THE EFFECT OF A CARBOHYDRATE SUPPLEMENT ON MULTIPLE BOUT RESISTANCE PERFORMANCE TRAINING DURING ENERGY RESTRICTION IN MALE RESISTANCE TRAINERS

BY

Lynette C. Poland

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Education

APPROVED:

Janet Walberg-Rankin, Chairman

Don Sebolt

Jay Williams

June 1994

Blacksburg, Virginia

C.2

LD
5655
V855
1994
P653
c.2

THE EFFECTS OF A CARBOHYDRATE SUPPLEMENT ON MULTIPLE BOUT RESISTANCE PERFORMANCE DURING ENERGY RESTRICTION IN MALE RESISTANCE TRAINERS

by

Lynette Charlene Poland

Committee Chairman: Janet Walberg-Rankin
Exercise Physiology

(ABSTRACT)

Carbohydrate has been shown to delay fatigue in aerobic activities. Only preliminary data (Lambert et al., 1991) has shown that there could be some effect of carbohydrate during multiple bout resistive exercises, especially when consuming a low energy diet. Twenty two experienced male bodybuilders were studied to test for the effect of carbohydrate ingestion on muscle endurance.

Fourteen subjects (PROT and CARB) were divided into two treatment groups, protein supplemented PROT (n=7), and the carbohydrate supplemented CARB (n=7). These subjects were placed on a prescribed exercise workout and a maintenance diet for 3 days. Then, testing was performed on all subjects before the two groups were placed on a low energy diet for 4 days. A control CONT (n=8) group was asked to record their normal diet and workout during the MAINT and EXPER phase days. Before the performance tests were performed, PROT received a protein supplement at 1.25g of protein/kg of body weight. The CARB group was given an

isocaloric amount of carbohydrate beverage 15 minutes before test performance. The test consisted of seven sets of decreasing repetitions of flat bench presses with the last set being performed until volitional fatigue.

No significant difference was found amoung groups and all tests with set 7 volume (kilograms lifted X repetitions in set seven) in baseline (CONT= 1095 $\pm$ 130.5, PROT= 1119 $\pm$ 119.1, and CARB= 1064 $\pm$ 110.3), pre-test (CONT= 981 $\pm$ 130.5, PROT= 1090 $\pm$ 119.1, and CARB= 1117 $\pm$ 110.3), and post-test (CONT= 1001 $\pm$ 130.5, PROT= 1046 $\pm$ 119.1, CARB= 1192 $\pm$ 110.3). The volume lifted by CARB tended to increase with each test while that for PROT tended to decrease in group by time interaction ($p=.067$). Therefore, it appears that carbohydrate ingestion given 15 minutes prior to a multiple bout bench press test of seven sets, had no significant effect on muscle endurance during resistance weight training.

ACKNOWLEDGEMENTS

There are a lot of people that have helped me in several ways towards completion of this project. First I would like to thank Stephen, for helping me through these tough college years and just being there. I hope things work out to make you happy in what ever direction you turn. I also want to acknowledge my family, my sister Elisa and Moose, for being there when I needed you most and especially my parents for not only funding this whole degree, but for always being there for the support I needed.

Next I would like to acknowledge my partner in crime, Tina Randall, without whom I would probably loose my mind throughout this ordeal. Thanks for being there and going through this with me.

I would especially like to thank Dr. Rankin, who has been very patient with me under some of the toughest circumstances. I have always thought of you as a true "mentor", and I have a lot of admiration for your work and your accomplishments.

Next I would like to thank Dr. Williams for his expertise in serving on my committee. You gave me some good ideas and foci for this study.

Finally, I would like to thank Dr. Sebolt for all his

hard work and time in helping me with data analysis. You took out a lot of your own time to help me to muddle my way through statistics, and I really appreciate it. See you in a few years at Daytona and/or Sturgis.

TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS.....iv
LIST OF TABLES.....viii
LIST OF FIGURES..... ix

I: INTRODUCTION
Statement of the Problem.....5
Research Hypothesis.....5
Significance of the Study.....6
Delimitations.....7
Limitations.....8
Basic Assumptions.....10
Summary.....11

II: REVIEW OF LITERATURE
Introduction.....13
Carboydrate Metabolism and Energy Use During Exercise.....13
Carbohydrates and Aerobic Performance.....20
Carboydrates and Anaerobic Performance.....33
Diets and Supplement Use.....42
Summary.....45

III: JOURNAL MANUSCRIPT
Introduction.....49
Methods.....52
Results.....57
Discussion.....60
References.....80

IV. SUMMARY AND RECOMMENDATIONS FOR FURTHER RESEARCH
Summary.....84
Research Implications.....91
Recommendations for Future Research.....92

APPENDIX A: Methodology.....96

APPENDIX B: Instructions to subjects, diet and Weight Lifting Protocols, Exercise Testing Forms.....106

APPENDIX C: Informed Consent, Human Subject Forms, and Medical Screening Forms.131

APPENDIX D: Raw data, statistical analysis, Example of workout routined, and Breakdown of supplements.....157

BIBLIOGRAPHY.....173

VITA.....181

LIST OF TABLES

Table Page

1: Weightlifting Routine.....66

2: Prescribed Maintenance Diet.....67

3: Protocol Bench Press Test.....68

4: Prescribed Low Energy Diet.....69

5: Dietary Data.....70

6: Workout Data.....71

7: Body Weight Data.....72

8: Reliability Data.....73

9: Flat Bench Press Data (Volume Reps last set).....74

10: Flat Bench Press Data (Reps last set).....75

LIST OF FIGURES

Figure Page

1: Timeline of Study.....77

2: Baseline, Pre-test, and Post-test Interaction For Volume on Last Set.....78

3: Baseline, Pre-test, and Post-test Interaction For Repetitions on Last Set.....79

Chapter I

INTRODUCTION

Diet is an integral part of athletic performance and achievement in many sports today. For example, endurance athletes need plenty of fuel to sustain long periods of exercise. In contrast, powerlifters alter their diets to increase strength and muscle mass. But athletes such as bodybuilders, use diets to enhance their physical physique.

Bodybuilders have two distinct phases of training for competition. The "mass building" stage, where diet is altered to obtain as much muscle mass as possible, and closer to the competition a "cutting" phase which typically involves reduction of calorie intake while maintaining an intense training program. If the calorie intake is severely restricted it may be detrimental to the athlete's health and/or physical performance (Hickson et al., 1990; Elliot et al., 1987; Freischlag et al., 1984).

A lot of bodybuilders have achieved this goal of muscle definition through the use of anabolic steriods or through dietary and exercise manipulations (Elliot et al., 1987). Many studies have shown the detrimental effects of steriods and the negative impact on the body, both short and long term (Kleiner et al., 1989). Where other studies such as that performed by Manore et al. (1993), examined a world-class bodybuilder who consumed a high carbohydrate

diet in preparation for a competition.

Although strength measurements were not taken, Manore et al., (1993), suggested the possibility that the athlete was able to endure this rigorous training while dieting due to a diet mostly in carbohydrates. It may be possible that the high carbohydrate diet allowed the bodybuilder to perform his rigorous training regime while still achieving his goal of muscle definition for competition, in comparision to other diets in previous competitions. This is in concurrence with the "typical" bodybuilding diet: high carbohydrate, low fat, and moderate to high in protein (Sandoval et al., 1991). Sandoval et al. (1991), state that the typical bodybuilding diet is high in complex carbohydrates, very low in fat, and very repetitive. They note that the bodybuilder's rationale for this type of diet is to reduce overall bodyfat (get cut) and to have enough energy to survive the training workouts.

Carbohydrates are an important macronutrient in providing energy to the body. The availability of carbohydrate can determine the rate of muscle fatigue (Costill, 1988). According to Costill, the rate of glycogen depletion depends on exercise intensity, physical conditioning, exercise mode, environmental temperature, and pre-exercise diet. Therefore, maintenance of muscle glycogen is difficult with repeated activity and involves many different factors.

Much research has shown that consumption of glucose can slow muscle and liver glycogen depletion and increase exercise endurance at intensities of 70-80% of maximum oxygen consumption (Bergstrom et al., 1967). Coyle and Coggin (1988) showed that maintenance of blood glucose through a carbohydrate supplement helped to delay fatigue in endurance athletes. Hargreaves et al.,(1983) and Neuffer et al.,(1987), supported these findings and determined that exercise was actually prolonged during the latter phases of exercise, and at performance at a sprint rate. It is suggested that this is due to the enhanced carbohydrate availability through beverage ingestion. This carbohydrate can be used for oxidation and helps to spare glycogen in the liver (Coyle and Coggin, 1988).

There is a wide array of literature to show the benefits of carbohydrate on aerobic performance. There are only a few studies however, that have examined the effect of carbohydrate ingestion on resistive exercise performance. Multiple bout weight training is a high intensity intermittent exercise that is usually performed by the training bodybuilders to achieve muscle size and definition. Researchers have shown that glycogen levels can be affected by certain types of training, especially a decrease in muscle glycogen after multiple-bout high intensity training (McCartney et al., 1986). With this type of high intensity exercise, Lambert et al., (1991),

suggested the possibility that muscle glycogen may become a limiting source of energy and therefore, carbohydrate ingestion could enhance performance by elevating blood glucose levels to spare muscle glycogen.

This importance of maintaining blood glucose for glycogen sparing is seen through studies that examine the positive effects of carbohydrate on physical performance. Lambert et al.(1991), found that carbohydrate ingestion enhanced anaerobic performance. Lambert et al. (1991), used multiple-bout weight training exercise to determine this. In this study they cite data which previously showed that a decrease in muscle glycogen of 40-50% is found after 6 sets of 6 repetitions of leg extensions. They suggested that carbohydrate ingestion during this type of exercise may help to delay fatigue by reducing muscle glycogen depletion. Although a study by Jacob et al. (1981), cites no change in performance with a high or a low carbohydrate diet, they used a one bout 50 maximal contraction exercise performance, where Lambert et al. (1991), used a multiple bout (around 15 sets, 10 repetitions) of resistive exercise. Therefore, the benefits gained from carbohydrate ingestion may only be seen with a multiple bout resistance exercises when glycolysis is the primary energy system used to generate ATP for muscle contraction.

Statement of the Problem

There is ample literature to show evidence that high carbohydrate diets enhance aerobic exercise performance. Although there is very little research on the effect of carbohydrate ingestion on anaerobic performance, it is theoretically possible that carbohydrate supplementation could enhance performance of multiple bout resistive exercise, especially in an energy depleted state. Thus, when bodybuilders consume a low energy diet during preparation for competition, their ability to tolerate the lactate produced during resistive exercise may be impaired. A carbohydrate supplement consumed before exercise may reduce ketosis and alleviate this situation. Therefore, the purpose of this study is to see if a carbohydrate supplement provided shortly before multiple bout weight training will increase multiple bout resistive training endurance volume in bodybuilders consuming an energy restricted diet.

Research Hypothesis

The following null hypothesis was tested in this study:

Ho: There was no difference in muscle endurance volume computed as (total number of repetitions * weight lifted) in the multiple bout resistance flat bench press test between the carbohydrate, protein, or

placebo groups, while the carbohydrate and protein groups underwent a low energy diet.

Significance of the Study

The sport of bodybuilding is filled with misunderstandings about nutrition, especially dieting, and the effect of nutrition on performance. With all the conglomeration of products available to these athletes who all claim "miracle results", many bodybuilders are confused and are often misinformed about proper nutrition and dieting for competition.

Carbohydrate supplement beverages are a common occurrence in any gym today. They are used by both trained bodybuilders and the "average" weightlifter to produce an ergogenic effect on performance (Burke et al., 1993). Many people misuse these drinks and some are confused as to the expected outcomes of what the beverage will provide, claiming that the beverage will alter the outcome of their workout (Grunewald et al., 1993). These researchers state that this lack of research in the area of supplementation with bodybuilders allows the athlete to utilize products with questionable claims from supplement companies.

The results from this study can inform these athletes whether there is an effect of the consumption of carbohydrate supplementation on helping them train for a bodybuilding competition. This study will determine the validity in the belief that the use of carbohydrate might

have some effect in helping them to train longer per session by prolonging their endurance, than if they were on a very low calorie diet with no supplementation. Thereby, the carbohydrate could possibly have some effect on their competition outcome.

Delimitations

The following delimitations were made:

1. The subjects were trained male bodybuilders ages 18-36.
2. The mode of training utilized was free weight training of a 3 day rotation of legs and biceps, chest and lats, and shoulders and triceps, plus 30 minutes/day on the stationary bicycle, at 60-75% range of their age predicted maximum.
3. A maintenance period of three days where diet and activity were controlled was completed by all subjects prior to beginning the study.
4. The hypoenergy diet consumed by both the carbohydrate and protein groups was a mixed diet consisting of 21 kcal/kg of body weight and 55% carbohydrates, 15% fats, and 30% protein.
5. The independent variables were a carbohydrate rich beverage for the carbohydrate group (CARB), a protein rich beverage for the placebo or protein group, (PROT), and a control group (CONT), receiving no beverage.

6. The dependent criterion score was: changes in the total weight lifted between the three groups (CHO, PROT, CONT), during the multiple-bout flat bench press delimited to 60% of 1 RM.

Limitations

The following limitations of the study were noted:

1. The small sample size may limit this study's findings to the subject sample studied.
2. Subjects were not living in a metabolic ward, and therefore were not continuously monitored to see if they strictly adhered to the study's guidelines.
3. The short length of the hypoenergy phase (4 days) might not be the same as the effects of long term dieting that many bodybuilders undergo during preparation for competition.
4. The difference among the 2 supplemental drinks (CARB, PROT, CONT) was not blind because it was not possible to make the fluids look and taste the same.
5. The CONT group was non-randomized and chosen mostly from the subject pool that did not wish to be put on a low energy diet.

Definitions and Symbols

The following definitions and symbols will be utilized:

1. Body Composition: The major components of the body which included muscle, fat, organs and bone (McArdle, Katch and Katch, 1981).
2. Percent Body Fat (% BF): Percentage of total body composition including essential and non-essential lipid stores (McArdle, Katch and Katch, 1981).
3. Body Builder: Subjects who have engaged in weight lifting 4-5 times/week, at around 60 minutes/session for at least one year.
4. Maintenance Diet: Diet prescribed for the two days before the experimental prior to the beginning of the experiment. It consists of an exchange diet of 35 kcal/kg of body weight, consisting of 55% carbohydrate, 30% fat, and 15% protein.
5. Hypoenergy Diet: Diet prescribed for four days immediately following the maintenance period. It consists of an mixed diet of 21 kcal/kg of body weight, consisting of 55% carbohydrate, 15% fat, and 30% protein.
6. Pre-Maintenance Phase (PRE-MAINT): the begining of the study to the Maintenance Phase. Includes all of the preliminary data that was gathered such as body fat, 1 RM etc.
7. Maintenance Phase (MAINT): immediately follows Practice 2 day. Beginning of workout and maint-

enance diet.

8. Experimental Phase (EXPER): Immediately follows MAINT phase. EXPER phase lasts for 4 days and begins with the Pre-test, low energy diet and second phase of workout cycle.
9. One repetition maximum (1RM): The maximum amount of weight that can be lifted one time.
10. Carbohydrate Group (CARB): The group that receives the carbohydrate beverage 15 minutes before testing.
11. Protein Group (PROT): The placebo group that receives the beverage that is highest in protein 15 minutes before testing.
12. Control Group (CONT): This group will eat their own diets and perform their own exercises during the entire experiment (6 days) but they will record exactly what is eaten and how they exercise.
13. Dependent Measure: endurance volume- (amount of weight lifted X total repetitions performed)

Basic Assumptions

The following basic assumptions were made:

1. It was assumed that during the muscle functioning tests, all subjects gave a maximal effort.
2. It was assumed that all subjects adhered to the prescribed diet and workout for the duration of

the study.

