal/day for 24 days. The researchers tested performance of treadmill walking, walking outdoors, an exhaustive run (every other day), grip strength, and speed of leg movements. They reported that with weight losses of less than 10% of the initial body weight, muscular strength (as measured by grip strength) was not affected. One problem the authors noted was that the rate of weight loss was important and that the subjects eating 580 kcal may have shown decrements had they dieted for longer than 12 days.

A study by Houston, Marrin, Green, and Thomson (1981) also looked at rapid weight loss and its effects on muscle function. Four wrestlers were examined for 1 week. The authors found that glycogen stores were greatly reduced after one week of a 66% caloric reduction from the baseline intake. The mean pre-diet value for muscle glycogen was 62.3±3.3 mmole glucose units/kg. This value decreased to 33.9±1.8 mmole glucose units/kg ($p<.05$) after 80 hours. Muscular strength, as measured by maximal torque output on the Cybex, decreased significantly at 30±/second (from 195 Nm to 170 Nm; $p<.05$). Decrements in strength were also seen at 180±/sec and 300±/sec but they were not significant.

Not all studies have found a detrimental effect of caloric restriction on muscle function. Hypocaloric dieting and its effects on muscular function was also examined by Russell, Walker, Leeter, Suma, Tanner, Mickle, Whitwell, Marliss and Jeejeebhoy in 1984. After one week on a 2500 kcal/day maintenance diet 5 obese women were placed on a 400 kcal/day diet. Muscle biopsies were taken at the beginning of the hypocaloric diet and again 2 weeks later. Unlike the study by Houston et al.(1982), no significant changes were seen in muscle glycogen concentration (57.0±5.9 g/kg dry wt and 59.7±6.8 g/kg dry wt). However, since no exercise regimen was included in this study the muscles were probably using less glycogen and subsequently only small changes were seen in muscle glycogen.

In 1982, a case study by Widerman and Hagan analyzed one wrestler prior to a wrestling competition. Over of period of 53 days the caloric intake decreased from 2000 kcal to 1200 kcal. Isokinetic strength was measured using right and left leg extensions and flexions and bench leg presses. The best of 3 trials was the criterion score. Maximal isotonic bench presses and leg presses were conducted on the Universal Gym Centurian machines. Examination of the results indicated maintenance of isotonic strength and increased isokinetic strength over the 53 day study.

Other studies have actually shown increases in strength during caloric restriction. Quadricep strength changes following 8 weeks of an 800 kcal diet were evaluated by Pavlou, Steffee, Lerman and Burrows in 1985. Exercising and non-exercising groups were tested before and after an 8-week aerobics program which met 3 times a week. The Cybex II dual channel isokinetic system was used to test quadricep strength. Three trials were given (after practice trials) at 30±/sec and the highest value was used as the criterion measure. The researchers found that the exercising group showed a significant increase in strength (from 172±7.0 to

210±6.6 N•m) while a non-significant decrease was found in the non-exercising group.

In summary, Houston et al. (1982) reported that muscular strength was significantly less after 72 hours when caloric restriction was 66% below normal and that glycogen concentrations were significantly decreased (62.3±3.3mmole glucose units/kg vs. 33.9±1.8 mmole glucose units/kg) after 80 hours. In contrast to Houston et al. (1982), Russell et al. (1984) reported that obese women on 400 kcal/day diets had no significant changes in muscle glycogen after 14 days. The women were not exercising, therefore less glycogen was likely being drained by the muscles.

The studies by Widerman and Hagan (1982) and Pavlou et al. (1985) found that muscular strength was increased or maintained during caloric reduction while the subjects were exercising.

Protein and Carbohydrate Intake and Body Composition Changes

While caloric intake is important to the body builder so is the percentage of macronutrients ingested. Many consume diets high in protein hoping to increase muscle size. However, the body will use only what protein it needs and the additional protein carbons will be stored as fat and the nitrogen excreted as urea. Recently, diets higher in carbohydrates have been suggested so as to supply enough glycogen to the muscles as well as provide a more efficient energy supply (Lemon, 1985 and Shaternikov and Koronikov, 1985). The following researchers have looked at the effects of varying percentages of protein and carbohydrates on body compostion changes.

In 1955, Werner examined 6 obese patients. Three were placed on high fat diets (2874 kcal, 122 gr. protein, 242 g. fat and 52 g. carbohydrate) and 3 followed a high carbohydrate diet (2878 calories, 104 g. protein, 146 g. fat and 287 g. carbohydrate). Both groups lost equal amounts of weight over the 38 day study. Werner felt that the weight loss was mainly due to the loss of fatty tissue since the subjects remained in overall nitrogen equilibrium. Percent body fat was not measured but it was probable that some lean body mass was lost because none of the subjects were exercising. The author concluded that weight loss could be achieved on diets containing more calories that what would be considered 'low calorie'. This could be beneficial to severly obese people.

A similar study using 6 obese males was conducted by Yang and Van Itallie in 1976. Three different diets were examined: starvation, an 800 kcal mixed diet and an 800 kcal ketogenic (low carbohydrate-high fat). The study lasted 50 days and between each 10 day experimental diet was a 5 day 1200 k-cal/day diet. During the ketogenic diet subjects' weight decreased 466.6±51.3 g/day. The isocaloric diet showed weight losses of 277.9±32.1 g/day. Finally, the starvation diet produced an average weight loss of 750.7±50.9 g/day. The two 800 kcal diets produced a mean fat loss of 163.4 g for the ketogenic and 166.7 g for the isocaloric. The authors concluded that subjects lost weight more quickly on the ketogenic low calorie diet than on the isocaloric low calorie diet. However, it was noted that the excretion of excess water during this period explained this difference in weight loss. The amount of body fat lost was not different due to the diet composition.

Another study by Young, Scanlan, Im and Lutwak (1971), found that low carbohydrate diets caused more fat loss than higher carbohydrate diets. The 8 subjects (2-3 per group) were placed on a maintenance diet for 3 weeks prior to the study. The experimental diets each consisted of 1800 kcal and 115 g. protein. The carbohydrate level was 104 g. for group A, 60 g. for group B, and 30 g. for group C. No exercise was required but subjects maintained their daily activities. The authors found weight losses in group A to be 11.85 kg, group B 12.78 kg and group C 16.18 kg. Fat losses for group A were 8.38 kg, 10.20 kg for group B and 14.85 kg for group C. Body weight loss as well as body fat loss increased with a lower carbohydrate intake. However, the researchers concluded that the diet with 104 g carbohydrate was probably the most suitable in practical terms because less ketone bodies were produced. No statistical analyses were made in this study therefore the results only indicate trends not significant differences.

In contrast to manipulating dietary carbohydrate content the following researchers studied protein ratios. Two groups of rats were studied by Crews, Fuge, Oscai, Holloszy and Shank in 1969 for 12 weeks. One group consumed a diet low in protein (8% casein, 74% sucrose, 4% corn oil, 10% Crisco, 3% salt mixture and 1% vitamins). The second group ate a diet with normal protein levels (22% casein, 60% sucrose, 4% corn oil, 10% Crisco, 3% salt mixture and 1% vitamins). Half of each group exercised while the other half remained inactive. The researchers found that the group that consumed normal amounts of protein and exercised had a significantly lower percent body fat than their sedentary counterparts. No significant differences between exercising and non-exercising rats were seen for the low protein group.

Nettleton and Hegsted (1977) analyzed rats in a study similar to Crews et al. (1969). Protein intake and energy restriction were examined in 2 groups of rats. The diets contained only protein or protein plus carbohydrate (totalling 12 or 24 kcal/day) for 3-16 days. The diets were designed to be low in calorie yet supply ample amounts of protein. The authors found that the 24 kcal/day group maintained their weight through the eight day period, however, immediate losses of body fat were noted. Nitrogen and water were stable throughout the 16 days. The group consuming 12 kcal/day lost body weight and body fat immediately. Nitrogen and water were maintained or slightly increased during the 8 days. Nettleton and Hegsted also found that the protein conserved lean tissue and body nitrogen only as long as enough fat stores were present. The authors concluded that the amount of protein ingested, the total energy provided, fat stores and the length of the diet are important factors in body composition changes when varying dietary protein contents are used.

Worthington and Taylor (1974) also examined diet of varying protein content in women. The authors contrasted a high protein diet (1182 kcal, 142.7 g protein, 58.3 g fat and 16.9 g carbohydrate) with a balanced low calorie diet (1186 kcal, 61.2 g protein, 62.3 g fat and 96.2 g carbohydrate). During the 14 day study the high protein group lost 12.0±3.7 lbs while the balanced low calorie group lost 8.7±3.5 lbs. This was significant at the .05 level.

The authors concluded that significantly more weight was lost during the first week on the high protein diet than on the isocaloric diet.

The effects of a hypocaloric high protein diet were further examined by Marliss, Murray and Nakhooda (1978). After a 3-7 day maintenance diet (2500 kcal/day containing 40% carbohydrate, 40% fat and 20% protein) the 14 obese subjects were divided into three groups. Group 1 (N=7) consumed a constant protein intake (81% protein, 16% fat, and 3% carbohydrate) for 21 days. After fasting for 21-28 days, group 2 (n=7) was refed the same diet as group 1 for 7 days. Group 3 (n=4) followed a diet with stepwise decrements of 0.5 g nitrogen for days 1-14 then a constant intake was maintained for days 15-21 (92±19 kcal/day with 19±2.2 g/day protein, 12±0.5 g/day of fat and 0.5±0.2 g/day of carbohydrate. The results showed that diets 1 and 3 produced similar weight loss (8.6±0.5 kg/day and 9.9±0.7 kg/day) while diet 2 showed a small weight gain (0.9±0.6).

In contrast to the findings of the previous studies indicating an effect of dietary protein content on body composition loss, the following two studies reported no changes with protein manipulation. In 1975, Hegsted, Gallagher and Hanford fed isocaloric diets to four groups of obese rats. Each group's diet contained varying amounts of protein. The rats were weighed once a week and sacrificed after 53 days. No significant differences were found between groups in terms of weight loss or percent body fat. The researchers concluded that a high protein/high fat/low carbohydrate diet did not produce a greater weight loss when compared to other diets with similar caloric intake.

Unlike Hegsted et al. (1975), Hickson and Hinklemann (1985) included an exercise regimen in their study. The amount of protein ingested during a 28 day weight lifting program and its effects on lean body weight were examined. Thirteen male subjects were randomly placed into one of four experimental groups. Group 1 (N=3) received the Recommended Dietary Allowance (RDA) for protein, (0.8 g/kg body weight) and did not exercise; group 2 (N=4) consumed 3 x RDA for protein (2.4 g/kg body weight) and did not exercise; group 3 (N=2) ate the RDA for protein and exercised and group 4 (N=4) received 3x RDA and exercised. The mean caloric intake for group 1 was 2923 kcal/day; for group 2 was 3030 kcal/day; for group 3 was 4607 kcal/day; and for group 4 was 4755 kcal/day (based on approximately 41 kcal/kg body weight/day for the non-exercising groups and 62 kcal/kg body weight/day for the exercising groups). The exercise consisted of a 36 minute strength building routine (per day) alternating arms and chest with back and legs. No significant changes were observed over the 4 weeks between the groups in lean body weight, and the authors speculated that the 36 minutes/day was an insufficient length of time to produce significant changes in lean body weight. They concluded that the small increases in lean body weight, 0.1 kg, 0.7 kg, 0.9 kg and 1.7 kg (for groups 1-4 respectively) were probably due to a learning effect that occurred for the hydrostatic weighing procedure. It was concluded that the increased protein intake did not significantly affect muscular strength.

Finally, a combination of high carbohydrate, high fat and high protein diets were fed to obese and lean rats for 3 weeks in a study by Vander Tuig, Rombos and Leveille (1980). All diets contained a basal mix of casein, corn oil, mineral mix, cellulose, vitamin, methionine and choline chloride for a total of 33.9 grams. In addition, the high carbohydrate contained 66.1 g glucose, the high fat diet consisted of 26.7 g tallow and the high protein had 60.2 g casein. The study lasted 21 days and the authors found that the diet composition did not significantly affect weight losses or body composition loss in either obese or lean rats. They also suggested that the amount of protein lost during caloric restriction may be related more to the amount of adipose stores than to diet composition.

The following authors reported that varying the carbohydrate content did not affect body fat. Werner (1955) found that obese patients lost weight whether they were on a hypocaloric, high carbohydrate diet or a high fat diet. Young et al. (1971) reported that body weight loss as well as body fat loss increased with a lower carbohydrate diet. Unfortunately, no statistical analyses were conducted so the authors could only conclude that trends were present. Finally, Yang and Van Itallie (1976) reported similar findings for obese males on a low carbohydrate diet. Although weight loss appeared to be different between the groups (low protein, isocaloric and starvation) it was explained by differing levels of water excretion for the groups.

All three of these experiments had one major drawback: a small sample size. With only 2-3 subjects per group it is very difficult to make any applications about the general population since the changes could have been individual rather than caused by the experiment.

Four of the studies examining protein manipulation reported differences between the groups in terms of body comopsition while two studies found no differences. Crews et al. (1969) and Nettleton and Hegsted (1977) found that body fat losses were higher in rats consuming diets with normal as compared to low amounts of protein. One difference between the studies was that the rats in Crews et al. study exercised while those in the latter study did not.

Using human subjects, Worthington and Taylor (1974) found that a high protein diet produced a greater weight loss than a balanced low calorie diet during the first week of the study. Weight loss was similar during the second week. This may have occurred because of an increased excretion of water with the high protein diet. Marliss et al. (1978) also reported a greater weight loss with high protein diets during a month long weight reduction.

No changes were seen by Hegsted et al. (1975) in a study using obese rats. It was concluded that one specific macronutrient ratio did not produce a greater weight loss compared to other diets when caloric intake was similar. Hickson and Hinklemann (1985) also reported no changes in lean body weight between weight lifters eating the RDA for protein and weight lifters eating 3xRDA for protein. Although this study lasted 28 days, the amount of exercise done each day was probably not enough to produce changes in lean body weight since the exercise portion was only 36 minutes a day.

Protein and Carbohydrate Intake and Muscular Function Changes

Just as body composition changes can vary depending on the percentage of protein and carbohydrate that is ingested so can function of skeletal muscle. During heavy strength training muscle glycogen is depleted (Rozenek & Stone, 1985), and if an adequate supply of carbohydrate is not ingested the workouts will suffer or the muscle will be broken down and used for energy. This section examines muscular function and how it can change with diets of varying ratios of protein and carbohydrate.

In 1962 Rasch and Pierson investigated 30 subjects, half of whom consumed 2.5 grams of protein (3 times the RDA) and half who ate normal amounts of protein (0.8 g/kg body wt). Calories were not restricted in either group. All subjects were placed on a weight training program which lasted six weeks and consisted of upper body exercises three times a week. The authors reported that the increases in strength were significant but there was no difference between the groups.

A later study by Rasch, Hamby, and Burns (1969) again examined the effects of additional protein in the diet of 32 U.S. Marines. Sixteen received a protein supplement (70% protein) while the remaining subjects received a placebo.

Both groups were tested on pullups, squat thrusts, standing broad jump and bent knee situps before a 4 week weight training session (4 hrs/day) and then again upon completion of the weight training. Both groups improved significantly but there was no significant difference between the groups. The researchers concluded that the additional protein did not aid physical performance. The diet was not controlled in this study and the subjects were not monitored on the weekends to check if they had consumed the protein supplement.

Unlike Rasch and Pierson (1962) and Rasch et al. (1969), Bogardus, LaGrange, Horton and Sims (1981) looked at varying carbohydrate levels of an isonitrogenous diet. Eight obese subjects were placed on one of two 830 kcal diets. The carbohydrate containing (CC) group consumed 35% protein, 29% fat and 36% carbohydrate while the carbohydrate restricted group (CR) consumed 35% protein, 64% fat and 1% carbohydrate. The results of the 6 week study showed that for the CC group the baseline, 1 week and 6 week endurance times (min) were: 83.0±3.1, 82.1±8.7 and 86.0±8.6. The CR groups values were significantly lower: 66.5±13.5, 29.0±4.5 and 31.7±5.0 for baseline, 1 week and 6 weeks respectively. Muscle glycogen was unchanged in the CC group over the 6 weeks while in the CR group it was 49% lower after 1 week and 51% lower after 6 weeks. The authors concluded that subjects on a carbohydrate containing diet were able to maintain endurance capacities and muscle glycogen while those subjects on a carbohydrate restricted diet were not. However, endurance in the CR group did increase slightly from week 1 to week 6.

Another study that analyzed diet composition and muscular function was done by Widerman and Hagan (1982). The authors studied one wrestler's diet and exercise regimen for 2 months. The goal of the wrestler's diet was to yield a high ratio of fat to lean tissue lost yet still provide enough energy for competition. The diet he consumed contained 25% protein, 63% carbohydrate and 12% fat. The percentage of protein allowed the wrestler to obtain at least 0.8 g/kg bw/day as well as providing sufficient energy to train. Isokinetic and isotonic muscular strength were maintained or increased during this diet.

Dragan, Vasiliu and Georgescu (1985) analyzed protein ratios in weightlifters. Twenty weightlifters were divided into 2 groups and a double blind crossover study was executed for 9 months. Both groups received approximately 3.5 g/kg body weight of protein during their respective experimental phases. Significant increases of scapular and lumbar strength and strength index were seen in both groups during the high protein portion of the experiment.

A study similar to Dragan et al. was done by Hickson and Hinklemann in 1985. Thirteen male weightlifters were randomly assigned to one of four diet/exercise groups. The diet for group 1 consisted of 8% protein (RDA for protein), 25% fat and 69% carbohydrate, and they did not exercise. Group 2's diet included 22% protein (3xRDA for protein), 33% fat and 45% carbohydrate, and they did not exercise. Group 3 consumed 6% protein (RDA for protein), 27% fat and 69% carbohydrate and they did exercise. Finally, group 4's diet consisted of 15% protein (3xRDA for protein), 36% fat and 47% carbohydrate and they did exercise. The authors found that strength increased significantly for the RDA-EX group, and for the 3x RDA-EX group as measured by 1 RM (repetition max) throughout the study. No results were shown for differences between the RDA group and the 3xRDA in strength and no changes were seen in either of the non-exercising groups.

In summary, Rasch and Pierson (1962) and Rasch et al. (1969) reported similar results from their studies. Both looked at a protein supplement and its effect on muscular strength changes. No differences between the groups were found although increases in strength were noted for all groups. Later, Bogardus et al. (1981) examined carbohydrate levels in 8 obese women. The authors reported that aerobic endurance and muscle glycogen were maintained by the group eating the carbohydrate containing diet (36%) while significant decrements in both were noted in the carbohydrate restricted group (1%). It was also reported that a slight nonsignificant increase in endurance was seen in the carbohydrate restricted group from week 1 to week 6.

While Widerman and Hagan (1982) did not look at specific macronutrients, they did analyze various diet compositions for a wrestler trying to lose weight yet maintain strength and wrestling ability. The results showed that isotonic strength was maintained and isokinetic strength was increased.

Two studies dealing specifically with weight lifters were conducted by Dragan et al. (1985) and Hickson and Hinklemann (1985). Dragan et al. noted increases in muscular strength by subjects fed a diet containing 3.5 g/kg body weight of protein. Hickson and Hinklemann also reported strength gains for the 2 exercising groups but no differences were reported between the group consuming the RDA for protein and the group consuming 3xRDA for protein.

Validation of Testing Body Composition

In the last fifty years numerous methods have been used to estimate body composition. Examples include: total body water, total body potassium, creatinine excretion, 3-Methylhistidine excretion, radiography, anthropomorphic measurements and hydrostaic weighing (Buskirk and Mendez, 1983). Hydrostatic weighing has become the 'gold standard' and is often used as a means to validate other methods. Unfortunately, most of the initial testing for hydrostatic weighing was done with a homogeneous population. Discrepancies have been found when applying the equations generated from that first testing to different populations (Wilmore, 1983).

Anthropomorphic measurements are used frequently because they are simple to do. However, many potential sources of error are present including: the tester, the reproducibility of choosing the site, the type of calipers and any combination of the above. Prediction errors range from approximately 3.1% fat to 3.6% fat, as compared to 1-3% for hydrostatic weighing (Pollock and Jackson, 1984).

In predicting body density from indirect measurements one must remember that it is still only a prediction. Correlations vary when comparing body density obtained hydrostatically and with skinfold measurements. Some explanations are: 1) that skinfolds only measure subcutaneous fat while hydrostatic weighing includes fat distributed elsewhere in the body; 2) differing densities of lean body masses between subjects (Lohman, 1982); and, 3) if the subject is dehydrated during hydrostatic weighing the body density may be overestimated and body fat underestimated because it will affect the Archimedes' Principle as it relates to hydrostatic weighing (McArdle et al., 1981). Dehydration can cause weight loss without fat loss due to a decrease in the body's fluids.

Exercise can also bring about changes in body composition thus affecting the prediction in body density. Exercise promotes an increase in bone mineral content which in turn will increase the bone density and increase the density of the fat-free tissue in the body (Lohman, 1983).

Problems with assessing and validating body composition still exist for populations other than white males, mainly children, women, athletes, the elderly and different races. Oftentimes body fat is underestimated or overestimated because the body density varies with sex, race, body type and physical activity (Lohman, 1982). The following studies examine body composition validation and testing.

Wilmore and Behnke (1969) predicted body density, percent body fat and lean body mass in 133 college males. Seven skinfold sites, 20 diameters, 25 circumferences, height and weight were measured for each subject by a thoroughly trained technician. Hydrostatic weighing was done to validate the prediction of the anthropomorphic measurements. Multiple regression equations were used to make the predictions using an equation from Sloan (1967) where density: 1.1043 - 0.001327x (thigh skinfold) - 0.00131 x (scapular skinfold). The results of this study showed a high correlation between hydrostatic weighing and 1) predicted body density (r=0.867); 2) predicted percent body fat (r=0.788); and, 3) predicted lean body weight (r=0.958). Since no cross validations were conducted the authors concluded that the given equations must be used with caution until they had been applied to different popuations.

Jackson and Pollock (1978) also analyzed the validity of body density prediction from anthropomorphic measurements. Skinfold thickness (6 sites), body circumferences (2 sites), and height and weight were measured in 403 males (ages 18-61). Hydrostatic weighing was used to validate the values from the anthropomorphic measurements. Equations were used to estimate the body density using the sum of the skinfolds, age, waist and forearm circumferences. A correlation, with measured body density, of r=0.90 resulted. The researchers concluded that for men varying in age and fatness general regression equations using skinfolds measurements and circumferences were valid.

In contrast to the findings by Wilmore and Behnke (1969) and Jackson and Pollock (1978), Wilmore, Royce, Girandola, Katch and Katch (1970) found skinfold measurements and circumference measurements did not correlate highly with body density. The researchers looked only at single site correlations (r=.36 to r=.73) and they assumed that a combination of sites would have produced a higher correlation but not high enough to be a reliable prediction. They concluded that skinfold measurements are not precise enough for research purposes but are suitable for screening.

Lewis, Haskell, Klein, Halpern, and Wood (1975) examined the body composition of active middle aged men. They predicted body density (BD), lean body weight (LBW), fat body weight (FBW) and percent body fat (% BF) with anthropomorphic measurements. These values were correlated with hydrostatic weighing and the results showed high correlations (r=.84-.95) with all four predicted values. However, this was done using equations generated from this study rather than previously determined equations. The correlations were 4-42% lower using other equations. The authors concluded that the application of previously generated prediction equations is less accurate for middle age active men than an equation generated specifically for this population.

Middle aged men were further analyzed by Pollock, Hickman, Kendrick, Jackson, Linnerud and Dawson in 1976. The authors predicted body density in middle aged men (40-55) and young men (18-22) to determine if generalized equations could be used for both populations. Body density was measured by hydrostatic weighing. Seven skinfold measurements, 11 girth measurements, 7 diameter measurements, age, height and weight were used to predict body density. Through multiple regression analysis it was found that 2 different equations were needed to accurately predict body density. Thus, the authors concluded that generalized prediction equations were not applicable in this study.

In contrast to the studies done using men, Slaughter, Lohman, Boileau, Stillman, Van Loan, Harswill and Wilmore (1984) examined children. Body density was predicted using skinfold measures. The researchers found that body density increases as maturation occurs. The prediction equations derived for adults tend to overestimate the body density for children and therefore it was concluded that equations applicable to adults should not be used for children.

Prediction of body density for female subjects was studied in 1985 by Shephard, Kofsky, Harrison, McNeill and Krondl. The authors looked at 12 moderately active women (ages 47-58). They found that anthropomorphic data was a better indicator of percent body fat than hydrostatic weighing using nitrogen and potassium measurements as the criterion values. Changes in density due to age and possible difficulties in obtaining accurate density may have complicated this study. However, the authors concluded from their study that with older women anthropomorphic data is more accurate in predicting body density than hydrostatic weighing.

In conclusion, Wilmore and Behnke (1969), Lewis et al. (1975), and Pollock et al. (1976) all reported that population specific equations were better for predicting body density, body fat and lean body mass than generalized equations. Later Jackson and Pollock (1978) claimed that using a wide variety of subjects generalized equations could be used as accurate predictors of body composition.

Two other studies, Wilmore et al. (1970) and Shephard et al. (1985) found low correlations between measured body density (using hydrostatic weighing) and predicted body density using anthropomorphic measurements.

Finally, body density in children was examined by Slaughter et al. (1984) and the researchers concluded that aging changes body density, thus special equations are needed for children to accurately predict body density.

Body Composition of Body Builders

Body composition is another important consideration for weight lifters and body builders. Minimum amounts of fat and maximum amounts of lean body mass are necessary if muscle size and definition are to be accentuated. Fahey, Akka and Rolph (1978) investigated the body composition of athletes who trained with weights. Densitometry was used to determine percent body fat and the authors reported that the body builders had the lowest value (8.4%) of all the subjects studied (wrestlers, power lifters, olympic weight lifters, discus throwers, and shot putters).

Katch, Katch, Moffatt and Gittleson (1980) examined muscular development and body composition in competitive male body builders. Thirty-nine males served as subjects and the mean percent body fat was 9.3% while lean body mass was 74.6 kg. Hydrostatic weighing was used to make the percent body fat measurements.

In 1980 Spitler, Diaz, Horvath and Wright investigated body composition in ten actively competing body builders. The authors reported that the average body fat was 9.9%. During this study it was suggested that diet rather than aerobic exercise was the preferred method of decreasing percent body fat.