3. It was assumed that all subjects had been weight training 4-5 days/week for at least one year prior to engaging in this study.

4. It was assumed that the flat bench press test was an accurate depiction of muscle endurance for this group of bodybuilders.

Summary

Bodybuilders preparing for competition put enormous demands on their body during their training phase in order to achieve their muscular, lean physique. They drastically reduce their caloric intake while maintaining grueling workouts of one to three hours a day. During this time their bodies may become depleted and their energy levels can become quite low.

Carbohydrates have been previously shown to improve endurance in many aerobic activities. Lambert et al. (1991), has shown evidence that points to the possibility that carbohydrate might also enhance multiple bout resistive training anaerobic performance.

The researchers in this study will examine the effects of carbohydrate supplementation on endurance in multiple bout weight training when ingesting a low energy diet. If carbohydrate supplementation is beneficial it could suggest that this would be a way for bodybuilders to enhance the quality of their workouts while dieting, in preparation for

competition.

Chapter II

REVIEW OF LITERATURE

Bodybuilding is a sport where the athlete competes on this basis of his or her physique rather than their athletic performance. This influences the type of training and the diet that the bodybuilder undergoes. The ultimate goal of the sport is to achieve large muscle mass that is defined and symmetrical (Newton, 1993). In addition to rigorous weight training and aerobic exercise, preparation for a competition includes a strict low calorie diet comprised of high carbohydrates, moderate to high levels of protein, and low levels of fat (Sandoval et al., 1991).

The focus of this study is the effect that carbohydrates have on multiple bout resistive weight training when on a low energy diet. Areas of research that will be discussed in this chapter will be broken into five broad categories: (1) carbohydrate metabolism during exercise; (2) the effect of carbohydrate supplementation on aerobic performance; (3) the effect of supplementation on anaerobic performance; and (4) the dietary practices of bodybuilders in preparation for competition.

I. Carbohydrate Metabolism and Energy Use During Exercise

Muscle Glycogen Utilization

In order to produce Adenosine Triphosphate (ATP) in moderate work intensities longer than 30 seconds, there must be muscle glycogen or blood glucose present to serve

as fuel for anaerobic glycolysis. Depletion of these fuels makes it very difficult to continue the work level because of the muscle's inability to meet the needs of the muscles for ATP. The breakdown of carbohydrate is the primary fuel that is used in body metabolism in this intense exercise of >30 seconds. Therefore, when the muscle is depleted of glycogen, the fibers are unable to produce the metabolites from the breakdown of carbohydrate to continue bodily metabolism (Costill, 1988).

At the first few minutes of this intense exercise, muscle glycogen is the primary source for energy. After about 60 minutes, the glycogen stores become depleted and fatigue starts to become more evident (Costill, 1988). According to Costill, this rate of fatigue varies with several factors such as exercise intensity, physical conditioning, exercise mode, environmental temperature, and the pre-exercise diet.

The higher the exercise intensity (%Vo2max), the higher the rate of muscle glycogen utilization, and therefore there is a higher dependence on carbohydrate for fuel. Costill cites evidence that at levels below 95% of a runner's Vo2max, both fats and carbohydrates are used as fuels. It is not until the athlete gets above this level, that carbohydrate appears to be used almost exclusively. Therefore, evidence points to the direction of carbohydrates as a necessary factor in anaerobic or high

energy activity. For example, a high intensity level of exercise at the onset of exercise leads to glycogen depletion and could possibly lead to premature exhaustion (Costill, 1988). Thus, carbohydrates are necessary in maintaining proper fuel levels during exercise.

Exercise in hot weather also stresses the glycogen level more than normal. Data listed by Costill has shown that as much as a 76% increase in glycogen use can occur if exercising in temperatures around 41 degrees Celsius rather than exercise in temperatures around 9 degrees Celsius. This mechanism occurs because there is a reduction in the blood flow to the exercising muscle, which will cause an increase in intramuscular temperature and therefore, greater use of glycogen (Costill, 1988).

Muscle glycogen depletion also depends on the type of activity engaged upon. Type of activity has a direct relationship on the muscle fiber types involved. There are two basic types of muscle fibers: Type I, which are high in oxidative capacity but contract more slowly, and Type II, which have a lower capacity for oxidative metabolism and are slower to contract. Type II is differentiated between Type IIa, which are more often recruited than Type IIb, which is mostly used in maximal exertions. More information about the type of muscle fibers that are recruited with various types of activities will be included later in this chapter. Basically, Type I fibers are mostly

depleted at exercise at or below 70% Vo2max, whereas Type IIa and finally Type IIb fibers are recruited more frequently as tension requirements increase. In addition to various types of muscle fibers that are recruited in various activities, different muscle groups recruited also vary on the type and intensity of activity involved. For example, cyclists show more glycogen depletion in the quadricep muscles than runners, who might show more depletion in the gatronemius and soleus.

Muscle glycogen is important in providing the carbohydrate needed for moderate intensity exercise of a long duration, but it is not the sole source of carbohydrate. Blood glucose contributes a large amount of energy to the muscle during moderate intensity endurance activity (Yaspelkis III et al., 1993). As activity continues, glucose broken down from the liver glycogen provides a constant supply of glucose to the muscle. Since the liver glycogen supply is limited, blood glucose levels can fall when exercise demands are greater than liver glycogen producing capacity. When the muscles and liver glycogen become depleted, liver gluconeogenesis must supply carbohydrate to the muscle. When these glycogen reserves become depleted and gluconeogenesis cannot keep up with glucose needs, fatigue develops. Therefore, consumption of exogenous carbohydrate may relieve fatigue by serving as a glucose source for the muscles (Yaspelkis III et al.,

1993).

Glycogen Stores and Performance

The storage of glycogen is pertinent to performance capacity in humans. There are differences in storage capacity between humans that depend upon factors such as diet, activity, and training levels of the individual. Studies have shown that liver glycogen stores will decrease rapidly when a resting individual is deprived of carbohydrate in as little time as 24 hours(Costill, 1988). Activity can also greatly deplete these stores, the combination of high activity with a low carbohydrate diet contributes greatly to a decreased glycogen storage level. Because liver glycogen cannot be regenerated by gluconeogenesis without extra carbohydrate ingestion, humans must rely on the intake of carbohydrate foods to restore these levels. Individuals who are non-athletes have a lower storage of glycogen than do endurance trained athletes. This is due to the combined influence of chronic exercise, glycogen depletion, and carbohydrate intake in athletes which makes them more efficient in storing glycogen (Costill, 1988). This is further varified in a study conducted by Zachwieja et al.(1993), who also noted that depletion rates of muscle glycogen vary with intensity and type of exercise. This area of mechanisms of depletion levels will be covered more extensively later in the chapter.

Timing of Carbohydrate Feeding Before Exercise

It is well known that carbohydrate feeding before the start of prolonged aerobic activity can help to reduce the time to fatigue. There is much debate over the best time to ingest carbohydrate before the onset of activity. It depends mostly on the type of carbohydrate ingested, the type of activity, and the duration of the activity to be engaged in. Later on in this chapter the debates over the best methods for each will be discussed. This section will give a brief overview of different methodologies that can be utilized.

Some research (Coyle et al., 1985 and Yaspelkis and Ivy, 1991) states that ingestion of carbohydrate immediately before exercise (less than 60 minutes) may result in a dramatic rise in blood glucose and insulin. This is followed by an increase in carbohydrate oxidation and a rapid fall in blood glucose during the first few minutes of exercise. What this means to the individual is a decrease, instead of an increase in time to fatigue, thus acting conversely to the original expected results of enhanced carbohydrate intake. However, this should be noted that this observation was taken in exercise of lower intensities (<50% Vo2 max). It appears that carbohydrate intake taken for exercise performed at 65-75% of Vo2 max, enhances performance through replenishing glycogen reserves and reducing the chance of a drastic drop in blood glucose,

thereby reducing fatigue (Yaspelkis et al., 1993).

There appears to be a trend towards prolonged exercise performance with ingestion of exogenous carbohydrate, thereby sparing the muscle glycogen as a fuel source. Therefore, carbohydrate ingestion should occur either immediately before and intermittently during exercise, or several hours before activity in order to prevent the drastic decline in blood glucose and insulin that occurs if carbohydrate is ingested 15 to 45 minutes before exercise. These lower levels of glucose and insulin are thought by Costill (1988) to increase glycogen oxidation and thus reduce fatty acid metabolism leading to earlier fatigue. Many other studies have argued this point and this entire issue will be discussed further in the section on aerobic metabolism.

It is now apparent how the basic mechanism of carbohydrate metabolism occurs to support the energy demands of exercise. There appears to be a dependence on the level of glycogen reserves to support the increased level of activity from exercise. As mentioned before, there are many factors such as glycogen storage, blood glucose, type/intensity of activity, and timing of glucose ingestion, that determine the success in carbohydrate metabolism.

II. The Effect of Carbohydrate Supplementation on Aerobic Performance

There is a vast array of studies that explore the effects of carbohydrate ingestion on aerobic activity. For the most part, the research is in agreement that the effects of carbohydrate are beneficial. There are a few studies, however, that report that glucose ingestion has no effect on endurance exercise time.

Research That Shows No Change In Aerobic Performance With Carbohydrate Ingestion Under Normal Calorie Intake

In many studies, carbohydrate ingestion improves exercise performance. For the most part, when performance is not enhanced by carbohydrate ingestion, it is mostly due to the type or timing of carbohydrate ingestion. In a study conducted by Cole et. al.(1993), there was no significant difference in performance between varying levels of glucose solutions and a water placebo, given intermittently throughout cycling at 70% Vo2max. This lack of improved performance is mainly attributed to the lack of glycogen depletion in the liver and the amount of exogenous carbohydrate given (42 g/hour). The exogenous carbohydrate given above is less than what is needed, and has no beneficial effect on performance. Cole et al. (1993), state that in other studies where dosage was higher (>42 g/hr.), they found improved performance with glucose ingestion. Therefore, there seems to be a correlation in the amount of glucose ingestion and the benefits it has on

performance.

In the same study, Cole et al. (1993), also found that lowered values of blood glucose was not significant between the groups, so they conclude that their subjects were not susceptible to hypoglycemia during exercise, and therefore didn't benefit from carbohydrate ingestion (Cole et al., 1993). The reason hypoglycemia was thought to promote earlier fatigue is when blood glucose levels are reduced, performance is reduced due to the increased dependency on glycogen reserves for fuel instead of glucose, which thereby quickly decrease muscle glycogen and promotes earlier fatigue.

Another study found little change in aerobic performance with variant levels of carbohydrate content in the diet. The four groups were divided into a control and diet groups of low (15%), moderate(50%), and high(70%) carbohydrate sources. Performance was measured from timed running of 20.9 km race (Costill et al., 1981). The lack of performance discrepancies among the four groups, was hypothesized to be due to the subjects in all groups finishing the run with similar muscle glycogen levels. Therefore, it was hypothesized that the additional intake of carbohydrate above the "minimal" level of necessary carbohydrate, was too excessive to have any erogenic effects and change in performance among groups.

A study conducted in 1991 by Foster et al.(1991),

states that ingestion of either water, 75 g of glucose, or a 15 g liquid meal given 30-45 minutes before exercise, showed no difference in cycling performance at both 80% and 100% Vo2max. But, there were reduced blood glucose and increased insulin levels with the carbohydrate ingestion group. This similarity in performance is due to the timing of glucose ingestion that impedes the mobilization of free fatty acids (FFA), thus contributing to earlier time to exhaustion than would be expected from carbohydrate ingestion (Foster et. al., 1979). Therefore, in order to continue activity at the desired level, energy must be met by oxidizing carbohydrate from glycogen stores, thus reducing the erogenic effect of carbohydrate ingestion. Yet later research by Sherman et al. (1991), states that in spite of lowered blood glucose and elevated insulin levels, pre-exercise carbohydrate consumption of 1.1-2.2 grams of carbohydrate/kg of body weight, can improve exercise performance at 70% Vo2 max via enhanced carbohydrate oxidation. Although absolute generalization of studies can prove to be problematic, each situation should be considered individually before a steadfast conclusion is made on erogenic effects with carbohydrates. Effects of exogenous carbohydrate on athletic performance is dependent on a multitude of factors. Timing and amount of carbohydrate ingestion are just as important as the frequency and intensity of activity that the athletes

undergoes.

Reaearch Showing An Increase In Aerobic Performance With Carbohydrate Ingestion Under Normal Caloric Intake

It is well established that long term exhaustive performance can be enhanced when initial glycogen stores are elevated by carbohydrate ingestion. Still there is a great controversy as to difference in performance being correlated with blood glucose levels.

Enhanced endurance performance with carbohydrate supplementation is a common finding among many of the studies involving carbohydrate ingestion with aerobic performance. However, as mentioned above, there is much controversy as to whether the prevention of hypoglycemia is related to enhanced performance. The following article shows increased performance as a result of carbohydrate ingestion, but also that blood glucose levels did not differ among the carbohydrate ingested groups and the non-carbohydrate ingested groups, suggesting that high blood glucose levels aren't the sole reason in enhancing performance.

A study in which a 5% carbohydrate solution or water was given to the subjects immediately before and every 5 kilometers of a 30 km race found improved endurance time for the carbohydrate fed group as compared to that who ingested water (Tsintzas et al., 1993). They state that

the carbohydrate supplementation resulted in maintenance of running speed while the subjects given water decreased their desired running speeds. Therefore, the supplementation proves beneficial in maintaining chosen running speed throughout the race. Results from this study also indicate that there was no difference in blood glucose between the two groups. Tsintzas et al.,(1993) attributes this to blood glucose oxidation being contributed equally to energy metabolism during the first two hours of exercise, whether fed water or carbohydrate. They also attribute some change between the groups to the carbohydrate fed group and not the placebo group increasing the liver glycogen stores, thus showing the difference in performance. So therefore, the performance changes are due to increased glycogen storage levels and not prevention of hypoglycemia.

The findings by Tsintzas et al., (1993) are varified by Coyle et al.,(1983). As a result of the findings from these two studies, carbohydrate ingestion does have some implication in improving muscle glycogen sparing, but it is possible this is due to glycogen sparing, not prevention of hypoglycemia. Coyle et al., (1983) found that there was improvement in performance with subjects that were fed carbohydrate over their control but that the blood glucose levels for both groups were similar. Therefore, Coyle et al. (1983), determined that the maintained blood glucose

levels allowed the slowing of muscle glycogen through blood glucose utilization. This idea of hypoglycemia not being the cause of fatigue for most exercise bouts is further strengthened by research conducted in 1983 by Ivy et al., (1983). This study concludes that exhaustion is not a function of central nervous system dysfunctioning. Ivy et al. (1983), found that exhaustion in a psychomotor performance test is not affected by low blood glucose levels. In this study, a glucose polymer was infused in their subjects throughout a walking activity (45%Vo2max), thereby maintaining muscle glycogen levels. Further studies have shown though Yaspelkis et al. (1993), that lower intensity activities are sometimes not enough to deplete these glycogen stores. Therefore, the erogenic effect of the glucose polymer drink should be questioned in such a low intensity activity (45% Vo2max) as performed in the study conducted by Ivy et al., (1993).

Rigorous endurance activity is taxing on the body's energy reserves. When this is confounded by a sprint performance at the end of the aerobic phase, energy demands are even higher. Blood glucose is the main source of energy that allows the body to endure a sprint performance at the end of such an aerobic workout. The theory stated above is strengthened by the work found by Millard-Stafford et. al. (1988), and Hargreaves et al. (1984), where no change in performance was noted between the carbohydrate

fed and placebo groups until sprint activity, at the end of the cardiovascular workout. Sprint performance was enhanced as a result of exogenous carbohydrate ingestion. The consumption of carbohydrate helped to maintain blood glucose levels. So in exercise of short duration (sprint), it appears that prevention of hypoglycemia is beneficial to enhancing performance.