A study conducted by Freedson, Mihevic, Loucks and Girandola (1983) analyzed the body composition of ten female body builders. Total body volume was calculated using hydrostatic weighing and percent body fat was determined from the body density. The results showed that percent body fat was 13.2%, lower than the reference female, and lean body mass was 46.6 kg, higher than the reference female.

All of these studies produced similar results and suggested that percent body fat was lower than the reference male or female and that lean body mass was higher than the reference man or woman. However, none examined the changes induced by training or dieting. Studies examining these parameters during weight loss would be of interest to body builders.

Summary

Current research examining hypocaloric diets, protein/carbohydrate intakes, muscular function and body composition for body builders is limited. Many of the studies reviewed used subjects other than body builders and therefore the conclusions obtained may or may not apply to studies analyzing body builders. The literature that examined caloric restriction and body composition showed some contrasts. Oscai and Holloszy (1969) and Pavlou et al. (1985) reported that when exercise was maintained during caloric restriction, lean body mass loss was slowed while body weight loss and fat loss increased. Widerman and Hagan (1982) and Hagan et al. (1986) reported conflicting results. Lean body mass was lost by subjects on hypocaloric diets even though exercise was continued.

The studies analyzing caloric restriction and muscular function also produced contrasts. Taylor et al. (1957), Widerman and Hagan (1982) and Pavlou et al. (1985) reported maintenance or improvement in muscular performance during hypocaloric dieting. (The subjects continued to exercise throughout the experiments.) In contrast, Houston et al. (1982) found significant strength and glycogen decrements after 72 hours.

Results for protein and carbohydrate intake and body composition changes were also varied. Worthington and Taylor (1974) and Marliss et al. (1978) reported that weight loss was greater with high protein diets. No changes were noted by Hegsted et al. (1975) and Hickson and Hinklemann (1985) in weight loss and lean body mass.

Conflicting results were also seen in the literature analyzing the effects of protein and carbohydrate intake and muscular function. Rasch and Pierson (1962), Rasch et al (1969) and Hickson and Hinklemann (1985) all reported that additional protein did not significantly increase muscular performance between groups. In contrast, Dragan et al. (1985) suggested that high protein intake resulted in improved strength performance.

The research on validation of body composition was also varied. Population specific equations were reported better for predicting body density by Wilmore and Behnke (1969), Lewis et al. (1975), and Pollock et al. (1976). However, in 1978, Jackson and Pollock found that generalized equations were equally accurate for predicting body density.

All the studies examining body composition revealed comparable results. The body builders analyzed by Fahey et al. (1978), Freedson et al. (1983), Katch et al. (1980) and Spitler et al (1980) were lower in percent body fat and higher in lean body mass than the reference man or woman.

Chapter III

JOURNAL MANUSCRIPT

The Effects of a Varying Protein/Carbohydrate Ratio of a Hypocaloric Diet on Body Composition and Muscular Function in Body Builders

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Introduction

In recent years most athletes have realized that diet is an essential factor during precompetition training. Wrestlers, weight lifters and body builders often use severe caloric deprivation as a means of losing weight. The goals of this diet are to decrease percent body fat while maintaining lean body mass thus maximizing muscular performance (13, 20).

A common belief among these athletes is that additional protein in the diet will lead to increased strength, size and definition of muscles (20). Only one study has supported this belief when 2-3 times the Recommended Dietary Allowance (RDA) of 0.8 g/kg body weight/day of protein was consumed (2). Other researchers have reported no differences in muscle function or body composition between subjects consuming a diet with normal amounts of protein and a diet high in protein (1, 7, 8).

Body builders frequently incorporate hypocaloric diets into their pre-competition regimen. Hypocaloric diets will decrease body weight and percent body fat (6, 17, 25), but may also decrease lean body mass and muscle function (6, 25).

Due to the scarcity of available scientific research on this population, this study was conducted to examine the effects of protein and carbohydrate intake on body composition and muscular function of body builders on a 7 day hypocaloric diet.

METHODS

Nineteen male body builders from the Virginia Tech Weight Lifting Club volunteered to serve as subjects in this study. The physical characteristics of the subjects are found in Table 1. All subjects had been weight lifting 3-7 times a week for at least 2 years. The subjects were randomly assigned to one of three groups: Control-C (n=5), High Protein/Moderate Carbohydrate HP/MC (n=7), or Moderate Protein/High Carbohydrate MP/HC (n=7). One week prior to the experimental phase all subjects were placed on a weight maintenance diet which supplied 35 kcal/kg body weight/day and 1.1 g/kg body weight/day of protein. The exchange system (which groups all foods into one of six groups: meats, dairy products, fruits, vegetables, breads and fats) was used and each subject was given a list with the number of exchanges that could be consumed per day from each group.

Insert Table 1 about here

Initial measurements of body weight (kg), percent body fat (% BF) and static endurance were obtained during the maintenance week. Percent body fat was calculated by skinfold measurements and hydrostatic weighing. Three skinfold sites (chest, abdomen and thigh) were measured 5 times by the same technician using Harpenden calipers. The highest and lowest values at each site were discarded, the remaining 3 values were averaged and the sum of the 3 sites were used to calculate %BF (21). Test/retest reliability for each site exceeded r=.95.

All 3 groups followed the same weight training regimen prescribed from a predicted 1RM for each lift obtained from a set of 5RM tests done prior to the maintenance week. The weight training regimen began during the maintenance week so that all subjects would be starting from the same baseline during the onset of the experimental phase. The regimen consisted of 8-10 repetitions 6 days a week and alternating legs/back/biceps with chest/shoulders/triceps. The intensity was prescribed at 70% of 1RM but some subjects needed to alter that weight so that they could achieve the prescribed number of repetitions. The actual intensity varied from 60-80% of 1RM. The exercises for biceps/back/legs included: bent bar curls, straight bar curls, one arm rows, lat pulldowns, back hyperextensions, squats, quad extensions, ham curls, calf raises and seated calf raises. Exercises for the triceps/shoulders/chest included: tricep extensions, tricep pushdowns, behind the neck press, seated dumbbell press, lateral raises, bench press, incline bench press, and dumbbell flyes. All weight lifting was supervised by the investigators and lasted approximately 2 hours per day. The actual weight lifted, number of repetitions and sets were recorded daily.

The hydrostatic weighing was done using a large metal tank. The recorder was calibrated using a known weight of 4.21 kg. After recording body weight to the nearest 0.1 kg, subjects seated themselves in the tank on a steel mesh bed suspended by four load cells attached to a transducer and a recorder. A supine position was assumed in the basket, after expelling as much air as possible, until a stable reading was recorded. Water temperature was measured prior to each test. Eight trials were conducted and the 3 highest values were used to determine underwater weight. Body density was calculated using the Keys and Brozek (12) equation, and from that the %BF was determined (21). Residual lung volume was calculated using the oxygen-dilution nitrogen equilibration method by Wilmore et al. (26) using Applied Electrochemistry (Model numbers: 5-3A, CD-3A) gas analyzers. At least 2 residual lung volume determinations were made on each subject. If the difference was less than 5% the two values were averaged and that number was used in the calculation of body density. A third trial was given if the difference between the values was greater than 5% and the mean of the three trials was used.

Static muscular endurance was measured using Cybex isokinetic machines. Prior to the actual testing subjects were familiarized with the placement of limbs and were given 3 practice trials for each test. The preferred limb was used for both tests. For the elbow flexion test subjects were in a supine position on the upper extremity machine with the elbow resting on a pad. The shoulder extension accessory was inserted into the dynamometer and the elbow was positioned at an angle of 110° (0° being full extension). This position was used because it best duplicated a body building pose for biceps. The dynamometer was aligned with the axis of rotation of the elbow. The hand was placed in a supinated position on the hand grip and the waist and elbow joint were securely fastened with a belt to isolate the bicep. Ten maximal contractions of 10 seconds each with 5 seconds of rest in between each trial were performed by each subject. During the knee extension test the subjects were seated and the preferred foot was secured to the long input adapter. Belts were fastened around the chest, waist and knee. The height of the shin pad, number of seat cushions, height of the dynamometer and distance from the subject had been measured during the practice sessions and remained constant for all subsequent tests. The knee was positioned at an angle of approximately 25° (0° being full extension) and the test consisted of 10 maximal isometric contractions of 10 seconds with 5 seconds of rest between each trial. Results from both the elbow flexion test and the knee extension test were recorded on the Cybex Dual Channel Recorder. The static endurance ratio was calculated by dividing the total area under the first 2 trials by the total area under the last 2 trials.

The caloric intake for both groups was calculated using 18 g/kg body weight. The HP/MC group consumed a liquid diet containing 1.6 g/kg body weight per day of protein and approximately 50% carbohydrate and 15% fat. The MP/HC group also consumed a liquid diet which consisted of 0.8 g/kg body weight per day of protein and approximately 70% carbohydrate and 13% fat. Both groups consumed two 8 oz. cans of Exceed Nutritional Beverage (Ross Laboratories) per day. Each can provided 360 kcal, 15 g protein, 47 g carbohydrate and 12 g fat. The remainder of the protein for the HP/MC group was supplied from Promod Protein powder (Ross Laboratories) and 3 cups nonfat milk which added 24 g protein and 240 kcal.

The MP/HC group consumed 1 cup nonfat milk supplying 80 kcal and 8 g protein and the remainder of the carbohydrate and protein was supplied by Exceed Carbohydrate Powder and Promod protein powder (Ross Laboratories), respectively. The control group continued with the maintenance diet.

A split plot factorial design was used in this study and repeated measures analysis of variance (ANOVA) was used to analyze the data. The alpha level was set at .05. Simple Main Effects tests and Tukey's post hoc test were used to determine statistically significant differences between the group means.

RESULTS

The initial values of body weight, percent body fat, lean body mass and endurance ratios for the three groups are found in Table 1. The pre-experimental values for the groups were not significantly different. The pre/post experimental data is found in Table 2.

Insert Table 2 about here

Weight Loss

Body weight was recorded daily and the average losses over the 7 day study were 0.9 kg, 3.6 kg, and 4.0 kg for the control, HP/MC, and MP/HC groups respectively. Thus, although the control group was instructed to maintain their weight, all control subjects lost from 0.2 kg to 1.5 kg during the experimental week. The individuals in the HP/MC group lost from 2.2 kg to 6.1 kg. Finally, the range of weight loss for the MP/HC group was 3.0 kg to 4.3 kg.

The repeated measures ANOVA analysis for body weight changes indicated that although no significant differences were noted between the groups, significant losses were reported over time ($F=64.96$, $p<.05$) and for the time/group interaction ($F=7.50$, $p<.05$) (see Table 3). The statistical test for simple main effects indicated that the body weight for the 2 experimental groups decreased significantly from day 1 to day 7 while the control group did not. Tukey's post hoc analysis showed that the only days that significant decrements were not seen were between days 2 and 3, 3 and 4, 4 and 5, and 5 and 6 for both the HP/MC group and the MP/HC groups. In addition, the analysis for the HP/MC group indicated a nonsignificant loss between days 6 and 7. Graphic representation of mean daily body weight changes can be found in Figure 1.

Insert Table 3 and Figure 1 about here

Body Fat

Initial values of body fat using skinfold measurements ranged from 4.0 to 13.0 with the mean being 7.7±2.3%. The hydrostatic weighing procedures resulted in a range of 4.5 to 22.9 percent body fat with a mean of 11.2±5.2%. The correlation between these two values was $r=0.69$ ($p<.0001$). The range for post-experimental body fat was 3.6 to 11.7 with a mean of 7.1±2.1% using skinfolds and 0.6 to 22.9 with a mean of 10.0±5.7% using the hydrostatic technique. The Pearson correlation between the two techniques for the post experimental values was $r=0.66$ ($p<.0001$). The subjects showed a significant percent body fat loss over the 7 day study using skinfold measurements ($F=5.80$, $p<.05$) and for hydrostatic weighing procedures ($F=5.60$, $p<.05$). No significant differences in percent body fat were observed between the groups over time with either method (see Table 4).

Insert Table 4 about here

Lean Body Mass

Initial lean body mass was calculated prior to the hypocaloric phase using skinfold measurements and hydrostatic weighing procedures. Using skinfold measurements, the percentage of total weight loss attributable to lean body mass was 100% for the control group; 77.8% for the HP/MC group; and 75% for the MP/HC group. The percentage of lean body mass lost using hydrostatic weighing was 0% for the control group; 39.0% for the HP/MC group; and 67.5% for the MP/HC group. Significant losses in lean body mass were observed over time using skinfold measurements ($F=46.72$, $p<.05$) and hydrostatic weighing ($F=9.92$, $p<.05$). A significant interaction between group and time was also seen using skinfold measurements ($F=5.13$, $p<.05$). Tukey's post hoc analysis indicated that the two experimental groups lost significantly more lean body mass than the control group, however, they were not significantly different from each other (see Table 5 and Figure 2).

Insert Table 5 and Figure 2 about here

<u>Muscle Function</u>

The initial ranges of quadricep endurance ratio were 58.2% to 94.2% for the control group; 53.9% to 69.9% for the HP/MC group; and 38.5% to 100.0% for the MP/HC group. Initial ranges for the bicep endurance ratio were 37.1% to 67.5% for the control group; 44.6% to 71.4% for the HP/MC group; and 53.4% to 70.8% for the MP/HC group. Significant losses in quadricep endurance ratio were seen over time ($F=7.24$, $p<.05$) for all groups (see Table 6). The decrement over time for the quadricep endurance ratios were -3.7% for the control group, -14.0% for the HP/MC group, and -5.3% for the MP/HC group. Nonsignificant changes bicep endurance ratios were +14.8% for the control group, +6.2% for the HP/MC group, and -1.5 % for the MP/HC group. No significant differences were found over time or between groups for the bicep endurance ratio, however, nonsignificant increases were seen for the HP/MC and control groups (see Table 2).

DISCUSSION

The results of this investigation indicate the effects of a low calorie, high protein/moderate carbohydrate and a low calorie, moderate protein/high carbohydrate are similar over a seven day period on body weight and composition changes.

Body Weight

Both hypocaloric groups lost similar amounts of weight which is in agreement with studies by Werner (24), Vander Tuig et al. (23), and Hegsted et al. (6). These researchers all reported no significant differences in body weight loss using variations in protein/carbohydrate ratio. The caloric intake was more important in determining the amount of weight lost than the percentage of macronutrients ingested. Conflicting results were reported by Young et al. (29), Worthington and Taylor (27), and Marliss et al. (14). Subjects consuming diets high in protein had greater weight losses than subjects on a balanced isocaloric diet or a fasting diet followed by refeeding. The duration of the experiment may have been important as those studies that were longer than 2 weeks were unable to find differences, while those less than 2 weeks found high protein diets were more effective for weight loss. Although this is in contrast to the results of the present study, the percentages were not as extreme as those researchers using high protein diets. In the present study, a sufficient amount of carbohydrates was consumed by the subjects on the moderate protein diet, thus the similar weight loss.

Percent Body Fat

Skinfold measurements and hydrostatic weighing were used to compute percent body fat. Hydrostatic weighing was used as the criterion measure for body fat in this study because of its general acceptance as the 'gold standard' for predicting body density (10, 26). Skinfold measures were taken to determine if the percentage fat predictions varied independently from the hydrostatically derived values. Percent body fat predicted from skinfold measurements was lower than that from hydrostatic in 16 of the 19 subjects for pre-test values and 14 of the 19 for the post-test values. It is likely that the skinfold measurements slightly underestimated percent body fat. Possible explanations for this were that assumptions regarding hydrostatic weighing were violated. The Siri (21) equation was used to determine percent body fat from the calculated body density and it was assumed that the fat free body density was 1.100 g/cc and fat density was 0.900 g/cc (12). If any of the subjects varied from these values, the body fat calculations would be in error. It was also possible that a learning effect occurred. This would cause the post-test measurements of body density to be higher without an actual change and thus the percent body fat would be lower. Finally, the possibility of dehydration during the hydrostatic weighing could have theoretically altered the values for body density. When dehydration occurs body weight will be less but body fat may not be different. Predicted body density may be overestimated, thus body fat will be underestimated (15).

Although both experimental groups had a decrease in their percent body fat over the seven day study, there were no significant differences between the groups. These findings were similar to those of Hegsted et al. (6) and

Yang and Van Itallie (28). Both reported that varying the dietary protein/carbohydrate ratio did not result in significant differences between the diet groups in loss of body fat. In contrast, Young et al. (29) reported a greater fat loss with subjects on low carbohydrate diets as compared to subjects on diets containing higher percentages of carbohydrates. Since no statistical analyses were made it is possible that this higher fat loss occurred purely by chance.

Lean Body Mass

During hypocaloric dieting, lean body mass is usually expected to be maintained or decreased. A body builder's goal is to maintain lean body mass while decreasing percent body fat. In this study, both experimental groups lost lean body mass and although they were not significantly different the HP/MC group tended to lose less than the MP/HC group (1.4 kg vs. 2.7 kg by hydrostatic weighing calculations). This was probably due to the higher percentage of protein that was consumed. This is in contrast to what Hickson and Hinklemann (8) reported. They found that lean body mass was not significantly different between subjects consuming 3xRDA for protein and subjects consuming the RDA for protein. It is important to note that these subjects were not on hypocaloric diets and theoretically could have been maintaining lean body mass with the weight training regimen that they were following. It is also interesting to note that in this study, the control group lost no lean body mass (using hydrostatic weighing) indicating that the higher caloric intake may have been more effective in maintaining lean body mass.

Research on caloric restriction and lean body mass changes without regard to diet composition reports that exercise is usually important in helping to maintain lean body mass. Most studies have examined this effect using endurance exercise. For example, Oscai and Holloszy (16) found that exercising rats lost 22% lean body mass while sedentary rats lost 38% lean body mass while on hypocaloric diets. Pavlou et al. (17) also reported that over 8 weeks an exercising group of human subjects lost 0.6 kg lean body mass while the non-exercising group lost 3.3 kg. Since our study did not have sedentary subjects, it is not possible to determine the influence of the weight training program used on body composition changes.

Since the water and protein contents of the body were not measured in this study, one can only speculate on the composition of the lean body mass loss. High protein diets usually increase water excretion and dehydration can occur. Thus, it is possible that the decrease in lean body mass was actually a decrease in water and/or protein.

Muscular Function

Significant decrements in static muscular endurance were reported in all three groups for the quadriceps in this study. Since the majority of the literature concerning the weight loss and muscle function relationship has examined strength rather than endurance, it is hard to make comparisons to our study. Decrements in quadricep strength were reported by Houston et al. (9) after 72 hours of caloric restriction. In contrast to strength decrements, Widerman and Hagan (25) and Pavlou et al. (17) found that strength was maintained or increased after 8 weeks of training in subjects losing weight. It is possible that if the present study had been longer, endurance may have been maintained due to an adaptation to the hypocaloric diet and to the weight training regimen. Also, Widerman and Hagan (25) only studied one subject and it is possible that in duplicating that study, those results would not have been found. During dieting and training the body should adjust to abnormal conditions and learn to function at these levels as the subjects in previous studies (16, 24) have. The body adapts to consuming less calories and over a period of time, burns more fat tissue (5).

Bicep endurance increased nonsignificantly for the HP/MC and control groups. In this study the increases may have been due to a less demanding exercise regimen for the biceps. The biceps were utilized less during the daily weight training sessions than the quadriceps with less glycogen drained. This may explain the ability of the subjects to maintain muscular endurance in spite of weight reduction.

The research that has examined protein/carbohydrate ratios and muscular function demonstrates variable results. Some studies found no difference between the strength of the groups when calories were not restricted as in this study (8, 18, 19). It seems evident that with sufficient calories, subjects who had not been weight training would show significant gains in strength upon the initiation of a weight training study. In contrast, Dragan et al. (2) found that added protein (3.5 g/kg body weight/day) did improve their performance on strength measures. Their subjects were elite weight lifters who had been weight training prior to the study. Two groups were used in a double-blind crossover study. This suggests that those athletes engaged in high resistance weight training may benefit from additional protein when energy intake is sufficient enough to prevent lean muscle mass from breaking down.

In conclusion, many body builders follow low calorie diets, prior to a competition, which contain up to 4 times the RDA for protein, hoping to maintain their lean body mass while decreasing their percent body fat. Body weight and percent body fat may be decreased, as was evident in this study. However, without enough fuel for training the body may also break down body protein for energy. It appears that subjects following a low calorie diet with the RDA or 2xRDA for protein cannot maintain lean body mass and quadricep endurance while losing body weight. The subjects consuming 2xRDA for protein tended to lose less lean body mass which may indicate that a diet higher in protein is needed for resistance weight training. Both diets produced similar weight losses. However, it is possible that methodological inaccuracies theoretically could have contributed to these losses rather than the actual treatment effect. Further research is needed on different protein/carbohydrate ratios and caloric intake to determine the ideal diet for body builders so that body fat can be lost while lean body mass and muscular performance are maintained.

Table 1. Physical Characteristics and Initial Values of Subjects

	C n=5		HP/MC n=7		MP/HC n=7	
Physical Characteristics						
Age (yr)	19.4	1.6	21.0	2.4	21.4	2.0
Weight (kg)	74.6	9.1	80.2	11.0	81.8	7.6
Body Composition						
Percent body fat - skinfold	6.4	2.1	8.6	10.3	7.8	2.5
Percent body fat - hydrostatic	7.2	2.7	14.4	1.7	10.8	4.3
Lean body mass - skinfold (kg)	69.8	9.2	73.3	10.3	75.4	5.7
Lean body mass - hydrostatic (kg)	68.9	8.8	68.4	10.6	72.7	7.2
Static Muscular Endurance (%)						
Quadricep	74.3	12.5	62.7	5.2	61.4	20.0
Bicep	56.0	10.9	58.1	8.0	59.4	5.6

Table 2. Pre/Post Experimental Data for the Three Groups

	Control			High Protein/ Moderate Carbohydrate			Moderate Protein/ High Carbohydrate		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Body weight (Kg)	74.6 ± 9.1	73.8 ± 8.0	-0.8	80.2±11.0	76.6±10.7	-3.6	81.8± 7.6	77.8± 7.7	-4.0
Percent body fat - skinfold	6.4 ± 2.1	6.3 ± 2.0	-0.1	8.6±10.3	8.0± 1.7	-0.6	7.8± 2.5	6.8± 2.3	-1.0
Percent body fat - hydrostatic	7.2 ± 2.7	6.6 ± 3.0	-0.6	14.4± 1.7	12.4± 6.2	-2.0	10.8± 4.3	10.0± 5.9	-0.8
Lean body mass - skinfold (kg)	69.8 ± 9.2	69.1 ± 8.5	-0.7	73.3±10.3	70.5± 9.7	-2.8	75.4± 5.7	72.4± 5.9	-3.0
Lean body mass - hydrostatic (kg)	68.9 ± 8.8	68.9 ± 8.3	0.0	68.4±10.6	67.0±10.1	-1.4	72.7± 7.2	70.0± 8.2	-2.7
Quadricep endurance ratio (%)	74.3 ±12.5	70.6 ±15.8	-3.7	62.7± 5.2	48.7± 6.2	-14.0	61.4±20.0	56.1± 9.0	-5.3
Bicep endurance ratio (%)	56.0 ±10.9	70.8 ±11.1	+14.8	58.1± 8.0	64.3±17.1	+6.2	59.4± 5.6	57.9± 5.8	-1.5

Table 3. Summary ANOVA for Daily Body Weights

Source	SS	df	MS	F
Group	636.61	2	318.30	0.52
Error 1	9757.61	16	609.85	-
Time	102.56	6	17.09	64.92*
Time*Group	23.69	12	1.97	7.50**
Error 2	25.26	96	0.26	

*significant at the .05 level; critical value df 6,96 = 2.10

**significant at the .05 level; critical value df 12,96 = 1.75

Figure Legends

Figure 1 - Mean daily body weight loss for the three groups. MP/HC = Moderate protein/high carbohydrate group; HP/MC = High protein/moderate carbohydrate group. Significant changes from the initial weight are indicated by a 1; from day 2 by a 2; etc.

Figure 2 - Lean body mass changes for the three groups using skinfold measurements. MP/HC = Moderate protein/high carbohdyrate group. HP/MC = High protein/moderate carbohydrate group. Significant changes from pre to post are indicated by a *.

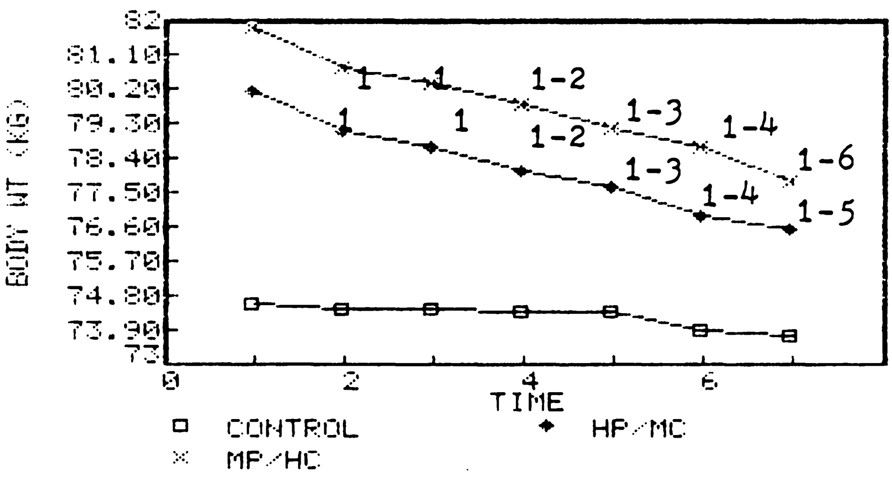

Figure 1. Changes in Daily Body Weight for the Three Groups

significant changes from the initial weight are indicated by a 1; from day 2 by a 2; etc.