In a study conducted by Neuffer et al. (1987), blood glucose levels help to reduce the effects of fatigue. They examined low hepatic and muscle glycogen stores after a 12 hour fast with a low carbohydrate diet. Performance is enhanced by ingestion of 45 grams of carbohydrate immediately before one hour of intense exercise (77% Vo2 max), followed by 15 minutes of isokinetic cycling. Improvement in exercise performance is affected by blood glucose and due to a state in which endogenous glycogen stores are very low. The results of this study differ from the results from Hargreaves et al. (1985), which show carbohydrate ingestion during intense exercise sparing muscle glycogen. This discrepancy is explained by Neuffer et al., (1987) in stating that Hargreaves et al. (1984), shows a periodic decreases in the demands on muscle glycogen. Therefore, when there is an increase in serum glucose, there will be accelerated conversion of glucose to glycogen eliciting an increase in glycogen sparing (Neuffer et al., 1987). In the study conducted by Hargreaves et al.

(1984), subjects were divided into three groups of : 1) a high dose carbohydrate group (21.5 g/60 minutes); 2) a more frequent interval of carbohydrate given (10.75g/30 minutes) ; and 3) the control of water (400 ml/60 min) under a 4-hour cycling bout followed by a sprint ride to exhaustion (100% Vo2max). There were no differences in muscle glycogen levels among the three groups, yet they had varying levels of blood glucose. There was enhanced sprint performance in the groups that were fed carbohydrate Hargreaves et al.,(1985) which suggests that glucose was the primary fuel source during that performance. This was due to enhanced performance in correlation with the blood glucose levels. The researcher noted though that muscle glycogen was still the primary fuel source in exercise of the longer duration because the quantity of carbohydrate given (21.5g/hour) was not large enough to supplement endogenous stores of liver and muscle glycogen during the 4 hours of exercise, despite glucose levels (Hargreaves et al., 1985).

The idea that glucose ingestion has a direct relationship to endurance performance is clear. Research points to possibilities that blood glucose levels are attributable to performance in sprint exercise but in endurance activities, blood glucose acts as a mediator to prevent glycogen depletion which would lead to fatigue. Two of the following articles explain why subjects who

ingest carbohydrate will have increased levels of performance at variable-intensity exercise. A recent study performed by Ivy et al. (1993), states that athletes who were supplemented with carbohydrate on mixed intensity cycling (45%- 75% Vo2max) had longer times to fatigue due to the reduction of dependency on muscle glycogen as a fuel source, thereby relying more heavily on blood glucose levels. In a similar study with alternating intensities of cycling (60-85% Vo2max), there was a prevention of decline in plasma glucose in the fasted state so that carbohydrate oxidation is maintained and fatigue is delayed by approximately 30 minutes (Coyle and Coggin, 1988). Even through the last third hour of cycling, the researchers notes that subjects were able to oxidize carbohydrate up to 2 g/min. This explains why glucose ingestion is so important to endurance rates, because it keeps glucose oxidation levels steady and reduces time to fatigue.

It should be noted that muscle glycogen was not measured during this study due to the findings in a previous study Coyle and Coggin (1986), which suggested that glycogen was not depleted at the late stages of exercise due to the high oxidation rate of blood glucose. This study is in accordance with the findings from Hargreave et al. (1985), that state exercise performance is enhanced by blood glucose. The intermittent exercises with intervals of rest, allow the elevated blood glucose level

to enhance conversion of glucose to glycogen and thus, spare muscle glycogen. Although the subject pool used by Coyle and Coggins (1988) were elite cyclists performing in multiple intensity activity, and Hargreaves et al. (1985), used ten non-athletes, the implications are the same.

So from the data given above, there appears to be some relationship between fatigue levels, muscle glycogen and blood glucose. It was established that fatigue is not due to the effects of hypoglycemia or CNS dysfunctioning at the end of activity but, there is a possibility that exogenous carbohydrate ingestion can reduce fatigue by sparing muscle glycogen levels through increasing blood glucose levels.

Types of Carbohydrates To Consume To Maximize Performance

It has been established that there is a relationship between carbohydrate ingestion and exercise performance. But what needs to be clarified is the relationship between the type of carbohydrate consumed and exercise performance. A study conducted that compares a liquid carbohydrate drink, a carbohydrate bar, and a combination between the two, shows no difference in blood glucose, insulin, time trial performances, or total carbohydrate oxidized during 120 minutes of cycling at 70% Vo2max (Lugo et. al., 1993). These findings were strengthened by Hargreaves et al., (1993) with trained runners using either a carbohydrate bar or liquid beverage. The researcher found no difference in

blood glucose or insulin in equal amounts of solid or liquid form of ingested carbohydrate (Hargreaves et al., 1993). In a similar study using solid and slurried bananas, no significant differences in maintenance of plasma glucose and endurance enhancement were noted between the two groups during an endurance bout of cycling and jogging (Murdoch et al., 1993).

Many of the researchers state that they were surprised by the results of the studies above. Lugo et al.(1993), hypothesized that the fat and protein in the solid form of carbohydrate would delay gastric emptying and intestinal absorption, resulting in earlier decline in blood glucose for the solid as compared to the liquid. In the study that examined the different consistencies of bananas, the researchers originally hypothesized that the solid bananas would be more effective for performance due to: 1) solid food supplying carbohydrate continuously by staying in the intestines longer; 2) solid foods providing more carbohydrate per unit weight; and 3) solid foods being more palatable (Murdoch et al., 1993). Therefore it appears that there is no difference in blood glucose, insulin, performance, or carbohydrate oxidation in the form of carbohydrate that an athlete ingests.

How Muscle Fiber Types Are Affected In Exercise

The depletion of muscle fiber glycogen depends on the

intensity and type of activity that the person engages in. In a study involving runners in a 30-km race, the researchers found total glycogen depletion in Type I fibers, showing that there appears to be a relationship between the activity type and muscle fiber glycogen depletion level (Tsintzas et al., 1993). This hypothesis is further strengthened by data found by Hargreaves et al. (1993), that states that at intensities below Vo2max, slow-twitch (I) fibers were the first to lose glycogen, followed by Type II fibers if exercise was continued. Therefore, if the subject is at a lower intensity level, the type II fibers are inactive and can synthesize glycogen in order to increase endurance when exercise continues and the type II fibers are called upon.

The research listed above basically describes depletion patterns in lower intensity aerobic activities. The two studies by Cheetham et al. (1986), and Maughan et al. (1981), describe depletion patterns in higher intensity exercise (>100% Vo2max) that show more depletion of type II fibers. This is because an aerobic activity requires a high amount of energy in a short amount of time, and type II fibers can provide this energy faster than type I- slow twitch oxidative fibers. This is demonstrated in the study conducted by Maughan et al. (1981), on supramaximal bicycle bouts of 1-2 minutes, depleting type IIb fibers while type I fibers contained significant amounts of glycogen (Maughan

et al., 1981).

There has been data to show a correlation between activity type and muscle fiber depletion. Repletion of muscle fibers is more exacting, it depends upon amount of glycogen depletion. The greater the amount of depletion in the muscle, the greater the rate of glycogen resynthesis. This is due to the glycogen synthase activity, and the ability of muscle to take up glucose, resulting in a higher resynthesis rate (Costill et al, 1991). The amount of depletion can significantly affect the rate of resynthesis during the early hours of post-exercise recovery. These researchers cite normal resynthesis rate between 5 and 8 mmol/kg/hour, therefore, carbohydrate ingestion should coordinate with this (Costill et al., 1991). They state that there seems to be an initial rapid phase of resynthesis during the first five hours of repletion, then the rate tapers down. Many people try to take advantage of this early onset by increasing carbohydrate ingestion but, the muscle regulates the resynthesis through negative feedback (Costill et al., 1991). In one study, researchers tried to rush this carbohydrate resynthesis by ingesting carbohydrate throughout exercise, yet this did not influence the rate of glycogen resynthesis because of the mechanism stated above (Costill et al., 1993). When carbohydrate is fed in normal amounts (1.5 g/kg body weight every hour), over a 6 hour period, muscle glycogen can be

restored to almost full amounts (Pascoe et al., 1993). One study states that the best type of carbohydrate to ingest to restore glycogen stores are starchy carbohydrates, or those with a higher glycemic index (Burke et al., 1993). Foods with a high glycemic index get into the blood stream more rapidly and thus are transformed into glycogen quicker than those foods that have a lower glycemic index.

From the literature presented above, one can see the trend towards carbohydrate ingestion affecting aerobic exercise. There is literature that shows that performance is affected by many different factors such as original glycogen storage level, blood glucose levels, intensity of aerobic activity, and low caloric dieting. Performance is dependent on the situation and varies due to the factors listed above, therefore, there is no universal formula for how best to enhance aerobic performance using carbohydrate. Instead, the type of aerobic activity, previous glycogen storage level, amount and timing of carbohydrate ingestion, amount of calories, and the type of muscle fibers affected should be considered before undergoing a carbohydrate ingestion regime to enhance performance.

III. Carbohydrate's Effect On Anaerobic Performance

There has been a vast amount of literature to assess the trend towards enhanced aerobic performance when ingesting carbohydrate. Fewer studies have been done on the effect that exogenous carbohydrate has upon anaerobic

exercise. The next section will describe the role between anaerobic exercise and carbohydrate ingestion during low and normal calorie intake.

The Role Between Carbohydrate Ingestion and Anaerobic Performance Under Normal Caloric Intake

There has not been a large amount of research done on the area of erogenic effects of carbohydrate ingestion on anaerobic performance. The type of anaerobic activity engaged in alters the fuel utilization mechanism. There is a great difference between resistive training exercise and intermittent maximal performance on which primary fuel system is engaged.

Energy System and Fuel Use During Intermittent Maximal or Supramaximal Exercise

In a study conducted by Gaintanos et al. (1993), data was gathered on a protocol of ten 6-seconds maximal sprints with 30 seconds of rest between sets performed on a cycle ergometer. Needle muscle biopsies of the vastus lateralis determined that the first 6-second bout had an equal concentration of phosphocreatinine (PC) degradation and anaerobic glycolysis (Gaintanos et al., 1993). As the last sprint performance occurred, the group hypothesized that more power was supplied by aerobic metabolism and PC degradation. So therefore, in a multiple bout sprint exercise, fuel utilization moves from a primarily PC and anaerobic glycolytic system, to a more aerobic and PC

system, which is contrary to what one would normally assume under these situations.

Surprising results also come from a study conducted at intensities greater than 100% Vo2 max by Maughan and Poole, (1981). The researchers compared varying diets of: a normal intake, carbohydrate free, and high carbohydrate after performance on a supramaximal workload (104% Vo2max) to exhaustion on the bike. Time to exhaustion was longer in the high carbohydrate diet, yet lactate accumulation levels were the same among all groups. Therefore, the researchers concluded that glycogen was not the limiting factor in the workload. And therefore, the change in capacity is considered uncertain in the study. They feel that more work is needed to determine which mechanism during a high carbohydrate diet is responsible for fatigue (Maughan and Poole, 1981).

Energy System and Fuel Usage In Resistive Training

Anaerobic performance, specifically resistive training, relies heavily on various anaerobic energy production systems such as hydrolysis of PC and ATP, glycogenlysis, and glycolysis (Dudley, 1988). The specific type of resistive training determines the magnitudes of these system usage. A power lifting type of exercise which requires more strength over a short amount of time relies more on hydrolysis of PC. As the number of repetitions

increase (per set) and rest time between sets decreases, more energy is supplied via glycolysis. This would be in keeping with the type of resistive training that a bodybuilder wanting to obtain muscle hypertrophy would undergo. Also, with this type of training regime, Dudley (1988) points out that there is an increase in plasma lactate, free fatty acids, and glucose. Another interesting aspect in endurance resistive training brought forth by this group includes lipids as a fuel source. When triglyceride in the muscle is decreased and free fatty acid increases in the blood, Beta Oxidation can be deemed a source of energy during this exercise type. So therefore, the degree to which the blood variables are involved depends greatly on the intensity of the workload used (Dudley, 1988).

From the research by Gaintianos et al (1993), there seems to be a trend towards muscle strength being more dependent on the PC system. Thus as the repetitions increase, and the workouts focus more on muscular endurance, and a change in this fuel utilization system occurs. There is now more reliance on glycolysis and aerobic fuel utilization systems. Because of this, there could be a causal relationship between carbohydrate ingestion and multiple bout endurance weight training. This is similar to findings in aerobic activity, but it appears that these similarities only hold true for

endurance muscle training, not power, because endurance training utilizes more aerobic metabolism.

Lambert et al. (1991), fed carbohydrate immediately before and during multiple bout resistive training and found that when glycogen is limited, a higher amount of substrate availability through glucose polymer can enhance performance. It was previously thought that lactate production from glycogen occurred after ATP and PC decreased, but at anaerobic exercise, lactate production occurs from immediate glycogenolysis. The researchers state that it is glycogen, not ATP and PC which is the primary fuel for multiple set exercise of short duration (Lambert et al., 1991). They feel that fatigue that is caused from one intense exercise bout is not due to glycogen depletion, because a normal or lower intake of carbohydrate in the diet is enough for this one bout. It is not until the subject performs multiple sets of exercise bouts that fatigue is correlated with glycogen depletion (Lambert et al., 1991). Therefore in maximal exercise testing strength, the fuel is CP rather than carbohydrate. Only when repeated contractions occur over several minutes would carbohydrate become a major source of ATP production.

So Lambert et al.(1991), suggests that intake of a carbohydrate supplement taken above what is contained in a normal diet, can be beneficial for individuals involved in multiple-bout resistive exercise. They suggest though,

that caution should be taken when extrapolating this data in lower training volume because it's the volume and intensity of training that are the determinants of carbohydrate use in exercise (Lambert et al., 1991).

The Effects of Low Calorie Dieting, Carbohydrate Ingestion, and Anaerobic Exercise on Performance

Since a few studies suggest a beneficial effect of carbohydrate ingestion on anaerobic exercise performance during normal energy intake, carbohydrate may have a similar effect on performance when in a low energy condition. Some studies show that carbohydrate content of a low calorie diet affects anaerobic performance. One study with wrestlers shows that a group ingesting a high carbohydrate low energy diet (70% kcal) maintained power in a Wingate Test while those on the low carbohydrate diet (50% kcal) had significant decreases in total and mean power output ($p<.05$) (McMurray et al., 1991). Therefore, during calorie restriction, the high carbohydrate diet maintained anaerobic exercise performance better than a lower carbohydrate diet.

In another study using a high carbohydrate low energy diet, the ingested carbohydrate helped sprint performance by decreasing the dependency on muscle glycogen. Since the rapid weight loss depletes muscle glycogen levels, the carbohydrate ingestion helps to maintain muscle glycogen and therefore aid performance by providing energy in the

sprint phase (Horswill et al., 1990). A high carbohydrate diet is also beneficial in buffering against ketosis and acidic blood levels, which can cause premature fatigue (Greenhalf et al., 1988; Horswill et al., 1990). The researchers also note that the high carbohydrate diet can help to prevent fatigue by reducing the chances of blood volume loss that sometimes occur with low carbohydrate diets.

A series of studies conducted by Greenhaff et al. (1987-1988), examines the effects of pre-exercise diet and exercise variations on blood acid/base status on high intensity exercise. According to Greenhaff et al.(1988), diets that are very low in calories, and/or low in carbohydrate will cause the formation of ketones and acidic blood. Even if there is enough calories in the diet, just a low carbohydrate intake is enough to allow this to occur. But, if there is a low consumption of carbohydrate and calories, the process will accelerate. The theory is that fatigue will be accelerated in this situation because hydrogen ion generated during the anaerobic work are not adequately buffered. Thus, pH of the blood will drop and cause an inhibition of glycolysis. This could reduce the rate of ATP resynthesis and promote muscle fatigue.

Horswill et al.(1990), showed the same results in that an energy restricted diet decreased the subject's ability to buffer metabolic acids, thus leading to less total work

done in an anaerobic exercise performance test in subjects consuming a low-carbohydrate as compared to a high-carbohydrate diet.

Contrary to what was presented above, some research cites little or no significant change in fatigue rate with high carbohydrate and low carbohydrate low calorie diets. Although this might seem contrary to what was presented above, the difference among the data is most likely due to degrees of calorie and carbohydrate restriction. In a study using obese women, anaerobic time to fatigue did not change with either a high carbohydrate ingestion or a low carbohydrate ingestion when performing isokinetic dynameter, testing endurance time in repetitions to fatigue (Davis et al., 1990). The author cites the possible cause of this difference as due to the low carbohydrate group receiving 20% more calories than the high carbohydrate group. Therefore, the low carbohydrate group received an added benefit of extra calories to fuel their anaerobic exercise. Therefore, there was no difference between the groups because the bonus in performance that the carbohydrate group would of received was offset by the extra calories that the low carbohydrate group received.

Another study conducted among obese women found a trend towards lowered strength with a low carbohydrate diet, but it was not significant ($p<.05$) (Scott et al., 1992). The researchers stated that in order to see

significance, there would need to be a greater disparity between the high fat/low carbohydrate (40%/40%) and low fat/high carbohydrate (20%/60%) groups. This is because a high fat diet affects performance by inducing a lower pH, which can cause premature fatigue, and the current study did not have enough disparity between the two groups for this to occur. The researchers also note that a greater degree of calorie restriction could show a difference between the two dieting groups (Scott et al., 1992). This study shows that anaerobic performance could have an effect on anaerobic performance (strength) if there was enough disparity between the two groups in terms of carbohydrate and calorie ingestion.

In a study conducted with bodybuilders undergoing a hypoenergy diet, quadricep isometric endurance in a low carbohydrate low energy diet was measured (Walberg et al., 1988). This study assigned bodybuilders to groups of control, moderate protein/high carbohydrate low calorie diets, and high protein/moderate carbohydrate low calorie diets. Although endurance of the smaller muscle group (biceps) was not affected, there was a decrease of quadricep endurance in the high protein group. This was suggested to be due to a decrease in muscle glycogen over time from intense anaerobic exercise with inadequate amounts of energy and carbohydrate given (Walberg et al., 1988).

IV. Dietary Practices of Bodybuilders in Preparation for Competition

Training for a bodybuilding competition requires a very rigorous and structured lifestyle. It dictates the athlete's entire daily choices, from activities to diet. Typically, the training bodybuilders has a very structured dieting program that he or she follows that usually includes some type of supplementation.

Dietary Intake of Training Bodybuilders

In preparation for competition, there are two distinct phases that the bodybuilders follow. The first is a "bulking" phase for muscular size development that occurs early in competition preparation. The later is the "cutting" phase that occurs just prior to competition to reduce subcutaneous fat (Hickson et al., 1990).

During the "cutting" phase of contest preparation, the athlete's goal is to consume a low calorie, low fat, high complex carbohydrate and high protein diet. Many times this diet encorporates some type of supplementation. In a study conducted by Kleiner et al. (1994), diets of bodybuilders in this phase were analyzed through food records and determined to be very repetitive and monotonous. Percent calories from protein, fat, and carbohydrate were 40%, 11%, and 49% respectively, and they consumed 33 kcal/kg of body weight (Kleiner et al., 1994). Results from dietary analysis from Sandoval et al. (1991),

and Newton et al. (1993), state similar findings that the diets were very low in fat, high in protein, and very restrictive.

Food selection patterns in these athletes tend to be high in lean meats (chicken, tuna) and egg whites, starchy grains and vegetables (rice, oatmeal, rice cakes, potatoes). They consume little fibrous vegetables and fruit, a very low amount of fat, and tend to shy away from dairy products (Kleiner et al., 1994; Sandoval et al., 1991). The rationale behind the avoidance of dairy products is that they are too high in fat and sodium (Kleiner et al., 1994). The fat is avoided to prevent unwanted weight gain and the sodium is avoided because they fear it will make them hold water, thus keeping them from their "ripped" appearance. But as Kleiner et al. (1994), points out, skim milk is fat free and lower in sodium (125 mg/cup), containing 302 mg of calcium than their commonly consumed egg whites of three large eggs containing 302 mg of sodium and 12 mg of calcium.

So from the example given above, the "typical" bodybuilding diet is deficient in some nutrients. This can lead to problems for the athlete in terms of his or her health status. Not only is the athlete depleting their body of needed nutrients through a limiting food selection pattern, the low energy intake could possibly affect their ability to adequately perform the workout. Because of

this, many bodybuilders turn to supplementation to fill the gaps.

In a study analyzing dietary supplementation practices of athletes, bodybuilders consume supplementation because they felt that the extra nutrient requirement of their training could only be met by supplementation and that the supplements could improve performance (Burke and Read, 1993).

Typical supplements that these athletes ingest are amino acid or protein mixtures, carbohydrate supplements, and vitamin or mineral supplements (Grunewald and Bailey, 1993). According to these researchers, the protein mixtures were ingested for proposed muscle gains during the "bulking" phase of training. Vitamin and mineral supplements were ingested to meet RDA, and carbohydrates were used to help achieve energy gains during the workout while consuming a low amount of energy (Grunewald and Bailey, 1993).

V. Summary

Through the vast amount of studies cited in this chapter, there is clearly a link between carbohydrate ingestion and enhancement of performance. It appears that the exact mechanism of fatigue cannot be answered as being absolutely due to limitations in glycogen levels or blood glucose. Additional factors such as the type of activity engaging in, previous glycogen storage levels, amount and

timing of carbohydrate ingestion, amount of calorie consumption, and the type of muscle fibers affected during exercise should be considered when determining whether carbohydrate ingestion will affect performance.

The results found from studies conducted in anaerobic exercise are of particular interest to this study. Results from one study stated that multiple bout weight training endurance had some correlation affected of carbohydrate ingestion. This may be due to the ingested carbohydrate reducing the dependency on muscle glycogen, therefore, increasing the time to fatigue. It was found that dieting alone can reduce exercise performance by reducing amounts of PFK and acetyl coA, reducing muscle mass, and generally reducing the overall working mechanism of the body's metabolism.

It is the purpose of this study to examine the possible effects of acute carbohydrate ingestion on multiple bout weight training while subjects are in negative energy balance.

Chapter III

JOURNAL MANUSCRIPT

The Effect of a Carbohydrate Supplement on Multiple Bout Resistance Performance During Energy Restriction in Male Resistance Trainers

Lynette Poland, Christine Randall, Janet Walberg-Rankin, Don Sebolt, and Jay Williams

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

The Effect of Carbohydrate Supplement on Multiple Bout Resistance Performance During Energy Restriction in Male Resistance Trainers

There are two distinct types of training that the bodybuilder performs, depending upon how close the training occurs to competition. Several months or years before a competition, a bodybuilder's regime consists of a "mass building" phase, where the desired end result is muscle size, and closer to competition, a "cutting phase", where a muscularly defined, "cut" physique is obtained from low calorie dieting and high intensity training (21).

A lot of bodybuilders have achieved this goal of muscle definition through the use of anabolic steroids or through dietary and exercise manipulations. Many studies have shown the detrimental effects of steroids and their negative impact on the body, both short and long term (13). Because of these effects, many supplement manufacturers recommend erogenic aids such as carbohydrate supplements to help the athlete perform a rigorous workout while ingesting a low energy diet. Some studies suggest that a high carbohydrate diet is beneficial to the athlete when undergoing physical activity in training for competition (16). It allows the athlete to perform their intense training regime while dieting. These findings are probably what helped to shape the "typical" bodybuilding diet: moderate carbohydrate, low fat, moderate to high in protein (16). This mix of macronutrients in a reduced energy diet may decrease overall body fat and provide enough energy for the training workouts.

Carbohydrates are an important macronutrient in providing energy to the body. The availability of carbohydrate can determine the rate of muscle fatigue (3). This availability is determined by exercise intensity, physical conditioning, exercise mode, environmental temperature, and pre-exercise diet (3). Therefore, maintenance of muscle glycogen is difficult with repeated activity and involves many different factors.

As mentioned above, there are a multitude of factors that can affect the storage of muscle glycogen. Pre-exercise diet, especially those low in energy can have an added drain on muscle glycogen relative to diets in which there is a normal energy balance (22). It is noted by Phinney et al.(22), that when obese subjects are put on a very low energy diet of 500-750 kcal/day for two weeks, there was a decrease in pre-exercise muscle glycogen of .66 g/100 g ($\pm$ .03) of wet weight and fell further after aerobic endurance exercise. In some studies, weight training exercises typically performed for muscle definition has been shown to deplete muscle glycogen (25). Since muscle glycogen is utilized during exercise, adding exercise to a reduced energy diet decreases muscle glycogen.

Carbohydrate supplementation has been demonstrated to delay fatigue in aerobic activity (3, 11, 19, 20, 26, 28), but recently, some research shows that carbohydrate can

also help in anaerobic performance such as multiple bout weight training (14). Multiple bout weight training is a high intensity intermittent exercise that is usually performed by the training bodybuilders to achieve muscle size and definition. As noted above, availability of carbohydrate or glycogen can affect performance (17). In a study examining multiple-bout high intensity training, the authors suggested that ingestion of exogenous carbohydrate enhanced performance by elevating blood glucose levels to spare muscle glycogen (14).

The study conducted by Lambert's group (12) showed an increase in performance with carbohydrate ingestion when subjects used a multiple bout resistive test. Another study using a one bout 50 maximal contraction exercise performance showed no benefit from a high carbohydrate diet (12). The explaination for difference in results between these two studies may relate to the duration of the resistance exercise. The longer the exercise is performed, (i.e. multiple bouts), the more reliance there is on muscle glycogen. Therefore, carbohydrate ingestion may show a greater effect on delaying fatigue in prolonged resistance training bouts compared to short bouts where phosphagen system is the main provider of ATP.

As a result of these findings, our study planned to see if carbohydrate supplementation would help bodybuilders in exercise performance when they are ingesting a low

calorie diet with an intense workout, in preparartion for a bodybuilding competition. This was conducted using males ingesting a 4-day low energy diet, with carbohydrate ingestion 15 minutes prior to performing a multiple bout, flat bench press test.

Methods

Subjects

Twenty-two volunteer male subjects between the ages of 19 and 33 were recruited from local gyms. All subjects denied previous steroid use, and had been resistance training for a minimum of one year, 3-4 times/week, for the purpose of muscle development. The subjects averaged 12.3% (±1.09) body fat with a mean body weight of 81.8 (±5.24) kg.

The subjects were screened before the experiment began for any metabolic, cardiac or orthopedic disorders that would hinder their performance/health during the study. The study was approved by the Virginia Tech Institutional Review Board for Research on Human Subjects, and all subjects signed an informed consent after they were informed of the risks of participation.

The subjects were randomly divided into two experimental groups of carbohydrate (CARB), n=7, or protein (PROT), n=7. The control subjects (CONT) n=8, were chosen from subjects that did not want to be in the experimental groups of low calorie dieting. Two of the subjects, one in

PROT and one in CARB were dropped from the study due to self-reported lack of compliance to the low energy diet. In addition to those two subjects, four additional subjects were dropped from analysis because they did not complete the full 69 repetitions in the first 6 sets. That makes the final subject total for each group to be CONT= 5, PROT= 6, and CARB= 7.

Experimental Procedures

CARB and PROT were assigned to a specific diet and exercise prescription throughout the study. CONT was asked to record their self-selected diet and workout during the time the other groups would adhere to assigned diets and workouts. The study lasted a total of eleven days (Figure 1). It began with a pre-maintenance phase (PRE-MAINT) with three days of preliminary information, testing of 1 repetition maximums (1 RM) (Table 1), body fat analysis, and one practice session of the performance test. The practice trial of the flat bench press test was included to reduce a learning effect on subsequent performance tests. Following the pre-maint phase, there was a three-day maintenance period (MAINT) and baseline bench test, where diet and exercise were controlled to ensure stabilization and congruency in body weight and muscle glycogen levels among subjects. After the MAINT phase and baseline test, there was a pre-test flat bench test given to the subjects to determine performance before the dieting phase. A four

day EXPER phase, then followed MAINT. The subjects were provided with a low energy diet and continued with the same rigorous workout routines as performed during the MAINT phase. The last day of the study (day 11), consisted of the Post-test, conducted by all subjects.

One repetition maximums was predicted from 5 RM for exercises that were considered too dangerous to perform 1 RM's. These exercises were squats, shrugs, and standing calf raises. The workout was prescribed based on the 1 RM's and consisted of a 3 day rotation (Table 1). The fourth day was considered a rest day where only the flat bench performance test was the exercise allowed. The exercises for the daily workout were performed at 65-70% 1 RM, for three to four sets, in a pyramid fashion of 8-15 repetitions. Biking was performed for 30 minutes/day on a stationary bicycle, at a target rate of 65-75 percent of maximal heart rate determined from age predicted maximum. The cycling was included in the prescribed workout to more closely depict the true bodybuilders routine in "cutting up" for a competition (13). These exercises were performed by the subjects on their own, although the examiners periodically checked in on the subjects. The same workout that was used for the MAINT phase of the experiment was repeated in the EXPER phase.

All three groups performed the flat bench test between the hours of 7 and 10 A.M., after a 12 hour fast. The

subjects were always tested within the same hour of the day. The subjects were asked not to do any exercise 18 hours before testing. Fifteen minutes prior to test performance, the PROT and CARB groups were given liquid supplements. The supplements contained 5 kcal/kg of body weight. The PROT supplement (Challenge's Instant 95% Isolated Soy Protein) contained 1.25 g of protein/kg of body weight, and no carbohydrate while the CARB supplement (Sport Shot's sugar, dextrose, and fructose mixture), contained 1.25 g of carbohydrate/kg of body weight and no protein. Thus the supplement was either 100% protein or 100% carbohydrate. The protein supplement was prepared by mixing the protein powder in a blender with approximately 3 cups of water and .5 cup of ice. The carbohydrate supplement was prepared by mixing 3 cups of water with .5 of ice. The study was not double blind study since the differences among the two supplements in terms of taste, smell and appearance could not be eliminated. However, subjects were not told what was in the supplement.

The flat bench press test (Table 3) was a multiple bout test performed with free weights. It was a 7 set test, at 60% 1 RM, with decreasing repetitions and 2.5 minutes of rest in between each set. In the last set, the subject was asked to perform the maximal number of repetitions until fatigue. Full repetitions were verified by an infrared beam set at the subject's full arm extension

length. The subjects were not given any verbal encouragement throughout the test in order to ensure congruency among subjects.

Immediately following this performance test, the subjects began the reduced energy diet which continued for 96 hours. The subjects in PROT and CARB were given the same reduced energy diet (21 kcal/kg of body weight). This consisted of 55% carbohydrate, 15% fats, and 30% protein. The diet was identical for all 4 days and consisted of oatmeal, rice, tuna fish, spaghetti, tomato sauce, peanut butter, and rice cakes (Table 4). The subjects were not allowed to add to or delete anything that contained energy from this diet. They were permitted to drink as much water, diet drinks, and coffee/tea as they wanted. In order to have some form of compliance to the diet, the subjects were to check off a sheet of all the foods they ate for the day. In addition to this diet, the subjects continued the same workout program that they performed in the MAINT phase.

On day eleven of this experiment, all subjects performed a post-test flat bench press test. The same stipulations applied to this test as were put forth in the pre-test, baseline and practice sessions. All of the performance tests were conducted in the morning (between 7-10 AM), and each subject was tested within 60 minutes of the time of their previous test. PROT and CARB groups were

given the same supplement as they recieved during the pre-test 15 minutes before the test.