Table 4. Summary ANOVA Tables for Percent Body Fat

Source	% BF (skinfold)			% BF (hydrostatic)		
	df	MS	F	df	MS	F
Group	2	10.77	1.17	2	118.28	2.23
Error 1	16	9.19	-	16	53.09	-
Time	1	2.87	5.80*	1	13.43	5.60*
Group*Time	2	0.51	1.03	2	1.50	0.62
Error 2	16	0.49	-	16	2.40	-

*significant at the .05 level; critical value df 1,16 = 4.49

Table 5. Summary ANOVA Tables for Lean Body Mass

Source	LBM (skinfold)			LBM (hydrostatic)		
	df	MS	F	df	MS	F
Group	2	58.28	0.42	2	47.34	0.30
Error 1	16	139.31	-	16	159.30	-
Time	1	43.72	46.72*	1	18.38	9.92*
Group*Time	2	4.80	5.13**	2	5.30	2.86
Error 2	16	0.94	-	16	1.85	-

*significant at the .05 level; critical value df 1,16 = 4.49

**significant at the .05 level; critical value df 2,16 = 3.63

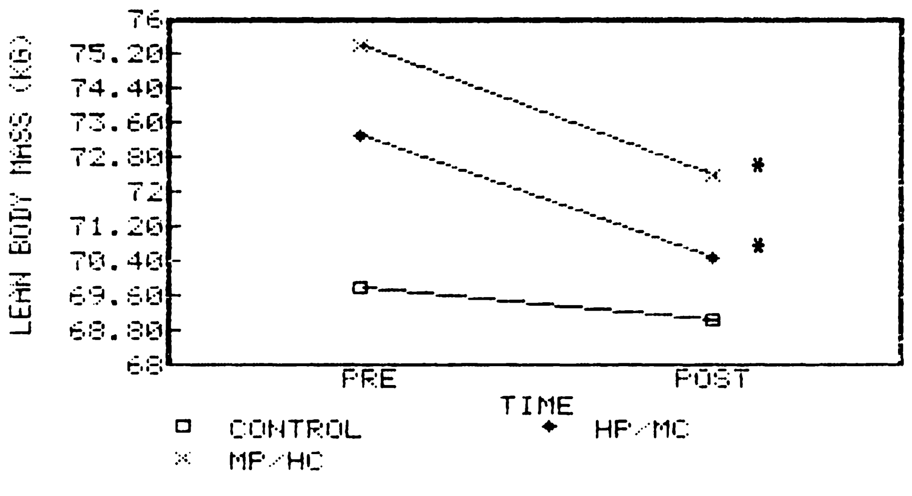

Figure 2. Changes in Lean Body Mass (Skinfold) for the Three Groups

* significant difference from pre to post

Table 6. Summary ANOVA Tables for Endurance Ratios

Source	Quadricep Endurance Ratio			Bicep Endurance Ratio		
	df	MS	F	df	MS	F
Group	2	887.68	3.39	2	66.70	0.51
Error 1	16	261.98	-	16	129.77	-
Time	1	541.72	7.24*	1	393.96	3.61
Group*Time	2	99.50	1.33	2	195.58	1.79
Error 2	16	74.84	-	16	109.08	-

*significant at the .05 level; critical value df 1,16 = 4.49

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Chapter IV

SUMMARY

Athletes are constantly searching for the diet that will decrease percent body fat, increase muscle size and definition, and improve performance. Wrestlers, weight lifters and body builders are specific examples of athletes who are willing to experiment with almost any diet or weight loss claim in order to achieve these goals. A high protein, low carbohydrate and low calorie diet is often the regimen followed by many body builders prior to a competition. Limited research is available on the practicality of these diets and the research that has been done indicates that the protein ingested or the muscle itself must be used as a source of energy when low calorie diets are followed. The purpose of this study was to examine the effects of protein and carbohydrate intake on body composition and muscular function in body builders. A week long study was utilized to determine if a high protein intake (1.6 g/kg/day)/ moderate carbohydrate intake or a moderate protein intake (0.8 g/kg)/high carbohydrate intake would have different effects on body composition and muscular function thus improving performance.

Nineteen male body builders were randomly assigned to one of three groups: control (n=5), high protein/moderate carbohydrate (n=7), or moderate protein/high carbohydrate (n=7). The two experimental groups consumed hypocaloric liquid diets supplying 18 kcal/kg body weight/day with varying amounts of protein, carbohydrate and fat. The control group followed a weight maintaining diet supplying 35 kcal/kg body weight. All 3 groups followed the same weight training program. One week prior to the study all groups followed the maintenance diet and began the weight training regimen so as to equalize the groups before the experimental phase. The study was 7 days in length. Measurements of body weight, percent body fat and lean body mass using skinfold values and hydrostatic weighing values, quadricep endurance ratio and bicep endurance ratio were obtained prior to the hypocaloric phase and on the seventh day of the study.

Results of the repeated measures analysis of variance indicated that daily body weight showed significant time and group interaction. Post hoc analysis showed that the two experimental groups lost more weight over time than did the control but were not different from each other. Results for percent body fat, lean body mass and quadricep endurance ratio also showed significant losses over time for all groups. Analysis of lean body mass using skinfold measurements found a significant group and time interaction.

Post hoc analysis indicated that the two experimental groups lost more lean body mass over time as compared to the control group, however, they were not different from each other. No significant changes over time or difference between groups were found in the biceps endurance ratio analyses. All dependent measures had been determined reliable prior to the study.

In this investigation the variation of protein and carbohydrate of a short-term weight reduction diet did not affect changes in body weight, body fat, lean body mass, or quadricep and bicep endurance ratio. The similar losses observed between the control group and the 2 experimental groups may be explained by methodological inaccuracies or learning effects. These would indicate changes when changes failed to occur. It was concluded that isocaloric diets of varying protein and carbohydrate content had similar effects on body composition and muscular function changes during weight loss. It was also concluded that predicting percent body fat from skinfold measurements may underestimate the actual body fat. Therefore, hydrostatic weighing may be more accurate for this population in the prediction of percent body fat. Although both diets produced a significant weight loss and a significant decrease in percent body fat, it appears that degree of caloric restriction rather than the percentages of protein and carbohydrate consumed was the determining factor. This is in agreement with studies by Werner (1955), Hegsted et al. (1975) and Vander Tuig et al. (1980), but in contrast to Young et al. (1971), Worthington and Taylor (1974) and Marliss et al. (1978) who all reported low calorie, high protein diets produced greater weight loss. Body builders who want to lose percent body fat, yet maintain lean body mass may want to increase their caloric intake somewhat (from the 1200-1700 kcal in this study) to provide sufficient energy for the training regimen, and maintain this regimen over a longer period of time (Lemon, 1985; Shaternikov & Korovnikov, 1985).

Research Implications

A study of this nature is important because body builders need to know if what they are doing to improve performance will actually accomplish this goal. It is also important to determine if the dietary regimens that body builders typically follow are healthy. This investigation suggested that a hypocaloric high protein/moderate carbohydrate or moderate protein/high carbohydrate diet was not effective in maintaining lean body mass or improving quadricep endurance over seven days. The treatment did produce a significant weight loss, a significant percent body fat loss and a nonsignificant increase in bicep endurance. The significance of this research indicates that the amount of calories consumed rather than the dietary protein or carbohydrate content is the major consideration for body builders who want to maintain lean body mass and endurance while losing weight and body fat. When the body is accustomed to consuming a diet high in calories and suddenly a hypocaloric diet is substituted, the body will use glycogen, muscle tissue and stored fat as energy. Thus, body builders who continue to follow diets low in calories may be increasing their chances of losing lean body mass and endurance ability, thus negatively affecting performance.

Recommendations for Future Research

The results of this investigation indicate a wide range of possibilities for future research. The following ideas are suggested: a longer experimental phase and variations in the protein/carbohydrate ratios and caloric intake. Shaternikov and Korovnikov (1985) recommend the following percentages of macronutrients: 22% protein, 36% fat, and 42% carbohydrate. They also state that deficiencies of any nutrient during training can negatively affect performance. A longer experimental phase would allow the subject's body to adjust to the caloric deficit, the metabolic rate would decrease, and less calories would be used for energy, thus possibly more lean muscle tissue would be spared. Body fat loss would also be greater during a longer study because the body starts to break down the stored adipose tissue much more readily (McArdle, et al., 1981; Grande, 1961) after 11-13 days of hypocaloric dieting. The maintenance of lean muscle tissue and decrease of percent body fat are the goals of every body builder.

Finally, a diet similar in protein/carbohydrate content with a higher caloric intake, would be of interest to analyze. Since some authors have suggested that athletes need more protein (Lemon, 1985; Shaternikov & Korovnikov, 1985) a diet higher in protein and calories would be of interest to the body builder. Perhaps lean body mass would be maintained while decreasing percent body fat and maintaining muscular function (Widerman & Hagan, 1982; Dragan et al., 1985) - the ultimate goal of the body builder.

APPENDIX A

DETAILED METHODOLOGY

METHODOLOGY

Selection of Subjects

Nineteen male body builders between the ages of 18-26 were randomly selected from a group of voluteers. Participants were recruited from the Virginia Tech Weight Lifting Club and had been weight lifting 3-7 times a week for 2 years. The subjects were asked not to have used anabolic steroids 3 months prior to the study and throughout the study. All claimed that they had never used anabolic steroids.

Sampling Procedures

The 19 subjects were randomly assigned to three groups and these groups were randomly assigned to one of the three treatments. Group 1 was a control (C) group which followed a body weight maintenance diet throughout the study. Group 2 was the High Protein/Moderate Carbohydrate (HP/MC) group and consumed a diet containing 1.6 g/kg/day of protein, and approximately 50% carbohydrate and 15% fat. Group 3 was the Moderate Protein/High Carbohydrate (MP/HC) group and followed a diet containing 0.8 g/kg/day of protein, and approximately 70% carbohydrate and 13% fat. All of the groups followed an identical weight training regimen for both the maintenance week and the experimental week.

Instructional Procedures

Prior to the study a general meeting was held for all of the subjects. Detailed explanations were made concerning the study and the necessity of strict adherence to the prescribed diet and exercise regimen. Before the study began all subjects were given 3 practice trials on the Cybex isokinetic machine for both quadricep and bicep endurance, using isometric contractions, so that a training effect would not confound the results. Weight training guidelines and schedules were given to all the subjects as well as diet instructions for the maintenance week.

Selection of Appropriate Criterion Scores for All Measures

The dependent measures chosen were body weight, skinfold measurements, hydrostatic weighing, bicep endurance and quadricep endurance. To determine the criterion scores for weight the body weight in kilograms (to the nearest 0.1kg) was recorded on day one of the experimental phase and again on day 7 of the experimental phase. (Body weight was also recorded on days 2-6 in order to carefully monitor weight changes).

To determine the criterion scores for skinfold, 5 measurements were taken with a Harpenden skinfold caliper at the chest, abdomen and thigh. They were measured to the nearest 0.1 millimeter by the same tester. The highest and lowest scores for each site were thrown out and the remaining three were averaged. The sum of the three sites was used in the equation by Jackson and Pollack (1978) where BD = 1.1093800 - 0.0008267(X2) + 0.0000016$(X2)^2$ - 0.0002574(X3). [X2=sum of chest, abdomen and thigh and X3=age]. The resulting BD was then used in the equation by Siri (1961) where %BF=(4.95/BD - 4.50) X 100.

The criterion scores for hydrostatic weighing were computed using a water-filled metal weighing tank. The recorder was calibrated using a known weight (4.21 kg). It was placed in the basket and the recorder was turned on. The calibration line was calcualted and used to determine the scores. Subjects were weighed in a supine position in a basket suspended by 4 load cells. Underwater weight was recorded on a recorder and by a digital display. After all air had been expelled and the subject achieved a supine position, the readings were recorded and the trial was completed. Eight trials were made and the 3 highest weights were averaged. The body weight underwater was calculated using the recorder displacement from the calibration weight in a ratio to calculate kilograms which was then converted to pounds. This underwater weight was inserted in the following equation: BD=BW/BW-UWW/H2O density - RLV. [BD=body density; BW=body weight; UWW=underwater weight; H2O density=water density; and RLV=residual lung volume] (Keys & Brozek, 1953). The %BF was then calculated using the Siri (1961) equation where %BF= (4.95/BD - 4.50) X 100.

The criterion scores for the static muscular endurance tests were determined using the Cybex isokinetic machine and were the endurance ratios achieved for the quadriceps and biceps following 10 ten second maximal isometric contractions. The preferred limb was used for all testing.

Reliability and Validity Estimates

The reliability estimates of skinfold measurements were determined by calculating an intraclass reliability. Oneway analysis of variance was used and the measurements were reliable if the r value was 0.7 or greater. The calculated r value for chest was R=.99, abdomen R=.99 and thigh R=.99

The skinfold measurements at the chest, abdomen and thigh were valid if calipers, tester reliability and caliper-tester interaction were consistent (Pollack and Jackson, 1984; Jackson et al, 1978) and an equation specific to the population was used.

Determination of reliability estimates for hydrostatic weighing were determined by using intraclass reliabilty. A oneway analysis of variance was used and the weights were reliable if the r value was 0.7 or greater. the calculated r value for hydrostatic weighing was R=.99. The hydrostatic weighing procedure was valid (Pollack & Jackson, 1983; Lohman, 1984).

Reliability estimates were determined for quadricep and bicep criterion measures by calculating test/retest scores from the first and second trials for each test. The Spearman-Rho correlation was used and the tests were reliable if the r value was 0.7 or greater. The test/retest score for endurance ratio for 1) quad pre r=0.95 2) quad post r=0.88 3) bicep pre r=0.93 and 4) bicep post r=0.93. The muscular endurance tests conducted using the Cybex were valid (Davies, 1984).