The data expressed in the text and tables is in mean (SEM), unless specified otherwise. All independent measures were analyzed to determine if the subjects were similar in their diets and workout lifting volumes. This was determined by using a repeated measure 2-way Analysis of Variance (ANOVA), or a One way ANOVA, with the alpha level = .05. The dependent variables for repetitions in set seven, and set seven volume, were analyzed using repeated measures 2-way ANOVA, with alpha levels at 0.05.

The original data set included a subject pool of 22 subjects. Four of these subjects were dropped from analysis because they did not complete the full 6 set test of 69 repetitions (Table 3). Three of these subjects were from the CONT group and one was from the PROT group. The reasoning behind excluding these subjects was that one could not compare subjects who completed the full 69 repetitions with those who did not when analying repetitons performed in set seven.

Results

Analysis of dietary intake during the MAINT phase indicated that there was no significant difference between the CONT, CARB, and PROT groups in energy and fat, but that there was significant difference among groups in carbohydrate and protein ingestion (Table 5). A Duncan's

Multiple Range Post-Hoc Analysis shows that the CONT group was different from the CARB and PROT group in these macronutrients. This is hypothesized to be due to CONT consuming their own diet, with no boundaries on what they could eat.

In addition to analyzing diet for changes among groups, the volume of the workout performed (kg lifted X total repetitions) for the prescribed workout performed during resistance among MAINT and EXPER was analyzed for differences among groups in different phases of the experiment (Table 6). No significant differences (31759 in MAINT and 27861 in EXPER) were found among these phases for the two different phases of the prescribed workout.

Body weight changes during the EXPER or low energy intake phase showed that there was no significant difference in weight loss among the three groups from the baseline test to post test (Table 7). The CONT group gained an average of 3.4 kg, the PROT lost 2.2 kg, and the CARB group lost 4.2 kg from baseline to the post-test period.

The reliability data for the flat bench press performance of the practice and baseline tests are depicted in Table 8. Pearson's Product Moment Correlation shows a correlation coefficient Of R= 0.096. Any discrepancy can be due to learning the protocol, which is common when undergoing a performance test. A closer look at the data

shows that the correlatiom shows significance at p=.01 between volumes of 5417 at practice and 5595 at baseline.

The data for muscle performance test at baseline, pre-test, and post-test is given in Tables 9 and 10. There was no significant main effect of time or group nor an interaction of groups over time when performance data from the last set were examined. Figure 2 shows that the average weight lifted by the CONT group decreased non-significantly from 1119 to 1090 while the average weight lifted by the CARB increased from 1064 to 1117. The same trends exist for the number of repetitions in set seven.

In analysis of data while in negative energy balance, pre-test to post-test data showed no significant difference among group and performance Figure 2 and Table 9 site data showing a slight increase in CONT and CARB group. Again, in analysis of repetitions in the last set, there was still no significant change in performance CONT and CARB group increases from 14.6 to 15 repetitions and 15 to 16 repetitions, while protein changed from 18.5 to 18 repetitions (Figure 3 and Table 10).

The difference in response by group tended to be significant as shown by a p value of 0.067 for volume and number of repetitions in the last set. Thus, CARB tended to improve performance with each trial while PROT tended to decline. So in summary, in a multiple bout flat bench press performance test there was no significant effect on

performance of the PROT or CARB supplement in energy balance or in a negative energy condition. However, there was a trend for an improved performance by CARB relative to PROT.

Discussion

The goal of a competitive bodybuilder training for competition is to increase muscularity while reducing body fat (21). Many bodybuilders achieve this goal by utilizing a low energy diet in combination with a high intensity training regime. Since muscle glycogen may be reduced during a low energy diet (22), and performance of repeated resistive weight training may further reduce muscle glycogen, dietary carbohydrate may be of critical importance for these athletes. From the data presented in the present study, acute ingestion of 1.25 g/kg of carbohydrate or protein given 15 minutes prior to a multiple bout resistive training test, showed no significant effect on performance in multiple bout resistive training when at maintenance or a low energy intake. There was a trend for improvement in performance during the last set for CARB over the three trials.

The various energy sources that the body utilizes during activity depends on the type of activity, intensity, and duration (3). In aerobic activities, muscle glycogen depletion is related to fatigue (2, 3, 26, 28). Muscle glycogen is the main source of energy for high-intensity

exercise of short duration (1, 17). In multiple bout weight training, muscle glycogen is the primary source of energy (14, 15). In a study conducted by Tesch et al. (25), a muscle biopsy from the vastus lateralis taken immediately after an entire resistive exercise session revealed a reduction in muscle glycogen of 26% from initial value (25). Similarly, MacDougal et al.(15), found a 25% reduction in muscle glycogen after three sets of bicep curls to failure. Therefore, with multiple bout resistive exercise, fatigue rates may be linked to a reduction of muscle glycogen stores.

This study used a resistive weight training regime of a typical bodybuilder in preparation for competition. In this type of training regime: higher intensity and long duration, there is a large dependency on muscle glycogen (5). Some research states the muscle glycogen availability may limit performance for this type of exercise (14). Therefore, for this type of exercise, carbohydrate ingestion may be valuable to meet the energy demands of exercise (16), especially if the initial muscle glycogen stores are depleted.

In our study, the subjects performed seven sets, 6-18 repetitions at 60% of 1 RM of free weight flat bench presses. Neither carbohydrate nor protein ingestion significantly affected performance during the test whether performance was defined as total weight lifted, or number

of repetitions during the last set. However, CARB tended to increase both of these dependent measures during the Post-Test as compared to the Pre-Test, while PROT tended to have lower values for these measurements during the Post-test. It would be interesting to see if this difference between groups would be further widened such that it attained significance if the subjects continued the performance test for more than 7 sets. Data from Lambert et al.(14), found that in a prolonged resistance training session of 15 sets, 7-10 repetitions, glucose polymer ingestion allowed the subjects to perform more work before fatigue. They found that the glucose polymer group performed 149 $\pm$ 16 repetitions versus 129 $\pm$ 12 repetitions for the placebo group (14). With this increase in lifting volume, there is a greater reliance on the glycolytic energy system which stresses muscle glycogen more and therefore, the glycogen reserves are more depleted than if the lifting volume was less. So the impact of the carbohydrate ingestion would be more pronounced because the carbohydrate would be utilized to a greater degree to reduce the effects of fatigue.

As shown above, muscle glycogen can be reduced by activity. A low energy diet can also deplete muscle glycogen (8, 18, 24). When a low energy diet and a low carbohydrate diet are combined with exercise, body glycogen stores may be depleted rapidly. The

"typical" bodybuilder's diet during the cutting phase is low calorie, low fat, and only moderate in carbohydrate and protein (13, 21, 22). This type of dieting regime may affect exercise performance due to the lower energy ingestion and depletion of muscle glycogen stores (25). In a study conducted by Walberg et al.(27), a 50% carbohydrate hypoenergy diet given to bodybuilders caused a decrease in quadricep endurance while the bodybuilders consuming a 70% carbohydrate diet of the same energy content did not have a reduction in performance. This may have been attributable to a decrease in muscle glycogen, although muscle glycogen was not measured in this study.

Volume of resistance training may be an important factor in determining the value of dietary carbohydrate. In a typical bodybuilders's "cutting" training workout (high volume, low intensity), carbohydrate might be beneficial to performance. In a bodybuilder's "mass" phase of training (low volume, high intensity), carbohydrate ingestion might not have an effect on performance time. In situations where the number of repetitions increase per set and the rest time between these sets decreases, more energy is supplied via glycolysis, thereby increasing the dependence on muscle glycogen and blood glucose (5).

The best timing for carbohydrate ingestion prior to exercise is undetermined. In our study, a glucose polymer solution of 1.25 g/kg of body weight was given 15 minutes

prior to performing the 7 set flat bench press test. In Lambert et al. (14), a similar amount of glucose polymer (1 g/kg body weight) was given immediately before exercise, and a solution of 0.17 g/kg was given after the fifth, 10th, and 15th sets of this test. Our study found no significant benefit with a single ingestion of carbohydrate shortly before the resistance exercise bout, therefore, it is not known whether consumption of carbohydrate between sets could have enhanced performance further. Again, more research on this area can help to clarify this issue.

In Lambert et al. (14), they found a change in performance with the carbohydrate ingested group after 15 sets of leg extensions. Also, they gave exogenous carbohydrate throughout the test. Perhaps if our test were extended to include more sets (>7) and carbohydrate was given throughout the test, then a signifcant increase in performance could be seen. Our study used just 7 sets for the performance test and not more because previous studies (16) show that bodybuilders training for competition typically utilize 5 sets on one muscle group. Therefore, the 7 set test for one body part used in our study is more applicable to bodybuilders than a 15 set test.

There are several potential explanations for the lack of the effect of the carbohydrate supplement on performance. The type of fuel energy system that is engaged depends greatly on the type of resistance training

performance. A power lifting type of exercise which requires more strength over a short amount of time relies more on hydrolysis of PC (5). According to Dudley (5), as the number of repetitions increase (per set) and rest time between sets decreases, more energy is supplied via glycolysis. In our study, perhaps the length of training (7 sets) was not long enough to engage this glycolytic system, therefore, show significant results. If there was a drastic increase in repetitions however, that type of training would not be in keeping with the "typical" bodybuilding workout (16). In opposition to this, the 7 set routine is long enough to not be entirely reliant on the PC system. Therefore, the exact mechanism of fatigue in this type of exercise is still uncertain. More research is needed to explain the value of carbohydrate ingestion on multiple bout resistance training.

In conclusion, this study found no significant changes in performance of multiple bout resistive exercise when a carbohydrate supplement drink was ingested in an energy balance state or an energy deficit condition. The trend for an improved performance in those ingesting carbohdrate suggest that further research is needed to explain if consumption of this nutrient could benefit performance of more prolonged resistance in competiting body builders.

Table 1. Weightlifting Routine During Maintenance and Hypoenergy Phase

Day 1 of each phase: Legs, calves, biceps, abdomen

	SETS	REPS	LOAD (% 1RM)
Squats	4	10-12	75%
Leg press	4	12-15	70%
Leg curls	4	8-15	70%
Standing calf raises	4	12-20	70%
Preacher curl	3	12-20	65%
Dumbbell curls	2 (each arm)	12-15	65%
Crunches	3	50+	

Day 2 of each phase: Back, chest, abdomen

Pull-ups	3	failure	
Lat pull-downs	4	8-15	70%
Bent-over rows	4	8-15	70%
Incline bench press	3	12-15	65%
Dips	2	12-15	
Crunches	3	50+	

Day 3 of each phase: Shoulders, triceps, abdomen

Military press	3	8-12	65%
Side lateral raises (shoulders)	2	12-15	65%
Front lateral raises	2	12-15	65%
Rear lateral raises (sitting)	2	12-15	65%
Shrugs	2	12-15	65%
Tricep cable pushdown	2	20-15	65%
Tricep kickbacks (dumbbell)	2 (each arm)	12-15	65%
Tricep extensions (supine, using E-Z curl bar)	2	12-15	70%
Crunches	3	50+	

Last day of each phase: Rest, perform only flat bench test

Table 2- Prescribed Maintenance Diet

Sample Diet Prescribed for 80 kg Individual

EXCHANGE	FOOD GROUP	KCAL	PROT(g)	CARB(g)	FAT(g)
4	meat	364	28	-	28
17	bread	720	30	150	-
8	vegetable	224	16	40	-
3	milk	429	24	36	21
7	fruit	420	-	105	-
7	fat	270	-	-	35
TOTAL		2427	98	331	84

--The subjects were asked to choose food servings from each designated exchange and record exactly what foods were eaten.

1 exchange= 1 serving

1 serving= varies depending on food
(e.g. 1 milk exchange= 8 ounces of milk)

Table 3. Multiple Bout Flat Bench Press Test

Performed at 60% of subject's 1 RM

SET 1- 18 Repetitions
(2.5 minutes rest)

SET 2- 15 Repetitions
(2.5 minutes rest)

SET 3- 12 Repetitions
(2.5 minutes rest)

SET 4- 10 Repetitions
(2.5 minutes rest)

SET 5- 8 Repetitions
(2.5 minutes rest)

SET 6- 6 Repetitions
(2.5 minutes rest)

SET 7-as many repetitions as the subject can perform to full extension.

Table 4- Prescribed Low Energy Diet

(example based on 70 kg individual)

MEAL	AMOUNT (grams)	FOOD	KCAL	PROT	CARB	FAT
Breakfast	* 5.5	Quaker Quick Oats	145	6	25	2
Lunch						
	285	Bumble Bee Tuna in Water	259	60	-	-
	*52	Uncle Ben's Quick Rice	223	4	50	-
Dinner						
	*114	Pace Spaghetti	360	10	63	1.5
	228	Hunt's Tomato Sauce	37	1.5	9	-
Snack						
	36	Quaker Rice Cakes	245	7	49	-
	21.375	Kroger's Smooth Peanut Butter	222	11.4	7	18.6
TOTAL			1491	100	203	22

*= based on dry weight

Table 5- Dietary Measurement of Data During MAINT Phase

n	5 CONT	7 CARB	6 PROT
Energy (kcal)	3032.4 (437.6)	2742.6 (369.8)	2828.5 (399.4)
Protein (% kcal)	21.4 (1.8)	17.3 (1.6)	15.7 (1.7)
Carbohydrate (% kcal)	57.2 (1.3)	61.7 (1.2)	63.3 (1.1)
Fat	23.8 (2.7)	22.5 (2.4)	19.1 (2.2)

Values are means (SEM)

Table 6- Prescribed Workout Volume Data During MAINT and EXPER Phases

N	17
MAINT	25513.6
(volume)	(2946.6)
EXPER	27861.5
(volume)	(3574.1)

Both phases are computed in volume means as totalvolume for 3 days, Volume=weight lifted (kg) * number of repetitions performed. (SEM)

Table 7. Comparison Between Baseline, Pre and Post Test Body Weight of Subjects

	CONT	PROT	CARB
n	5	6	7
Baseline BW (kg)	79.7 (4.78)	83.5 (4.78)	81.4 (4.78)
Pre-test BW (kg)	80.9 (4.78)	83.4 (4.78)	83.1 (4.47)
Post-test BW (kg)	83.1 (4.47)	81.3 (4.78)	77.2 (5.16)

Values are means (SEM).
CONT= control
CARB= carbohydrate supplemented group
PROT= protein supplemented group

Table 8- Reliability data for Baseline and Practice Flat Bench Tests

Pearson's Product Moment Correlation

Estimate of reliability R=.96*

*significant at P=.01

Table 9- Flat bench performance data for total weight lifted in the last set of the test

N	CONT 5	PROT 6	CARB 7
Total wt. lifted= total reps (in set 7) X wt. lifted in kilograms			
Baseline	1095 (130.5)	1119 (119.1)	1064 (110.3)
Pre-test	981 (130.5)	1090 (119.1)	1117 (110.3)
Post-test	1001 (130.5)	1046 (119.1)	1192 (110.3)

Values are means (SEM)

Table 10- Repetitions in last set of flat bench test

N	CONT 5	PROT 6	CARB 7
BASELINE	16.6 (1.96)	19.3 (1.79)	14.4 (1.66)
PRE-TEST	14.6 (1.96)	18.5 (1.79)	15.0 (1.66)
POST-TEST	15 (1.96)	18 (1.79)	16 (1.66)

Values are mean repetitions at set 7 (SEM).

FIGURE LEGEND

figure 1. Timeline for study.

figure 2. Weight lifted during set seven at baseline, pre-test and post-test for protein, carbohydrate, and control groups.

figure 3. Number of repetitions performed during set 7 during baseline, pre-test, and post-test periods for the protein, carbohdyrate, and control groups.

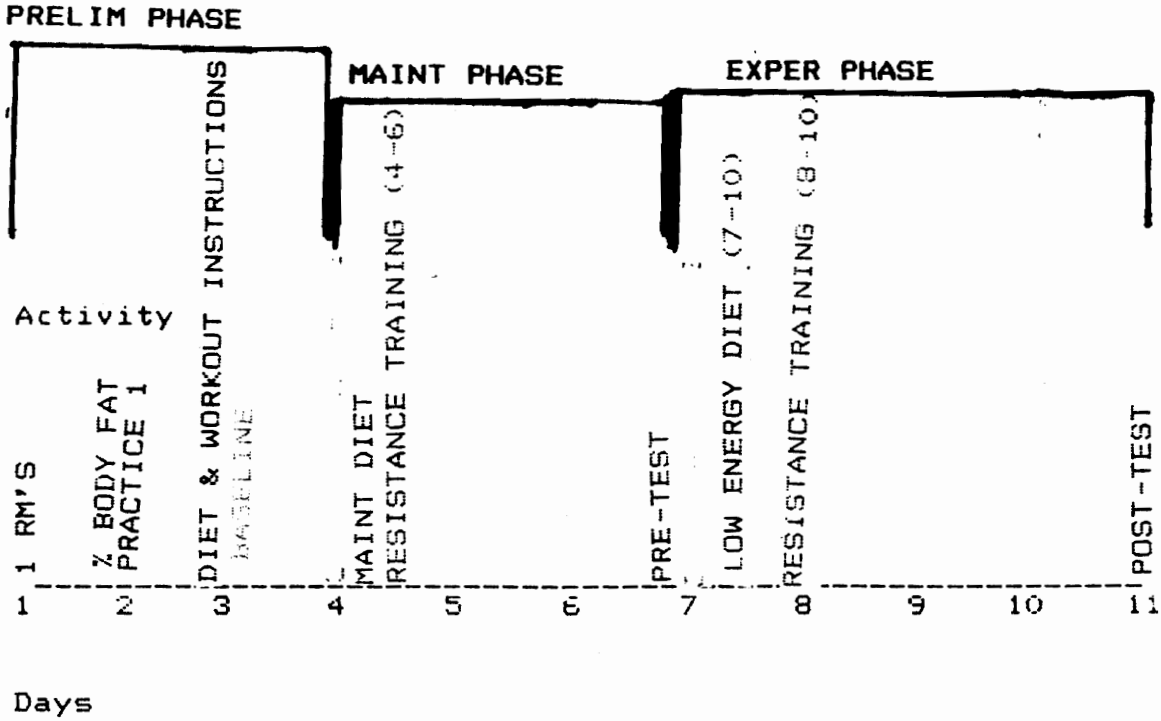

FIGURE 1 Timeline for Study

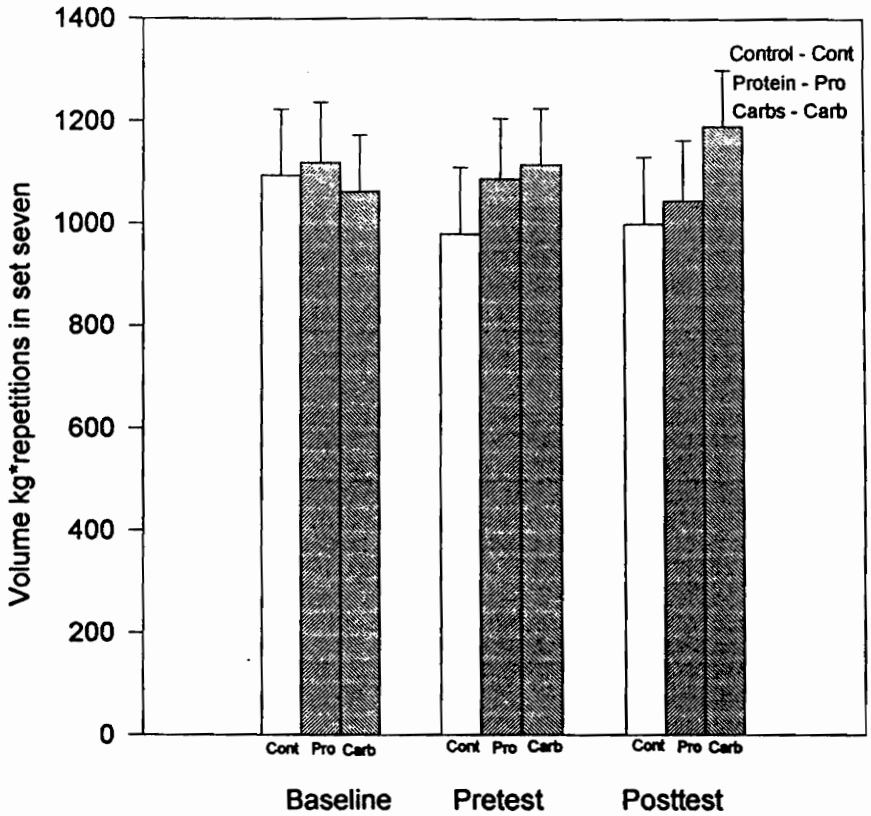

Fig. 2 Mean volume of set seven for groups across time

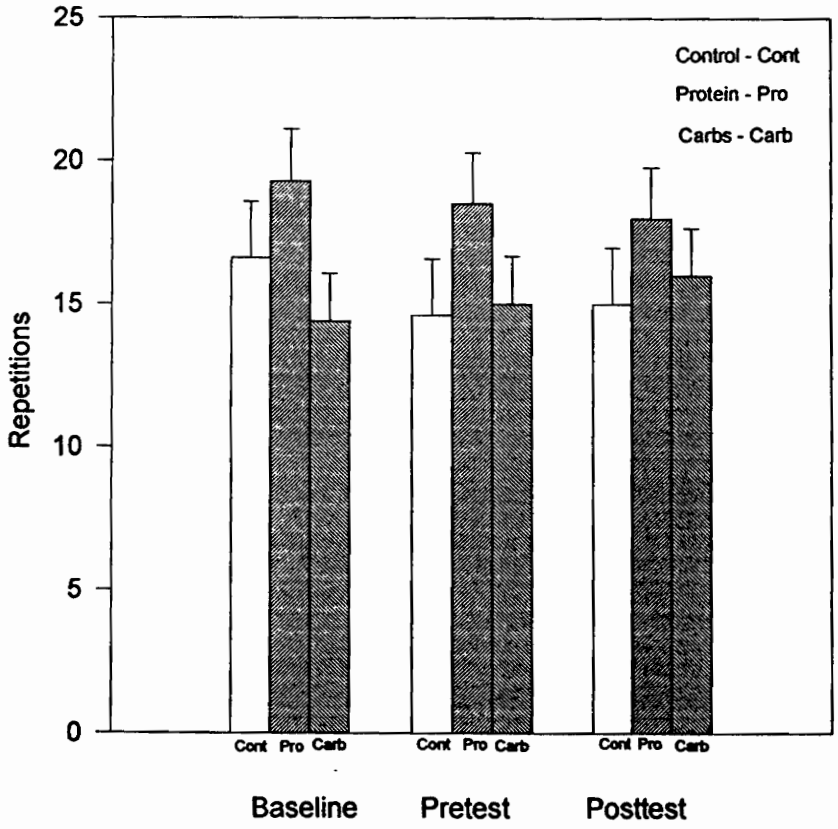

Fig. 3 Mean repetitions of last set for groups across time

References

1. Cheetham. M. E., Boobis, L. S., Brooks, S., and Williams, C. (1986). Human muscle metabolism during sprint running. Journal of Applied Physiology, 54-60.

2. Cole, E.F., Coggan, A. R., Hemmert, M. K., and Ivy, J. (1993). The effect of carbohydrate composition on fluid balance, gastric emptying, and exercise performance. International Journal of Sports Nutrition, 3, 408-417.

3. Costill, D. (1988). Carbohydrates for exercise: dietary demands for optimal performance. International Journal of Sports Medicine, 9, 1-18.

4. Davis, P. G., and Phinney, S. D. (1990). Differential effects of two very low calorie diets on aerobic and anaerobic performance. International Journal of Obesity, 56, 109-114.

5. Dudley, G. A. (1988). Metabolic consequence of resistive-type exercise. Medicine and Science in Sports and Exercise. 20, S158-S161.

6. Gaitanos, G. C., Williams, C., Boobis, H., and Brooks, S. (1993). Human muscle metabolism during intermittent maximal exercise. Journal of Applied Physiology, 712-719.

7. Greenhaff, P., Gleeson, M., & Maughan, R. (1988). The effects of diet on muscle pH and metabolism during high intensity exercise in man. European Journal of Applied Physiology, 57, 531-539.

8. Hargreaves, M., Costill, D., Coggan, A., Fink, W., and Nishibata, I. (19184). The effects of carbohydrate feedings on muscle glycogen utilization and exercise performance. Medicine and Science in Sports and Exercise, 16, 219-222.

9. Horswill, C., Hickner, R., Scott, J., Costill, D., and Gould, D. (1990). Weight loss, dietary carbohydrate modifications, and high intensity_physical performance. Medicine and Science in Sports and Exercise, 22 (4), 470-476.

10. Horton, E. S. (1982). Effects of low energy diets on work performance. The American Journal of Clinical Nutrition, 35, 1228-1233.

11. Ivy, J. L., Yaspelkis, B. B., Patterson, J. G., Anderla, P. A., and Ding, Z. (1993). Carbohydrate supplementation spares muscle glycogen during variant intensity exercises. Journal of Applied Physiology, 1477-1485.

12. Jacobs, I. (1981). Lactate concentration after short, maximal exercise at various glycogen levels. Acta Physiological Scandinavian, 111, 465-469.

13. Kleiner, G. M., Calabrese, L. H., Fiedre, K. M., Naito, H. K., and Skibinski, C. I. (1989). Dietary influences on cardiovascular disease risk in anabolic steroid-using and nonusing bodybuilders. Journal of American College and Nutrition, 8, 109-119.

14. Lambert, C. P., Flynn, M. G., Boone, J. B., Michaud, T. J., and Rodriguez-Zayas, J. (1991). Effects of carbohydrate feeding on multiple-bout resistance exercise. Journal of Applied Sports Science Research, 5 (4), 192-197.

15. MacDougal, J. D., Ray, S., McCartney, N., Sale, D., Lee, P. and Garner, S. (1988). Substrate utilization during weightlifting. Medicine and Science in Sports and Exercise, 20, S66.

16. Manore, M., Thompson, J., and Russo, M. (1993). Diet and exercise strategies of a world-class bodybuilder. International Journal of Applied Physiology, 46, 211-219.

17. McCartney, N., Spriet, L.L., Heigenhauser, G., Kouralchik, J., Sutton, J., and Jones, N. (1986). Muscle power and metabolism in maximal intermittent exercise. Journal of Applied Physiology, 60 (4), 1164-1169.

18. McMurray, R. G., Proctor, C. R., and Wilson, W. L. (1991). The effect of calorie deficit and dietary manipulation on aerobic exercise. International Journal of Sports Medicine, 12, 167-172.

19. Murdoch, S. D., Bazzarre, T. L., Snider, I. P., and Goldfarb, A. H. (1993). Differences in the effects of carbohydrate food form on endurance performance to exhaustion. International Journal of Sports Nutrition, 3, 41-54.

20. Neuffer, P., Costill, D., Flynn, M., Kirwan, J., Mitchell, J., and Houmard, J. (1987). Improvements in exercise performance: effects of carbohydrate

feeding and diet. Journal of Applied Physiology, 62, 983-968.

21. Newton, L. E., Hunter, G., Bammon, M., Roney, R. (1993). Changes in psychological state and self-reported diet during various phases of training in competitive bodybuilders. Journal of Strength and Conditioning Research, 7 (3), 153-158.

22. Phinney, S. D., Horton, E. S., Sims, E. A. et al. (1980). Capacity for moderate exercise in obese subjects after adaptation to a hypocaloric, ketogenic diet. Journal of Clinical Investigations, 66, 1152 -61.

23. Sandoval, W. M., and Heyward, W. (1991). Food selection patterns of bodybuilders. International Journal of Clinical Nutrition, 1, 61-68.

24. Scott, C., Carpenter, R., Taylor, A., and Gordon, N. (1991). Effect of a macronutrient composition of an energy-restrictive diet on maximal muscle performance. Medicine and Science in Sports and Exercise, 814-818.

25. Tesch, P.A., Colliander, E. B., and Kaiser, P. (1986) Muscle metabolism during intense, heavy-resistance exercise. European Journal of Applied Physiology and Occupational Physiology, 55, 362-366.

26. Tsintzas, K., Liu, R., Williams, C., Cambell, I., and Gaitanos, G. (1993). The effect of carbohydrate ingestion on performance during a 30 kilometer race. International Journal of Sports Nutrition, 3, 127-139.

27. Walberg, J., Leidy, M. K., Sturgill, D. J., Hinkle, D. E., Ritchey, S. J., and Sebolt, D. R. (1988). Macronutrient content of a hypoenergy diet affects nitrogen retention and muscle function in weight lifters. International Journal of Sports Medicine, 9, 261-266.

28. Yaspelkis, and Ivy (1991). Effect of carbohydrate supplementation and water on exercise metabolism in the heat. Journal of Applied Physiology, 71, 680-687.

CHAPTER IV

Chapter IV

Summary

Carbohydrate supplementation has already been demonstrated to delay fatigue in aerobic activity (Coyle et al., 1983, Costill, 1988, Ivy et al., 1983, Murdoch et al., 1993, Neuffer et al., 1987, Tsintzas et al., 1993, and Yaspelkis and Ivy, 1991), but recently, some research shows that carbohydrate might also help in anaerobic performance such as multiple bout resistive weight training (Lambert et al., 1991). A bodybuilder's regime consists of a "mass building" phase, where the desired end result is muscle size, and a "cutting phase", where a muscularly defined "cut" physique is obtained from low calorie dieting and high intensity training (Newton et al., 1993).

A lot of bodybuilders have achieved this goal of muscle definition through the use of anabolic steroids or through dietary and exercise manipulations. Many studies have shown the detrimental effects of steroids and their negative impact on the body, both short and long term (Kleiner et al., 1994). Because of these effects, many supplement manufacturers recommend erogenic aids such as carbohydrate supplements to help the athlete perform a rigorous workout while ingesting a low energy diet. Some

studies suggest that a diet mostly in carbohydrates is beneficial to the athlete when undergoing physical activity in training for competition (Manore et al., 1993). It allows the athlete to perform their intense training regime while dieting. These findings are probably what helped to shape the "typical" bodybuilding diet: high carbohydrate, low fat, and moderate to high in protein, to reduce the overall body fat and to have enough energy to survive the training workouts (Sandoval and Heyward, 1991).

Carbohydrates are an important macronutrient in providing energy to the body. The availability of carbohydrate can determine the rate of muscle fatigue (Costill, 1988). This availability is determined by exercise intensity, physical conditioning, exercise mode, environmental temperature, and pre-exercise diet. Therefore, maintenance of muscle glycogen is difficult with repeated activity and involves many different factors.

The type of activity engaged upon has a large bearing on the specific metabolic pathway that might occur to provide energy. In our study, most of the energy was probably provided by glycolysis, or breaking down of stored glucose in the muscle for energy. This involved process involves a series of complex chemical reactions that yields lactate or pyruvate, depending on whether the system is

anaerobic or aerobic. Eventually ATP will be formed, which provides the energy for muscle contraction. In heavy exercise where lactate production is favored, there is a build up of lactate in the muscle, leading to fatigue. What this lactate does is alters the pH in the area, making it more acidic which eventually alters the cellular contractile and metabolic activity, therefore leading to fatigue.