Experimental Procedures

Nineteen male body builders between the ages of 18-26 were studied for 7 days. One week prior to the hypocaloric phase the subjects followed a maintenance diet using the exchange system. Subjects were counseled prior to the diet and sample diets were given to all subjects. In addition, cards were distributed to all subjects with the number of servings that should be consumed each day. Cards were filled out by the subjects and turned in daily. The diet supplied 35 kcal/kg body weight (McMurray et al., 1985) and supplied 1.1 grams of protein per day. This diet created a baseline from which to compare the data observed during the hypocaloric phase. The following is an example of the maintenance diet:

Food Group	Servings	Calories/Serving	Kcal/meal
Breakfast			
Fruit	2	40	80
Bread	4	68	272
Meat	3	73	219
Milk	1	170	170
Fat	2	45	90
Coffee/Tea		As much as desired	
Lunch			
Meat	3	73	219
Bread	4	68	272
Raw vegetables		As much as desired	
Vegetables	1	36	36
Fruit	2	40	80
Milk	1	170	170
Fat	2	45	90
Coffee/Tea		As much as desired	
Dinner			
Meat	3	73	219
Bread	5	68	340
Raw vegetables		As much as desired	
Vegetables	2	36	72
Fruit	2	40	80
Milk	1	170	170
Fat	3	45	90
Coffee/Tea		As much as desired	

After the maintenance week subjects were assigned to one of three diet groups: control (remained on maintenance diet), high protein/moderate carbohyrate (HP/MC) and moderate protein/high carbohydrate (MP/HC). Within each diet group there were different weight classes. The following example is for the HP/MC 68 kg class:

Protein = 1.6 g/kg body weight/day (447 kcal)

Carbohydrate = 160 g (640 kcal)

Fat = 21 g (192 kcal)

Total kcal/day = 1279 kcal

and for the MP/HC 68 kg class:

Protein = 0.8 g/kg body weight/day (218 kcal)

Carbohydrate = 224 g (895 kcal)

Fat = 18 g (166 kcal)

Total kcal = 1279 kcal.

The diet for both experimental groups throughout the hypocaloric phase consisted of two 8 oz. cans of Exceed Nutritional Beverage and PROMOD Protein powder both from Ross Laboratories and non-fat dry milk powder. Each can of Exceed contained 360 kcal, 15 g protein (casein and soy), 47 g carbohyrate (corn syrup) and 12 g fat (corn oil). In addition, those subjects on the MP/HC diet received varying amounts of Exceed Carbohyrate Powder (Ross Laboratories) which contained no protein or fat.

An example of the HP/MC diet (for 68 kg weight class):

	2 cans Exceed	3 c nonfat milk	Promod	Total
g			72.9 g	
kcal	730 kcal	240 kcal	308.9 kcal	1278.9 kcal
protein	30 g	24 g	55.2 g	109.2 g

and of the MP/HC diet (for 68 kg weight class):

2 cans Exceed		1 c nonfat milk	Promod	Hi Carb	Total
g			21.9 g	100.5 g	
kcal	730 kcal	80 kcal	92.9 kcal	376 kcal	1278.9 kcal
protein	30 g	8 g	16.6 g		54.6 g

Preliminary measures of weight (to the nearest 0.1 kg), skinfold measurements, hydrostatic weight, lean body mass, and endurance ratios were obtained during the week prior to the experimental week. Weight was recorded every morning when the subjects reported in for the workout. Skinfold measures, hydrostatic weighing and endurance tests were done again on day 7 of the experimental phase.

Skinfold Procedures

Harpenden calipers were used to determine percent body fat. Measurements were taken at the chest, abdomen and thigh and repeated 5 times by the same tester. Measurements were made to the nearest 0.1mm and the highest and lowest were thrown out. The three reamining values were averaged and the sum of the three sites was used to determine percent body fat. The equation by Jackson and Pollack (1978) was used to calculate body density and the resulting body density was used in the equation by Siri (1961) to determine percent body fat. All measurements were made on the right side of the body.

Hydrostatic Weighing Procedures

Percent body fat (% BF) was also calculated by hydrostatic weighing. A metal tank was used to determine body density (BD). After expelling as much air as possible subjects assumed a supine position in the basket supported by 4 load cells until a stable reading was achieved on the recorder. Water temperature was recorded prior to each test. Eight trials were conducted and the three highest values were averaged and used to determine underwater weight (pounds). This number was divided by 2.2 kg/lb and the resulting number was used as the underwater weight. Body density was calcuated using the equation by Keys and Brozek (1953) and % BF was determined from the Siri equation (1961) where (4.95/BD - 4.50)X100 was equal to %BF.

Residual lung volume (RLV) was determined using the oxygen-dilution nitrogen equilibration method by Wilmore et al. (1980). An evacuated 5 liter anaesthesia bag was filled with 100% oxygen to 85% of the subject's vital capacity. One end of the bag was clamped shut and the open end was fitted with a 3 way valve. A mouthpiece was attached to the valve. Subjects assumed a supine position and a noseclip was placed on the nose. The mouthpiece was positioned in the mouth and a metronome was turned on to 60 beats/minute. Subjects were instructed to breath at a rate of 1 breath every 2 seconds. After 2 minutes of normal breathing, with the valve open to room air, the subjects were instructed to exhale as much air as possible. When this was completed the valve was opened to the bag (100% oxygen) and 5-7 breaths were taken at the rate of 1 breath every 2 seconds. A maximal exhalation was made again after the 5-7 breaths and the valve was turned back to room air. The noseclips and mouthpiece were removed and the contents of the bag were analyzed for oxygen and carbon dioxide concentrations with the Applied Electrochemistry (Model numbers 5-3A, CD-3A) gas analyzers. [RLV was calculated using the equation RLV=VO2 X (b-a)/(c-d) where RLV=Residual lung volume; VO2=volume of oxygen in bag at beginning of test; a=%nitrogen impurity of original O2 (assumed to be 0.0%); b=%nitrogen in the mixed air in the bag at point of eqilibrium (100%-(%O2+%CO2); c=%nitrogen in the alveolar air at the beginning of the test (assumed to be 80.0%); and d=%nitrogen in alveolar air during the the last maximal breath (assumed to be 0.2% nitrogen higher than the equilibrium % i.e. b+0.2% nitrogen)].

<u>Muscular Endurance Test Procedures</u>

Two static muscular endurance tests were performed on the Cybex isokinetic machine. The quadriceps and the biceps were the two muscle groups that were examined due to their prominent use during body building competitions. The preferred limb was used for both the elbow flexion test and the knee extension test. Prior to both tests the subjects were familarized with the positions and movements required and were given 3 practice trials for each test. During the elbow flexion tests subjects were in a supine position with the elbow resting on a pad. The shoulder extension accessory bar was inserted into the dynamometer and the elbow was positioned at an angle of 110° (0° being full extension). Measurements for height of bar, position of dynamometer and hand grip had been recorded during the practice trials. The hand was placed in a supinated position on the hand grip and the waist and elbow joint were fastened securely with a belt to the machine so as to isolate the bicep as much as possible. The test consisted of 10 maximal isometric contractions of 10 seconds with 5 seconds of rest between each trial. The results were recorded by the Cybex II Dual Channel Recorder. During the knee extension tests the subjects were seated and the foot was secured to the long input adapter. Belts were fastened around the chest, waist and knee. The height of the shin pad, number of seat cushions, height of the dynamometer and length of the dynamometer from the subject were measured during the practice trials and remained constant throughout the testing. The knee positioned at an angle of 25° (full extension being 0°) and the test consisted of pushing up against the bar. Ten maximal isometric contractions of 10 seconds were completed with 5 seconds of rest in between each trial. The results were recorded by the Cybex II Dual Channel Recorder. The Cybex was calibrated before and after the the experimental week. To calculate the endurance ratio for each subject a planimeter was used to measure the area (square inches) under the curves of the first two trials and the last two trials. The planimeter was calibrated before and after the measurements were taken and the same technician measured all the curves. The percent change from the first 2 trials to the last 2 trials was the endurance ratio (Davies, 1984).

Exercise Procedures

The resistance weight training program was the same for all 19 subjects. It consisted of approximately 2 hours a day, 6 days a week and alternating biceps/back/legs with triceps/shoulders/chest. Three sets of 8-10 repetitions at 60-80% 1RM were done each day. The 5RM was determined prior to the study so as to calculate 1RM. The exercises for biceps/back/legs included: bent bar curls, straight bar curls, one arm rows, lat pulldowns, hyperextensions, squats, quad extensions, ham curls, calf raises and seated calf raises. Exercises for triceps/shoulders/chest included: tricep extension, tricep pushdown, behind the neck press, seated dumbbell press, lateral raise, bench press, incline bench press, and dumbbell flyes. All the lifting was supervised by the same investigators each day.

APPENDIX B

DATA TABLES

Results of Tukey Test on High Protein/
Moderate Carbohydrate Group

Source	Q
Difference between Day 7 and Day 1	18.56*
Difference between Day 6 and Day 1	17.01*
Difference between Day 5 and Day 1	12.89*
Difference between Day 4 and Day 1	10.82*
Difference between Day 3 and Day 1	7.73*
Difference between Day 2 and Day 1	5.67*
Difference between Day 7 and Day 2	12.89*
Difference between Day 6 and Day 2	10.82*
Difference between Day 5 and Day 2	7.22*
Difference between Day 4 and Day 2	5.15*
Difference between Day 3 and Day 2	2.06
Difference between Day 7 and Day 3	10.82*
Difference between Day 6 and Day 3	9.28*
Difference between Day 5 and Day 3	5.15*
Difference between Day 4 and Day 3	3.09
Difference between Day 7 and Day 4	7.73*
Difference between Day 6 and Day 4	6.19*
Difference between Day 5 and Day 4	2.06
Difference between Day 7 and Day 5	5.67*
Difference between Day 6 and Day 5	4.01*
Difference between Day 7 and Day 6	1.55

*p<.05, Qcv (.05) = 4.56 for df = 16

Results of Tukey Test on Moderate Protein/
High Carbohydrate Group

Source	Q
Difference between Day 7 and Day 1	20.62*
Difference between Day 6 and Day 1	15.98*
Difference between Day 5 and Day 1	13.40*
Difference between Day 4 and Day 1	10.31*
Difference between Day 3 and Day 1	7.22*
Difference between Day 2 and Day 1	5.15*
Difference between Day 7 and Day 2	15.46*
Difference between Day 6 and Day 2	10.82*
Difference between Day 5 and Day 2	8.25*
Difference between Day 4 and Day 2	5.15*
Difference between Day 3 and Day 2	2.06
Difference between Day 7 and Day 3	13.40*
Difference between Day 6 and Day 3	8.52*
Difference between Day 5 and Day 3	6.19*
Difference between Day 4 and Day 3	3.09
Difference between Day 7 and Day 4	10.31*
Difference between Day 6 and Day 4	5.67*
Difference between Day 5 and Day 4	3.09
Difference between Day 7 and Day 5	7.22*
Difference between Day 6 and Day 5	2.56
Difference between Day 7 and Day 6	4.63*

*$p<.05$, Qcv (.05) = 4.56 for df = 16

ANOVA Table with Tests of Simple Main Effects - Body Weight

Source	SS	df	MS	F
Group (A)	636.61	2	318.31	0.52
Group at Day 1	158.78	2	79.39	0.13
Group at Day 2	122.31	2	61.16	0.10
Group at Day 3	104.93	2	52.47	0.09
Group at Day 4	87.69	2	43.85	0.07
Group at Day 5	70.67	2	35.34	0.06
Group at Day 6	66.67	2	33.34	0.05
Group at Day 7	48.74	2	24.37	0.04
Error1	9757.61	16	609.85	
Day	102.56	6	17.09	10.82*
Day at Control Group	2.81	6	0.47	0.30
Day at HP/MC Group	66.69	6	11.12	7.04*
Day at MP/HC Group	75.25	6	12.54	7.94*
Group*Day	23.69	12	1.97	7.50*
Error2	25.26	16	1.58	

*significant at the .05 level; critical value df 6, 16=2.74

ANOVA Table with Tests at Simple Main Effects - Lean Body Mass (skinfold)

Source	SS	df	MS	F
Group	116.55	2	58.28	0.42
at Pre	93.69	2	46.85	0.34
at Post	32.46	2	16.23	0.12
Error 1	2228.92	16	139.31	-
Day	43.72	1	43.72	46.5*
at Group 1	1.09	1	1.09	1.15
at Group 2	27.44	1	27.44	29.19*
at Group 3	32.71	1	32.71	34.80*
Group*Day	9.59	2	4.80	5.13*
Error 2	14.97	16	0.94	-

* significant at the .05 level; critical value df 1, 16 = 4.49

ANOVA Table with Tests at Simple Main Effects - Pre/Post Body Weight

Source	SS	df	MS	F
Group	191.20	2	95.60	0.55
at Pre	158.79	2	79.40	0.46
at Post	48.74	2	24.37	0.14
Error 1	2756.21	16	172.26	-
Day		1		
at Group 1	1.76	1	1.76	4.63*
at Group 2	46.08	1	46.08	121.27*
at Group 3	67.26	1	67.26	177.00*
Group*Day	16.22	2	8.11	21.22*
Error 2	6.12	16	0.38	-

* significant at the .05 level; critical value df 1, 16 = 4.49

Summary ANOVA for Bicep Endurance Ratio

Source	SS	df	MS	F
Group	133.41	2	66.70	0.51
Error 1	2076.28	16	129.77	-
Daye	393.96	1	393.96	3.61
Group*Day	391.16	2	195.58	1.79
Error 2	1745.29	16	109.08	-