Multiple bout weight training is a high intensity intermittent exercise that is usually performed by the training bodybuilders to achieve muscle size and definition. As noted above, availability of carbohydrate or glycogen can affect performance (McCartney et al., 1986). In a study examining multiple-bout high intensity training, muscle glycogen may become a limiting source of energy since ingestion of exogenous carbohydrate enhanced performance. They suggested that the mechanism for this improvement involved elevation of blood glucose levels which may spare muscle glycogen (Lambert et al., 1991).

Twenty-two male bodybuilders were randomly divided into groups of control (CONT), carbohydrate supplemented group (CARB), and the protein supplemented group (PROT). Just the CARB and PROT groups were assigned to the diet and exercise prescription in the study. The CONT group was

asked to record their diet and workout during the time the other groups would adhere to specific diets and workouts. The duration of the study was for 11 days, and it was broken up into a 3 day maintenance period (MAINT), where diet and exercise was controlled to ensure stabilization and congruency among subjects, and a four day experimental phase (EXPER), where the subjects endured a low energy diet and the same prescribed rigorous workout as performed in the MAINT phase.

The four day EXPER period began immediately after the MAINT phase and began with a pre-test on the flat bench. Fifteen minutes prior to test performance, the PROT and CARB groups were given liquid supplements. The supplements were either a high protein or a high carbohydrate drink.

The flat bench press test was a multiple bout test performed with free weights. It was a 7 set test, at 60% 1 RM, with decreasing repetitions and 2.5 minutes of rest in between each set. In the last set the subject was to perform as many full repetitions as he could. This same protocol was used for all of the flat bench press tests: practice, baseline, pre-test and post-test, performed immediately after the 4 day EXPER phase.

Results of a repeated measures 2 way Analysis of Variance (ANOVA) showed no significant difference between

repetitions on set 7, and volume of exercise (kilograms lifted X total repetitions set 7) of the multiple bout flat bench press test and groups (p=.05). But, in examining just the averages, there is a trend for an increase in performance from baseline to pre-test and further at post-test in CARB while the opposite trend existed for PROT. Although these changes were not significant, it suggests the possibility that another experimental design could determine that when the athlete is on a low energy diet, a carbohydrate supplement could help multiple bout training performance. Further research is needed to examine supplement's effects on a longer bout test (> 7 sets). Again, the reason this experiment utilized a 7 set test because most bodyduilders training for competition perform around 5 sets/body part (Manore et al., 1993).

The various energy sources that the body utilizes during activity depends on the type of activity, intensity, and duration (Costill, 1988). In general, aerobic activity relies more on muscle glycogen for fuel and anaerobic sprint activities rely on phophocreatinine. Longer duration anaerobic activities, such as the multiple bout resistive exercises, rely more heavily on muscle glycogen for fuel utilization. In our study, the subjects trained 6 days/week, 5-15 repetitions, for 2-5 sets. In this type of

training regime; high intensity and low duration, there is a large dependency on muscle glycogen, yet some research states the substrate availability may limit performance (Lambert et al., 1991). Therefore, in our study as well as similar research, carbohydrate ingestion is a possible factor in meeting the energy demands on exercise.

With anaerobic activity, exogenous carbohydrate ingestion helps to spare muscle glycogen and therefore increase performance time only in longer duration anaerobic activities. In the present study, carbohydrate ingestion started to show some (non-significant) increase in repetitions to fatigue at the end of a 7 set multiple bout flat bench press test. Although muscle glycogen samples were not taken, it is thought that carbohydrate ingestion may enhance performance (at the 7th set), by limiting the muscle glycogen depletion through elevated serum blood levels. This hypothesis was further seen by data gathered by Lambert et al.,(1991), and a study conducted by Ball State University (unpublished), which both state a reduction in muscle glycogen in the later stages (>6 sets) of multiple bout weight training exercise. This might explain why there was no significant difference found in the data from our study. In Lambert et al. (1991), they utilized a 15 set test, as opposed to our 7 set test. The

15 set test might allow for more glycogen depletion than the 7 set test, thereby increasing the demand on carbohydrate as a fuel.

So the issue in whether carbohydrate ingestion is helpful to resistance performance might fall to the volume of training. In a typical bodybuilder's "cutting" training workout (high repetitions and sets, and lower weight loads), carbohydrate might be beneficial in performing this type of workout. But when the training becomes higher in weight and lower in sets and repetitions, carbohydrate ingestion might not have an effect on performance time. Typically, the bodybuilder training for a competition performs 5 sets per muscle group (Manore et al., 1993). Thereby explaining the 7 set test used in our study. However, since a full workout does multiple sets of various lifts, a bodybuilder's workout meets the above criteria for carbohydrate ingestion having an effect on performance.

The importance of muscle glycogen sparing is important in multiple bout resistive training, but there is another factor which might contribute to fatigue. When subjects undergo a low calorie diet, especially if the diet is low in carbohydrates, the body may produce ketones, which cause the blood to be very acidic. This acidity in the blood can inhibit glycolysis and reduce the rate of ATP formation,

thereby promoter earlier muscle fatigue (Greenhaff et al., 1987-1988).

Questions might arise to whether weight loss alone seemed to affect performance. Although our study showed no significant weight loss in the experimental groups, it is difficult to state whether weight loss affects overall physical performance. As stated above, it appears that the changes that can come from low energy dieting affect multiple bout resistance performance (depleted glycogen, lower energy intake, etc..), not the weight loss itself.

Timing of carbohydrate ingestion greatly affects it's usefulness in delaying fatigue. Our study gave the subjects 1.25 g of glucose polymer 15 minutes prior to a 7 set flat bench press test. In a study conducted by Lambert et al., (1991), 1 g of glucose polymer was given immediately before and .17 g of solution was given every fifth set thereafter of 15 set leg extension exercise. So it appears from the research above, that glucose polymer should be given every 5th to 7th set of resistance performance to show some change in performance.

Research Implications

The goal of a competitive bodybuilder training for competition is to get as muscularly defined as possible. The way in which this goal is achieved is by utilizing a

low energy diet in combination with a high intensity training regime. In order for these athletes to perform the desired training volume while ingesting a low amount of energy, carbohydrate was shown in one study to aid in offsetting time to fatigue during multiple bout resistive training (Lambert et al., 1991). From the data presented in the present study, carbohydrate ingestion of 1.25 g/kg of body weight given 15 minutes prior to a multiple bout resistive training test, appeared to have no significant effect on fatigue in subjects who are consuming a low energy diet, yet there was a trend for the CARB group to increase in performance compared to pre-test than the other groups after the low energy phase.

So from a practical standpoint, carbohydrate consumption may have benefit for the performance of higher set multiple bout resistive training when there is depletion of muscle glycogen. Normally, it is likely that carbohydrate beverage ingestion consumed before a power or strength type of weight training program, will not have the same beneficial effects as performing an endurance resistance program (>7 sets).

Recommendations for Future Research

After compiling the data from this study, the researchers noticed some possible areas for expansion and

further research. It was assumed that muscle glycogen levels would be reduced after a low energy diet. If muscle biopsies were taken, it would be possible to determine glycogen depletion patterns and determine whether carbohydrate consumption affects the depletion of this fuel.

One of the major drawbacks to this study was that the supplements were too different in taste, appearance and smell to make it a double blind study. The protein supplement also caused a lot of comments from the subjects. All seven of the subjects in the PROT group complained about the taste and odor of the supplement. Two subjects stated that they felt nauseous and one subject actually vomited. Therefore, the data from this subject was not analyzed in this study. If this supplement could be made to taste and smell better, and look more like the supplement given to the CARB group, some of these problems can be avoided.

Although trends were seen in increased performance with carbohydrate ingestion, the diet and test given in this study gave no significant changes at the last set of the test. If the test were longer in duration, (>7 sets), it would be interesting to note any change in performance that might occur. Lambert et al., (1991), used a 15 set

test, but they did not put the subjects through a low energy diet period. So possibly some significant changes could be seen if the test were longer in the low calorie phase (longer than 4 days), and the performance test included more sets and body parts. A test that included a several muscle groups performed 5 to 7 sets per group, would be more in keeping with a typical bodybuilders's training routine and would be longer in duration. Another interesting area for further research would be to do a similar test on various muscle groups. The bench press utilizes fairly smaller muscles than an exercise such a squats, which utilizes several large muscle groups. Since smaller muscles tend to fatigue quicker because they contain less muscle glycogen than larger muscles, it would be interesting to see how the larger muscles fatigue in relation to supplement ingestion.

In addition to alterations in the performance test, making changes in the diet might result in some different effects. This study was relatively short in time (11 days), with a low energy diet of only four days. The EXPER phase showed no significant change in body weight, so, it would be interesting to see if a longer low energy phase would effect performance. A longer diet time would then be more realistic to what a bodybuilder does in actual

preparation for competition.

Another issue that arose with this study was concerning subject selection. Although all 22 subjects met the criteria for being in the study, some of the athletes performed more of a powerlifting routine, higher weight and lower repetitions. When it came time for them to perform the 7 set flat bench test, these athletes were unable to complete the entire 69 repetitions during the 6 sets. After several trials of the flat bench test they did improve performance, yet they still did not complete the full test. If the athletes routinely performed weightlifting routines that were higher in repetitions and lower in weight, they could perform the designated flat bench test. Therefore, it would be beneficial to either chose subjects who had previously performed weightlifting routines similar to the performance test, or to train the subjects to lift a lower weight, higher repetition workout for 1-2 weeks prior to the performance test.

In conclusion, there are still many unanswered questions concerning dietary supplements in bodybuilding. There is so much unfounded information and rumors about how carbohydrates affect physical performance that the more research and information that can be gathered, the more these athletes can be correctly informed.

Appendix A

METHODOLOGY

Selection of Subjects

The subjects selected for this study were volunteer males ages 19 to 33, gathered from area gyms in Blacksburg, Virginia. They had all been lifting for a minimum of one year, 3-4 times/week, for 60 minutes a session, for the purpose of muscle development. Their average percentage of body fat was 12.3% (±1.09), a mean body weight of 84.5 (±.2) kg. All subjects denied previous use of steroids during their history of weightlifting.

The subjects were screened before the experiment began for any metabolic, cardiac or orthopedic disorders that would hinder their performance/health during the study. Even though the study was approved by Virginia Tech Institutional Board for Research on Human Subjects, the subjects were informed of risks and asked to sign an informed consent after they were informed of the risks of participation.

Sampling

The subjects in the two experimental groups, PROT (n=7), and CARB (n=7), were randomly assigned to these groups. The remaining eight subjects were put into the control group (CONT). Two of the subjects (1 in PROT and 1 in CARB) were dropped from the study due to lack of self -reported compliance to the low energy diet.

General Methodology

The study began with a general meeting to explain the

study and to determine the subject's compatibility for the study. The subjects were told that the study lasted for eleven days and that they would need to be scheduled for eight visits. The first day began with determining one repetition maximums for all the exercises that were to be done in the prescribed workout. Days two and three were practice days on the flat bench, while days four through six (MAINT) were when the subjects started the prescribed work-outs and maintenance diets. On day seven, the subjects came in for a flat bench pre-test and began their first day of low calorie dieting. On days eight through ten (EXPER), the subjects showed up for daily food pick up. Then on the last day of the study, the subjects performed their post-test flat bench press test. A more detailed explanation will follow on what activity each day contained.

The CONT group does not follow this schedule. During the MAINT and EXPER phases, the CONT group records their own diet and workout, and just performs the flat bench tests on the designated days.

Selection of Criterion Scores

The dependent measure investigated in this study was the total number of repetitions performed at the last set of the test, and total volume (kilograms lifted*total repetitions in set seven) performed on the flat bench multiple bout bench press test.

Experimental Procedures

PRE-MAINTENANCE PHASE

Day 1- One Repetition Maximums

One the first day of the experiment, the subjects arrived at the free weight room of the University Gym and were paired with an examiner to determine their one repetition maximums (1 RM) on all the lifts to be performed during the prescribed workout. These exercises included 1 RM lifts on:

supine bench press
incline bench press
tricep cable pushdowns
tricep dumbbell kickbacks (right and left)
supine tricep extension
lat pulldowns
bent over t-bar rows
leg curl
leg press
leg extension
military shoulder press
dumbbell side lateral deltoid raise
dumbbell front lateral deltoid raise
dumbbell rear lateral deltoid raise
preacher curl
concentrated dumbbell curl (right and left)

Five repetition maximums were performed on exercises that were considered unsafe to do 1 RM's on. These included squats, straight bar shrugs, and standing calf raises. Percentages of 1 or 5 RM were then calculated to determine

the exercise prescription, see Appendix B, page 114.

Day 2- Practice One

On day 2, the subjects were measured for height, weight, percentage of body fat, and performed the multiple bout flat bench test. The test was performed on a free weight bench at 60% of their 1 RM and consisted of:

SET 1- 18 Repetitions
(2.5 minutes rest)
SET 2- 15 Repetitions
(2.5 minutes rest)
SET 3- 12 Repetitions
(2.5 minutes rest)
SET 4- 10 Repetitions
(2.5 minutes rest)
SET 5- 8 Repetitions
(2.5 minutes rest)
SET 6- 6 Repetitions
(2.5 minutes rest)
SET 7- as many repetitions as the subjects can perform to full extension

Full repetitions were verified by an infrared beam set at the subject's full arm extension length. The practice session was performed to offset any effect that might occur from the subjects learning the test protocol.

Day 3- Baseline

At the onset of this visit, the subjects were taught portions and exchanges and how to record these during the following three days in the maintenance diet phase of the experiment, based on the American Diabetes Association Diabetic Exchange Diet. They were also given record sheets to record this information on as well as memeographed sheets explaining what each exchange group was (i.e. bread,

milk, vegetable, meat, fruit, and fat) and the amount of food that comprises one exchange, see Appendix b, p. 125. Then, the subjects performed their second flat bench test as, known as the baseline test, as described earlier in the text.

MAINT PHASE

Days 1-3 - Maintenance Diet

During these three days the subjects did not see the examiners but the CARB and PROT groups followed a diabetic exchange diet based on 35 kcal/kg of body weight (55% carbohydrate, 30% fat, 15% protein), as well as adhering to the three days of their prescribed workout. A sample exchange diet based on 70 kg of body weight was:

BREAD- 10
MEAT- 4
VEGETABLES- 8
FRUIT- 7
MILK- 3
FAT-7

During these days no alcohol or tobacco consumption was allowed. They subjects were also asked to record their daily exchange intake on the forms provided.

The workout prescribed to the subjects follows a three day rotation of:

Day 1- legs, calves, biceps, abdominals, cycling
Day 2- back, chest, abdominals, and cycling
Day 3- shoulders, triceps, abdominals, and cycling
Day 4- rest, just perform bench press test

Exercises were performed at 65-70% 1 RM, for three to four sets at 8-15 repetitions. Biking was performed for 30 minutes on a stationary bicycle at a target heart rate

based on age predicted maximum. The subjects were asked to verify their workouts by recording each repetition performed on each exercise, see Appendix B, p.123-124.

The control group (CONT) were asked to record their exercise and dietary intake during these three days and to report on day 7 for pre-testing, after a 12 hour fast and not working out for 18 hours before their appointment time.

EXPER PHASE

Day 1- Pre-Tests

All subjects began the test with fasting for 12 hours and not performing any activity for 18 hours before the flat bench test. Again, no tobacco or alcohol consumption was allowed during this period. When the subjects arrived to the examiners they returned their completed form from the three day maintenance days (CONT group included). They were then weighed to determine if they were weight stable and given their supplemental drink (PROT and CARB groups only) 15 minutes prior to performing the multiple bout flat bench press test.