Summary ANOVA for Quadricep Endurance Ratio

Source	SS	df	MS	F
Group	1775.37	2	887.68	3.39
Error 1	4191.74	16	261.98	-
Day	541.72	1	541.72	7.24*
Group*Day	198.99	2	99.50	1.33
Error 2	1197.38	16	74.84	-

*significant at the .05 level; critical value df 1,16 = 4.49

Summary ANOVA for Percent Body Fat (Hydrostatic Weighing)

Source	SS	df	MS	F
Group	236.56	2	118.28	2.23
Error 1	849.37	16	53.09	-
Day	13.43	1	13.43	5.60*
Group*Day	2.99	2	1.50	0.62
Error 2	38.33	16	2.40	-

*significant at the .05 level; critical value df 1,16 = 4.49

Summary ANOVA for Percent Body Fat (Skinfold)

Source	SS	df	MS	F
Group	21.55	2	10.77	1.17
Error 1	146.98	16	9.19	-
Day	2.87	1	2.87	5.80*
Group*Day	1.02	2	0.51	1.03
Error 2	7.90	16	0.49	-

*significant at the .05 level; critical value df 1,16 = 4.49

Summary ANOVA for Lean Body Mass (Hydrostatic Weighing)

Source	SS	df	MS	F
Group	94.68	2	47.34	0.30
Error 1	2548.74	16	159.30	-
Day	18.38	1	18.38	9.92*
Group*Day	10.59	2	5.30	2.86
Error 2	29.65	16	1.85	-

*significant at the .05 level; critical value df 1,16 = 4.49

Raw Data for Cybex - Pre-Test

Subject	Quad	Bicep
1	2.44/1.68=68.9%	1.78/1.04=58.4%
2	2.08/0.80=38.5%	3.08/1.84=59.7%
3	2.88/1.56=54.2%	4.12/2.20=53.4%
4	3.32/2.32=69.9%	2.68/1.44=53.7%
5	3.36/2.08=61.9%	1.68/1.20=71.4%
6	1.40/1.32=94.3%	1.60/1.08=67.5%
7	2.68/1.60=59.7%	3.00/1.92=64.0%
8	2.68/2.68=100.0%	2.60/1.84=70.8%
9	2.00/1.52=76.0%	2.16/1.28=59.3%
10	3.48/2.44=41.0%	2.64/1.64=62.1%
11	3.60/2.52=70.0%	2.28/1.24=54.4%
12	4.88/3.32=68.0%	1.32/0.72=54.5%
13	1.28/0.96=75.0%	1.64/0.52=31.7%
14	4.90/2.84=58.0%	3.48/2.04=58.6%
15	5.60/3.02=53.9%	2.96/1.32=44.6%
16	4.12/2.56=62.1%	2.76/1.56=56.5%
17	2.20/1.28=58.2%	2.60/1.60=61.5%
18	4.52/3.08=68.1%	2.32/1.32=56.9%
19	2.24/1.40=62.5%	3.32/1.92=57.8%

Raw Data for Cybex - Post-Test

Subject	Quad	Bicep
1	2.72/1.16=42.6%	3.12/2.04=65.8%
2	2.76/1.56=56.5%	3.84/1.80=46.9%
3	2.86/1.38=48.3%	3.18/1.96=61.6%
4	2.60/1.40=53.8%	2.56/2.32=43.1%
5	1.92/1.04=54.2%	1.56/1.52=97.4%
6	1.52/1.52=100.0%	2.04/1.52=74.5%
7	3.80/1.70=44.7%	3.40/2.32=68.2%
8	3.84/2.92=76.0%	3.60/2.08=57.8%
9	1.76/1.04=59.1%	1.76/1.20=68.2%
10	4.56/2.60=57.0%	3.84/2.08=54.2%
11	2.36/1.16=49.2%	2.52/1.48=58.7%
12	3.24/2.20=67.9%	2.72/1.52=55.9%
13	2.52/1.56=61.9%	2.68/2.36=88.1%
14	4.88/2.52=51.6%	4.44/2.80=63.1%
15	3.52/1.40=39.8%	2.92/2.00=68.5%
16	4.10/2.32=56.6%	2.92/1.76=60.3%
17	2.80/1.80=64.3%	1.84/1.24=67.4%
18	2.96/1.60=54.1%	2.52/1.60=63.5%
19	2.52/1.24=49.2%	1.96/0.92=46.9%

Raw Data for Hydrostatic Weighing - Pre-Test

Subject	Ave of 3 Highest Trials (lbs)	Body Density BD (g/ml)	Percent Body Fat (%)
1	6.3	1.0556091	18.9
2	12.2	1.085534	6.0
3	9.2	1.0687913	13.1
4	6.3	1.0467861	22.9
5	6.7	1.0604774	16.8
6	8.1	1.0716261	11.9
7	12.6	1.071872	11.8
8	9.3	1.08352	6.8
9	10.6	1.0885308	4.7
10	9.9	1.0760501	10.0
11	6.9	1.0548077	19.3
12	11.9	1.0845933	6.4
13	9.2	1.0863105	5.7
14	12.1	1.0737235	11.0
15	12.0	1.089175	4.5
16	8.9	1.0741305	10.8
17	11.3	1.0785109	9.0
18	11.9	1.0783098	9.1
19	8.7	1.0641732	15.1

Raw Data for Hydrostatic Weighing - Post-Test

Subject	Ave of 3 Highest Trials (lbs)	Body Density BD (g/ml)	Percent Body Fat (%)
1	6.1	1.0573815	18.1
2	11.7	1.0877665	5.1
3	10.0	1.0777655	9.2
4	7.0	1.0537806	19.7
5	7.5	1.0698988	12.7
6	8.3	1.0724529	11.6
7	11.7	1.0697454	12.7
8	8.9	1.0865464	5.6
9	10.7	1.0909047	3.8
10	9.6	1.0790963	8.7
11	5.3	1.0467031	22.9
12	11.2	1.0813713	7.8
13	9.1	1.0877249	5.1
14	11.1	1.0713223	12.1
15	12.8	1.0984541	0.63
16	9.3	1.0803434	8.2
17	12.5	1.0885561	4.7
18	12.5	1.0839414	6.7
19	8.0	1.0645153	15.0

Raw Data for Skinfold Measurements (in millimeters) - Post-Test

Subject	X Chest	X Abdomen	X Thigh	Sum	% BF
1	8.2	20.7	9.1	38.0	10.3
2	6.1	11.0	8.5	25.6	6.4
3	5.0	8.7	12.0	25.7	6.6
4	4.0	19.6	11.3	34.9	10.1
5	6.1	23.8	9.5	39.4	10.7
6	5.8	16.1	15.9	37.8	10.1
7	5.4	15.6	11.1	32.1	8.7
8	5.1	7.8	7.1	20.0	5.1
9	4.2	6.6	7.3	18.1	4.0
10	4.7	11.7	8.7	25.1	6.8
11	5.5	19.2	8.2	32.9	9.1
12	4.6	9.3	9.0	22.9	5.6
13	5.2	8.2	10.9	24.3	6.4
14	5.5	25.7	15.7	46.9	13.0
15	5.4	7.9	9.1	22.4	5.7
16	5.2	9.0	11.7	25.9	6.6
17	6.2	7.0	10.8	24.9	6.1
18	6.5	11.4	9.9	27.8	7.5
19	6.1	13.5	9.1	28.7	7.8

Raw Data for Skinfold Measurements (in millimeters) - Post-Test

Subject	X Chest	X Abdomen	X Thigh	Sum	% BF
1	5.4	12.4	9.2	27.0	6.9
2	5.4	9.1	7.2	21.7	5.2
3	4.6	7.9	10.9	23.4	5.9
4	3.8	21.8	11.9	37.5	10.9
5	4.5	20.9	8.8	34.2	9.2
6	5.0	15.6	14.4	35.0	9.3
7	4.9	14.4	10.5	29.8	8.0
8	4.6	7.1	7.0	18.7	4.7
9	4.4	6.4	6.2	16.0	3.6
10	4.1	9.5	7.5	21.1	5.5
11	5.1	15.7	8.2	29.0	7.9
12	5.3	8.8	9.3	23.4	5.8
13	6.1	9.0	11.1	26.2	7.0
14	5.8	22.9	13.9	42.6	11.7
15	5.6	7.4	8.7	21.7	5.5
16	6.0	8.5	11.9	25.4	6.5
17	6.2	7.3	9.5	23.0	5.8
18	5.9	9.6	10.2	25.7	6.8
19	6.4	15.8	9.9	32.1	8.8

Raw Data for Residual Lung Volume

Subject	Trial 1 (liters)	Trial 2 (liters)	Trial 3 (liters)	X (liters)
1	1.76	1.63	1.43	1.61
2	1.05	1.10		1.075
3	1.28	1.65		1.47
4	1.64	1.58		1.61
5	0.96	1.08		1.02
6	1.27	1.36		1.32
7	1.23	1.14		1.19
8	1.50	1.46		1.48
9	0.93	0.84		0.89
10	1.66	1.71		1.69
11	1.18	1.10		1.14
12	1.73	1.69		1.71
13	1.53	1.56		1.54
14	1.57	2.11	1.90	1.74
15	1.04	1.02		1.03
16	1.36	1.29		1.33
17	1.20	1.31		1.26
18	1.05	1.12		1.09
19	0.96		0.99	0.98

WHAT WAS THIS STUDY MEASURING????

The study was examining the optimal protein/carbohydrate ratio during weight reduction in weight lifters. Some people claim high protein low carbohydrate diets are better while others take a more moderate approach.

Some people were on a diet containing the recommended daily allowance for protein while others were on a diet containing less carbohydrate but twice the recommended daily allowance of protein. The diets were measured out to give you the right proportion of these nutrients for your body weight.

Protein was provided from the chocolate beverage, milk, and protein powder (Promod from Ross Laboratories). The carbohydrate was also in the chocolate drink and some in the milk. However, the people in the higher carbohydrate group also had a large bag of a fruit punch drink (Exceed High Carbohydrate). Both the chocolate Exceed and the High Carbohydrate Exceed were fortified with vitamins and minerals.

So.... no drugs, appetite supressants etc. were included.

Moderate Protein/ High Carbohydrate	High Protein/ Moderate Carbohydrate
17% protein	35% protein
70% carbohydrate	50% carbohydrate
13% fat	15% fat

Everyone got 18 calories per kilogram of body weight.

LOW CALORIE DIETS

Why? The purpose of the diet is to:

1. Control calorie intake to decrease your body weight.

   The diet will supply approximately 60-70% of your calorie needs. You can expect to lose from five to ten pounds this week (note that some of the loss is water weight).

2. Control the nutrient intake.

   Everyone is on a slightly different diet depending on their body weight and group assignment. Please consume all of your diet every day but no other sources of calories.

   OK List
   nutrasweet gum (called extra)
   diet drinks
   coffee
   water
   a stalk of celery if you get desperate for something to munch on

When? The low calorie diet begins Monday, April 14th and continues through Sunday, April 20th. Starting Monday, April 21 you may eat whatever you want but I recommend that you work up slowly to your original food intake. Give your system a chance to reaclimate to solid foods. You might want to have lots of soup and hot cereal, etc.

You will gain a few quick pounds that first day due to water gain.

What is the diet?

All low calorie people will pick up their diet for the next day from the lab after their workout. Everyone will get two (2) cans of chocolate Exceed Nutritional Beverage daily. You can drink this cold, from the refrigerator or heat it if you'd like. You will also receive several packages that can be mixed with water (each of you will get your own specific instructions on how to mix it). Pre mix some of it the night before so that it is cold. You may add nutrasweet or flavor extracts if you wish. You could also mix it up in a blender with ice cubes plus nutrasweet/vanilla for a "milkshake."

Fatigue is normal on any weight loss regime but let us know if you have any other unusual symptoms.

I recommend you drink lots of water and take a multivitamin tablet each day.

INSTRUCTIONS FOR RESIDUAL LUNG VOLUME

Report to lab (Gym 230) at assigned time and check in with technician.

In a prone position on the cot noseclips will be fitted and an anesthesia bag with a mouthpiece attached will be placed in the mouth. Keep a tight seal around the mouthpiece at all times!

After 1 minute of regular breathing a maximal exhalation will be made and the stop valve on the mouthpiece will be opened.

6 breaths will be taken and a maximal exhalation is made into the bag. Do not stop exhaling until all the air is out of lungs.

Signal the technician when all the air is exhaled and the valve is shut.

Noseclips and mouthpiece are then removed.

INSTRUCTIONS FOR CYBEX MEASUREMENTS

Report to lab (Gym 230) at assigned time and check in with technician.

If testing quad endurance sit on lower extremity machine and if testing bicep endurance lay in a prone position on the upper body machine.

Technician will adjust machine to proper position and lock it at the proper angle. Straps will be tightened around body.

After three practice trials are given testing will begin.

Ten trials of holding a maximal static contraction are made for ten seconds for both the quads and the biceps.

All tests will be performed with the preferred limb.

INSTRUCTIONS FOR SKINFOLD MEASUREMENTS

Report to the lab (Gym 230) at assigned time and check in with technician.

Bring shorts and change into them prior to having skinfold measurements taken.

Measurements will be taken on the right side of the body at the chest, abdomen and thigh with muscles in a relaxed state.

5 trials will be made at each site.

INSTRUCTIONS FOR HYDROSTATIC WEIGHING

Arrive at the lab (Gym 230) at assigned time.

Bring bathing suit to the lab.

Upon arrival check in with technician.

Change into bathing suit and have technician record body weight.

Technician will explain procedures prior to the underwater weighing.

After adjustment to the water is made trials will begin.

Legs and chest will be held down with weights and air will be pushed out of suit.

While holding nose closed begin exhaling and submerging until a prone position is achieved in the basket.

Continue exhaling until air is completely out of lungs.

When this occurs technician will knock on the side of the tank indicating that the trial is finished.

Repeat procedure 8 times.

RESIDUAL LUNG VOUME DATA

Subject ______________________________

VO_2: ____________________

a: 0% N_2

b: ________

c: 80% N_2

d: ________

RLV = VO_2 x (b-a)/c-d)

RLV = ________

SKINFOLD DATA-PRE EXPERIMENTAL

Subject ____________________ Age ________

	Chest	Abdomen	Thigh
Trial 1	_____	________	_____
Trial 2	_____	________	_____
Trial 3	_____	________	_____
Trial 4	_____	________	_____
Trial 5	_____	________	_____
AVERAGE:	_____	________	_____

SUM OF 3 SITES __________ % BF: __________

SKINFOLD DATA-POST EXPERIMENTAL

	Chest	Abdomen	Thigh
Trial 1	_____	________	_____
Trial 2	_____	________	_____
Trial 3	_____	________	_____
Trial 4	_____	________	_____
Trial 5	_____	________	_____
AVERAGE:	_____	________	_____

SUM OF 3 SITES __________ % BF: __________

CYBEX DATA

Subject ______________________________ Date ______________

Length for lower extremity machine _______________

Height for lower extremity machine _______________

Height for shin pads _________________

of seat cushions ____________________

Height of "L" bar _____________________

Position of hand grip ________________

HYDROSTATIC WEIGHING DATA

Subject ______________________

Weight (kg) _______________

Age __________

Water Temperature (C) _________

	boxes on graph	equivalent lbs.
Trial 1	______	______
Trial 2	______	______
Trial 3	______	______
Trial 4	______	______
Trial 5	______	______
Trial 6	______	______
Trial 7	______	______
Trial 8	______	______

AVERAGE OF 3 HIGHEST TRIALS __________

lbs
----------- = ___________ kgs BODY DENSITY = _______ kg
2.21 lbs/kg

_________________-_______

BD = ___________

%BF = 4.95
_______ -4.50 x 100 = ____________

DATA FOR 1RM LIFTS

Subject ______________________ Age ____________

Height __________________ Weight _______________

	5RM	1RM	75% 1RM
SQUATS	_____	_____	_____
HACK SQUATS	_____	_____	_____
QUAD EXT.	_____	_____	_____
HAM FLEX.	_____	_____	_____
SEATED CALF	_____	_____	_____
CALF RAISE	_____	_____	_____
LAT PULLDOWN	_____	_____	_____
ONE ARM ROWS	_____	_____	_____
UPRIGHT ROWS	_____	_____	_____
HYPEREXT.	_____	_____	_____
PREACHER CURLS	_____	_____	_____
STR. BAR CURLS	_____	_____	_____
BENCH PRESS	_____	_____	_____
INC. BENCH	_____	_____	_____
PEC DEC	_____	_____	_____
DB FLYES/FLAT	_____	_____	_____
TRI EXTEN.	_____	_____	_____
TRI PUSHDOWN	_____	_____	_____
BEHIND NECK PRESS	_____	_____	_____
SEATED DB PRESS	_____	_____	_____
LAT RAISE	_____	_____	_____

SKINFOLD DATA-PRE EXPERIMENTAL

Subject ______________________ Age ______________

	Chest	Abdomen	Thigh
Trial 1	_____	_______	_____
Trial 2	_____	_______	_____
Trial 3	_____	_______	_____
Trial 4	_____	_______	_____
Trial 5	_____	_______	_____
AVERAGE:	_____	_______	_____
TOTAL:	_____	% BF:	__________

SKINFOLD DATA-POST EXPERIMENTAL

	Chest	Abdomen	Thigh
Trial 1	_____	_______	_____
Trial 2	_____	_______	_____
Trial 3	_____	_______	_____
Trial 4	_____	_______	_____
Trial 5	_____	_______	_____
AVERAGE:	_____	_______	_____
TOTAL:	_____	% BF:	__________

Raw Data for Weight

Subject	Group	Day1	Day2	Day3	Weight (kg) Day4	Day5	Day6	Day7	Total Wt Loss
1	HP	78.2	77.1	76.6	76.3	75.9	75.4	75.1	3.1
2	MP	79.4	78.1	77.6	77.0	76.7	75.8	75.3	4.1
3	MP	85.3	84.6	83.7	83.4	82.5	82.5	81.5	3.8
4	HP	89.8	89.1	88.6	87.75	87.85	86.75	86.6	3.2
5	HP	66.2	64.9	64.4	64.2	63.9	63.2	63.5	2.7
6	C	70.4	69.3	70.4	70.3	70.2	68.0	70.0	0.4
7	HP	97.1	94.05	94.2	93.5	93.7	92.3	93.0	4.1
8	MP	69.8	67.5	67.2	67.0	66.9	66.0	65.7	4.1
9	C	66.9	67.3	66.5	66.4	66.7	65.9	65.7	1.2
10	MP	82.6	81.8	81.3	80.7	80.1	79.2	78.3	4.3
11	MP	76.4	75.8	75.7	74.8	74.0	73.5	72.3	4.1
12	C	86.4	86.0	86.0	86.5	85.7	86.2	84.9	1.5
13	C	67.0	67.6	66.9	66.2	66.5	66.8	66.8	0.2
14	MP	94.0	93.4	92.8	91.6	91.1	91.0	89.7	4.3
15	HP	84.2	84.2	84.0	82.5	82.1	81.4	80.15	4.05
16	HP	69.0	68.35	68.3	68.3	68.0	67.05	66.8	2.2
17	C	82.4	82.1	82.5	82.5	82.7	82.8	81.4	1.0
18	MP	85.0	84.7	84.4	84.3	83.4	83.0	82.0	3.0
19	HP	77.1	75.7	74.6	73.8	72.5	72.3	71.0	6.1

PERCENTAGE OF MAXIMUM TABLE

MAX	60%	65%	70%	75%	80%	85%	88%	91%	95%
600	360	390	420	450	480	510	530	545	570
590	355	385	415	440	470	500	520	535	560
580	350	375	405	435	465	495	510	530	550
570	340	370	400	430	455	485	500	520	540
560	335	365	390	420	450	475	495	510	530
550	330	355	385	410	440	470	485	500	525
540	325	350	380	405	435	460	475	490	515
530	320	345	370	400	425	450	465	480	505
520	310	340	365	390	415	440	460	475	495
510	305	330	355	380	410	435	450	465	485
500	300	325	350	375	400	425	440	455	475
490	295	320	345	370	390	415	430	445	465
480	290	310	335	360	385	410	420	435	455
470	280	305	330	355	375	400	415	430	445
460	275	300	320	345	370	390	405	420	435
450	270	290	315	340	360	380	395	410	425
440	265	285	310	330	350	375	385	400	420
430	260	280	300	320	345	365	380	390	410
420	250	275	295	315	335	355	370	380	400
410	245	265	285	310	330	350	360	375	390
400	240	260	280	300	320	340	350	365	380
390	235	256	275	295	310	330	345	355	370
380	230	245	265	285	305	325	335	345	360
370	220	240	260	280	295	315	325	335	350
360	215	235	250	270	290	305	315	325	340
350	210	230	245	260	280	300	310	320	330
340	205	220	240	255	270	290	300	310	320
330	200	215	230	250	265	280	290	300	315
320	190	210	225	240	255	270	280	290	305
310	185	200	215	235	250	265	275	280	295
300	180	195	210	225	240	255	265	275	285
290	175	190	200	220	230	245	255	265	275
280	170	180	195	210	225	240	245	255	265
270	160	175	190	200	215	230	240	245	255
260	155	170	180	195	210	220	230	235	245
250	150	165	175	190	200	215	220	230	240
240	145	155	170	180	190	205	210	220	230
230	140	150	160	175	185	195	200	210	220
220	130	145	155	165	175	185	195	200	210
210	125	135	145	160	170	180	185	190	200
200	120	130	140	150	160	170	175	180	190
190	115	125	135	145	150	160	170	175	180
180	110	115	125	135	145	155	160	165	170
170	100	110	120	130	135	145	150	155	160
160	95	105	110	120	130	135	140	145	150
150	90	100	105	115	120	125	130	135	145
140	85	90	100	105	110	120	125	130	135
130	80	85	90	100	105	110	115	120	125
120	70	80	85	90	95	100	105	110	115
110	65	70	75	85	90	95	95	100	105
100	60	65	70	75	80	85	88	91	95

APPENDIX E

Weight Training: (Daily Exercise Chart)

Student:____________________ Instructor:____________________

Group:____________________ Time:____________________

note: 20kg bar = 44 lbs
45 lb bar = 20.5kgs

EXERCISES	Date:________ Body Weight:_______					Date:________ Body Weight:_______				
	load / reps					load / reps				
	set #1	set #2	set #3	set #4	set #5	set #1	set #2	set #3	set #4	set #5
	/	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/	/
Comments →										

EXERCISES	Date:________ Body Weight:_______					Date:________ Body Weight:_______				
	load / reps					load / reps				
	set #1	set #2	set #3	set #4	set #5	set #1	set #2	set #3	set #4	set #5
	/	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/	/
	/	/	/	/	/	/	/	/	/	/
Comments →										

APPENDIX C

INFORMED CONSENT

CERTIFICATE
OF
APPROVAL FOR RESEARCH
INVOLVING HUMAN SUBJECTS

Division of HPER

The Human Subjects Committee of the Division of Health, Physical Education and Recreation has reviewed the research proposal of

Mary Leidy and Daphne Sturgill

entitled Macronutrient needs of body builders during weight reduction.

The members have judged the subjects participating in the related experiment (not to be at risk) as a result of their participation.

(If a risk proposal) Procedures have been adopted to control the risks at acceptably low levels. The potential scientific benefits justify the level of risk to be imposed.

Members of Divisional
Human Subjects Committee

____________________ ____________________
Chairman Date

____________________ ____________________
Date

____________________ ____________________
Date

REQUEST FOR APPROVAL OF RESEARCH PROPOSAL
IN THE DIVISION OF HPER

Submitted to

Charles Baffi
Chairman, Division Human Subjects Committee and/or
Chairman, Institutional Review Board

by

Mary Leidy and Daphne Sturgill
Principal Investigator

TITLE: Macronutrient needs of body builders during weight reduction.

BACKGROUND/SCIENTIFIC JUSTIFICATION: There has been little scientific research conducted concerning weight lifters and their diets during the weight reduction phase prior to competition. Due to this lack of research these athletes tend to formulate diets through trial and error, thus possibly negatively affecting performance.

PURPOSE(S): To examine muscular endurance, percent body fat, and nitrogen balance of weight lifters.

EXPERIMENTAL METHODS & PROCEDURES: This study will include one week on a maintenance diet and supervised weight training program, followed by one week on a hypocaloric diet (1200 kilocalories) and supervised weight training program. Protein/carbohydrate ratio will vary for the experimental groups and weight training program will remain the same. Tests of muscular endurance, determination of percent body fat, and urine and sweat collections will be done throughout the study.

STATEMENT DESCRIBING LEVEL OF RISK TO SUBJECTS: Due to the short duration of the hypocaloric diet risks to the subjects are low. They may experience irritability, fatigue, or muscle soreness.

PROCEDURES TO MINIMIZE SUBJECT RISK (IF APPLICABLE):
Correct weight lifting techniques will be demonstrated and there will be constant supervision during the weight training sessions. Body weight will be recorded daily thereby giving the researchers daily contact with the subjects.

RISK/BENEFIT RATIO (IF RISK PROJECT):

HUMAN PERFORMANCE LABORATORY

Division of Health, Physical Education and Recreation
Virginia Polytechnic Institute and State University

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 of Virginia Polytechnic Institute and State University.

Title of Study: Macronutrient needs of body builders during weight reduction.

The purposes of this experiment include: To examine muscular endurance, percent body fat, and nitrogen balance of weight lifters.

I voluntarily agree to participate in this testing program. It is my understanding that my participation will include: Pre-tests and post-tests of percent body fat and muscular endurance; one week maintenance diet (35 kilocalories/kilogram/day); one week hypocaloric diet (1200 kilocalories/day) with varying protein/carbohydrate ratios; daily 90 minute weight training sessions; daily weigh-in; daily urine collection; periodic sweat collection.

I understand that participation in this experiment may produce certain discomforts and risks. These discomforts and risks include: Irritability, fatigue and muscle soreness.

Certain personal benefits may be expected from participation in this experiment. These include: The subjects' maximal muscular endurance, percent body fat, and enhanced knowledge of the effects of hypocaloric dieting.

Appropriate alternative procedures that might be advantageous to you include: The subject will be excluded from the study if weight loss is too great during the week long study.

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 preexisting 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. 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 _________________ Telephone ______________

HPER Human Subjects Chairman Dr. Don Sebolt Telephone _____

Dr. Charles Waring, Chairman, International Review Board for Research Involving Human Subjects. Phone 961-5283.

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