The PROT group received a high protein shake with water blended with ice cubes in a blender. The amount given was based on kg of body weight and the breakdown was:

5 kcal/kg
1.2 g protein/kg
0 g carbohydrate
0 g fat

The CARB group received a similar drink with water, although the differences among the two supplements in terms

of taste, smell and appearances made it impossible to have a double blind study. The amount given was also based on kg of body weight and included:

5 kcal/kg
0 protein
1.25 g carbohydrate/kg
0 fat

The control group simply performed the flat bench test after weighing in. After performing the test, the PROT and CARB groups received their food for the day which was pre-measured on an electronic scale. Their dietary intake for the following four days consists of 21 kcal/kg of body weight, 55% from carbohydrates, 15% from fats, and 30% from protein. A sample diet included:

BREAKFAST- oatmeal
LUNCH- rice and tuna fish
DINNER- spaghetti and tomato sauce
SNACK- peanut butter and rice cakes

The subjects were asked to not add or delete any part of their diet. They were allowed as much water as they wanted, artificial sweeteners, diet drinks, and dry herbs and spices. For more details on the diet, see Table 4. They also recorded their daily consumption on the provided sheets and performed the same three day rotation of exercise as was given during the three maintenance days. It should be noted that on the testing days (pre and post), the PROT and CARB groups did not perform any exercise except the flat bench test, so that the data gathered from this test would not be affected by

any exercise performed on that day.

The control group was asked to record their diets and workouts for the next four days until they arrived for their post-test.

Days 2-4 -Food Pick Up

During these three days, the CARB and PROT subjects arrived for daily weigh ins, food, and continued their prescribed workouts on their own. The control group continued recording their own diets and workouts.

Day 11- Post-Test

Before arrival for the post tests, all subjects were in a 12 hour fasted state, didn't exercise for 18 hours prior to their appointment, and didn't consume any tobacco or caffeine for four hours before testing. They returned their proper log forms, got weighed and then performed the flat bench press test. Upon completion of the flat bench test, the subjects were given a questionnaire asking them if they felt the supplement helped/hindered their performance in any way (Prot and CARB groups only), and if they thought they knew the composition of the beverage they consumed.

Research Design and Statistical Procedures

The experimental design was a two-way factorial. Analysis of volume of exercise in set seven and repetitions of last set, were performed on a repeated measure Analysis of Variance (ANOVA), with the alpha level

set at .05. Diet was analyzed and averaged over a three day period and then analyzed for differences in energy, and macronutrient intakes among groups using a repeated measures ANOVA, p = .05. Analysis of body weight changes was also performed using a repeated two way ANOVA. The dependent variables for volume and repetitions performed at the last set of the test were also analyzed using a repeated measures two way ANOVA, with an alpha level = .05.

Appendix B

INSTRUCTIONS TO SUBJECTS

DIET AND WEIGHT LIFTING PROTOCOLS

EXERCISE TESING FORMS

SCHEDULE OF IMPORTANT DATES TO REMEMBER

Subject:

Feb. 14 - 1 Repetition Maximum (1 RM)
at : meet "arm room" of Hokie Gym in War Memorial Hall (Check in with Lynette)

Feb._____- Practice 1, Skinfolds
at : meet in Room 230, War Memorial Hall

Feb._____- Baseline Test, get record sheets
at : meet in Room 230, War Memorial Hall

Feb.___thru
Feb._____-Start maintenance diet, record food and do start workouts 1 to 3, record on workout sheets.

Feb. _____- Flat Bench Test Pre-Test; *give examiners maintenance diet forms and workout sheets;* Pick up Food for day(don't forget to record food intake); meet in Room 230, War Memorial Hall
at :

Feb._____-Pick up food; meet in 230, War Memorial Hall
AT :

Feb. _____-Pick up food; meet in 230, War Memorial Hall
at :

Feb _____-Pick up food; meet in 230, War Memorial Hall
at :

Feb_____-Flat bench test post-test, don't eat anything after : p.m. on 2 / /94, report to 230 War Memorial Hall with *completed food sheets from low calorie diet phase and workout log,*
at : *Have these ready to turn in TODAY!!!!*

** If you have any problems or questions, you may contact one of the examiners

Lynette Poland: 961-0332 Dr. Janet Rankin: 231-6355

Tina Randall: 552-7649

DATA SHEET

Name: _____

Date:
Time:
Technician:

Body Weight:
_____kg _____lbs.

Body Height:
_____ cm. _____ inches

Age:

Training Target Heart Rate: _____bpm

Skinfold Measurements:

Chest: _____, _____,
Abdomen: _____, _____ ,
Thigh: _____, _____,

Sum of measurements: _____ mm

% of bodyfat

INSTRUCTION SHEET FOR 1 RM DETERMINATION

1) The subject should warm up with one set of 5-10 repetitions with approximately (40-50% ofperceived max.).

2) After approximately a minute of rest and stretching, the subject should perform one set of 3-5 reps with a weight approximately (60-80% of perceived maximum).

3) After another minute of rest and stretching, have the subject perform 3-4 one rep maximal attempts spaced 30-60 seconds apart for rest.

4) The last successfully executed lifted weight (full extension/flexion) is recorded as the subject's 1 RM in that particular lift.

DATA FOR 1RM LIFTS

Subject: _____ Date:

	1 RM	%
SUPINE BENCH PRESS		60% =
INCLINE BENCH PRESS		65% =
DIPS	BW	
CABLE PUSHDOWN		65% =
KICKBACKS R)		65% =
L)		65% =
SUPINE TRICEP EXTENSION		65% =
PULL-UPS	BW	
LAT PULLDOWNS		70% =
BENT-OVER ROWS		70% =
LEG CURL		70% =
SQUATS (5 RM)		75% (cal 1RM) =
LEG PRESS		70% =
LEG EXTENSION		70% =
CALF RAISES (5 RM)		70% (cal 1RM) =
MILITARY PRESS		65% =
SIDE LATERAL RAISE		65% =
FRONT LATERAL RAISE		65% =
REAR LATERAL RAISE		65% =
SHRUGS (5 RM)		65% (cal 1RM) =
PREACHER CURL		65% =
CONC. DUMBBELL CURL R)		65% =

EXPLANATION OF STUDY

During the next few days we will ask that you come in to perform a flat bench press test. This is the same test that you will perform during the experiment week. We want you to give your maximum effort for each test in order to get the best results from the study.

During the 8 days of the study we will ask you to record EVERYTHING you eat and drink on the provided forms. This includes supplements, tea, coffee, etc. Also, we will ask you to record any exercise that you perform during this time, from running to any weight lifting that you do. We do ask, that you limit your aerobic activity (i.e. running, cycling, etc.) to no more that 30 minutes, 3-4 times/week. This is to ensure that all subjects stay basically at the same activity level. Again we will provide you with the forms to record these activities. During the experiment week, you will be asked to come in two separate mornings for the flat bench press test. We ask that before you come in to be tested that you DON'T EAT ANYTHING FOR 12 HOURS BEFORE YOUR APPOINTMENT AND THAT YOU DON'T EXERCISE FOR 18 HOURS BEFORE YOUR APPOINTMENT. The times of these tests are listed on your schedule sheet. Your dietary and exercise logs will be collected on the last day you come in to be tested.

If you have any questions or concerns during the study, please contact one of the examiners.

INSTRUCTIONS FOR FILLING OUT WORKOUT AND DIETARY DAILY LOG

Workout Log

1) Make sure specify which exercise you are performing and at what amount of weight and the number of repetitions you perform at that set.

2) Please fill out name, time, and muscle groups exercising during workout.

3) Don't forget to list any aerobic activity you engage in (i.e. running, swimming, biking, etc.). Make sure to include the duration and intensities of these activities. Also, please remember to limit this time to 30 min. 3-4 times/week.

4) If you experience any abnormal discomforts or changes while exercising, then list these on the log page.

4) Turn in workouts for Days 1-3 on
Turn in workout sheets for day 4-7 on

Dietary Log

1) Make sure to list amounts of food (i.e. 1/2 cup, 8 oz., 2 g, etc.), as well as type or style of preparation (i.e. creamed corn, baked potato, steamed broccoli, etc.).

2) Don't forget to include any supplements you may be taking as well as all beverages you consume.

3) If you have any comments to make on your diet, please do so on the back of the provided log pages.

4) Turn in dietary logs for days 1-3 on
Turn in dietary logs for days 4-7 on

WORKOUT LOG

Please be sure to include any aerobic act. in log, but limit it to 30 min.

NAME:

DAY 1:
TIME OF WORKOUT:
BODY PART(S) LIFTING:

Exercises	wt/rep	wt/rep	wt/rep	wt/rep	wt/rep

COMMENTS:

DAY 2:
TIME OF WORKOUT:
BODY PART(S) LIFTING:

Exercise	wt/rep	wt/rep	wt/rep	wt/rep	wt/rep

COMMENTS:

NAME:

Please be sure to list any aerobic acivity, but limit time to 30 minutes*

DAY 3:
TIME OF WORKOUT:
BODY PART(S) LIFTING:

Exercises	wt/rep	wt/rep	wt/rep	wt/rep	wt/rep

COMMENTS:

DAY 4
8:
REPORT TO WMH 230 AT _____FOR TESTING... **Don't Workout For 18 Hours Before The Test & don't eat anything for 12 hours before your appointment**

WORKOUT LOG

Please be sure to include any aerobic act. in log, but limit it to 30 min.

NAME:

DAY 5:
TIME OF WORKOUT:
BODY PART(S) LIFTING:

Exercises	wt/rep	wt/rep	wt/rep	wt/rep	wt/rep

COMMENTS:

DAY 6:
TIME OF WORKOUT:
BODY PART(S) LIFTING:

Exercise	wt/rep	wt/rep	wt/rep	wt/rep	wt/rep

COMMENTS:

NAME:

Please be sure to list any aerobic acivity, but limit time to 30 minutes*

DAY 7:
TIME OF WORKOUT:
BODY PART(S) LIFTING:

Exercises	wt/rep	wt/rep	wt/rep	wt/rep	wt/rep

COMMENTS:

DAY 8:
REPORT TO WMH 230 AT _____FOR TESTING... **Don't Workout For 18 Hours Before The Test & don't eat anything for 12 hours before your appointment**

DIETARY LOG

NAME:
DAY 1

BREAKFAST:

Food	Amount	Way Prepared

LUNCH:

Food	Amount	Way Prepared

DINNER:

Food	Amount	Way Prepared

SNACKS:

Food	Amount	Way Prepared

EXPLANATION OF STUDY

This study demands an intense amount of your concentration and time for a very brief period. During the next few days, we will ask you to come in and perform what is known as "One Repetition Maximum" test or 1 RM for all the exercises you will be performing during this study. After this information is gathered you will receive a prescribed workout telling you EXACTLY what exercise to do and how to do it.

The experiment phase of the study will be divided into a "maintenance" phase and an dieting phase. The maintenance phase will last three days. The dieting phase will last 4 days. Detailed explanations of each phase is included below.

MAINTENANCE DAYS

The purpose of the three maintenance days are to:

1) ensure that you don't gain or loose weight

2) start everybody on the same type of diet

The exercises you are to perform during these three days is listed in your packet under Exercise Protocol (days 1-3). Please perform these exercises in the order listed and check off exercises performed on the exercise protocol sheet. Please DO NOT delete or add any exercises to this list. If you have problems with one of the exercises or feel that your workout needs adjustment, call Lynette (961-0332). These completed sheets will be collected on day 4, when you come in for your flat bench test. It is important that you DO NOT EXERCISE FOR 18 HOURS, AND NOT EAT FOR 12 HOURS BEFORE THE TEST.

The diet you will be following during these three days is based on a diabetic exchange system. This type of system functions on a per serving basis rather than amount of calories. Please follow the prescribed exchange diet given to you for the three maintenance days and record what you eat on the provided form. These forms will be collected at the *end of your three maintenance days*, before you start the dieting phase(day 4). You may refer to the enclosed memiographed sheets on determining an exchange or ask one of the examiners if you have any problems or questions concerning the diet.

EXERCISE PROTOCOL

Please don't add or delete any reps, wt. or ex.*

NAME _____

DAY 1 _____

Legs/calves/Biceps

	Weight (lbs)	*Sets*	*Reps.*	*Actual Reps Perf.*
Squats		4	10-12	
Leg Press		3	12-15	
Leg Extension		4	8-15	
Leg Curls		4	8-15	
Donkey Calf Raises		4	12-20	
Preacher Curl		3	12-20	
Dumbbell Curls		2(each arm)	12-15	
Crunches		4	50+	

Stationary Cycling for 30 min. at heart rate of bpm

COMMENTS:

Day 2:

Back/Chest

	Weight (lbs)	*Sets*	*Reps*	*Actual Reps. Perf.*
Pull-Ups	body weight	3	failure	
Lat Pull-downs		4	8-15	
Bent-over Rows		4	8-15	
Incline Bench Press		3	12-15	
Dips	body weight	2	12-15	
Crunches		3	50+	

Stationary Cycling for 30 min. at heart rate of

Day 3: _____ ***Please don't add/delete any sets, reps, wt., or ex.**

NAME: _____

Shoulders/Triceps

	Weight (lbs)	*Sets*	*Reps.*	*Actual Reps. Perf.*
Military Press		3	8-12	
Side Lateral Raises (shoulders)		2	12-15	
Front Lateral Raises		2	12-15	
Rear Lateral Raises (sitting)		2	12-15	
Shrugs		2	12-15	
Tricep Cable Pushdowns		2	20-15	
Tricep Kickbacks (dumbbell)		2(each arm)	12-15	
Tricep Extensions (lying using E-Z curl bar)		2	12-15	
Crunches		4	50+	

Stationary Cycling for 30 min. at heart rate of _____ bpm

COMMENTS:

Day 4:

DO NOT EXERCISE FOR 18 HOURS BEFORE YOUR APPT. TIME, REPORT TO LAB FOR FLAT BENCH PRESS TESTING.
(MAKE SURE YOU DON'T EAT ANYTHING FOR 12 HOURS BEFORE TESTING)

MAINTENANCE

Your Diet Prescription is:

_____ meat _____ milk

_____ bread _____ fruit

_____ vegetable _____fat

Please note the following guidelines of exchanges:

1 bread exchange= 1/2 cup of cereal, grain, or pasta
1 ounce of a bread product

1 meat exchange= 1 oz. meat
1 oz. cheese
1/4 cup canned tuna

1 vegetable exchange= 1/2 cup cooked vegetables or vegetable juice
1 cup of raw vegetables

1 fruit exchange= 1/2 cup of fresh fruit or fruit juice
1/4 cup of dried fruit

1 milk exchange= 1 cup milk
8 ounces of nonfat/plain yogurt

1 fat exchange= 1 tsp. oil, butter, margarine or mayonnaise
1 tablespoon diet margarine or diet mayonnaise
2 tablespoons of sour cream
1 tablespoon salad dressing

free foods= unlimited amounts
herb seasonings, sugar sub., mustard, vinegar diet sodas, coffee, tea
pickles, lemon/lime juice
nonstick pan spray

If you have a question about a food category, please follow your enclosed memiographed sheets, or contact one of the examiners.

MAINTENANCE DIET RECORD

DAY 1: _____ NAME:

Breakfast

FOOD
SERVINGS EXCHANGE:

Lunch

FOOD
SERVINGS EXCHANGE:

Dinner

FOOD
SERVINGS EXCHANGE:

Snack

FOOD
SERVINGS EXCHANGE

Name: _____ Time:
Date:

INSTRUCTIONS FOR TESTING

Please report to Room 230, War Memorial Hall at the above date and time. You will be involved in the performance flat bench test and the mood state test. Please come prepared by:

1) Wearing clothes you can work out in

2) Not eating anything for 12 hours before your scheduled appointment

3) Not exercising FOR 18 HOURS before arriving to your appointment

FLAT BENCH PRESS TEST

Name: _____ Test: Pract1/Base/Pre/Post

Date:

Time:

Flat Bench Press 1RM: _____lbs.

Weight at 60% 1RM_____lbs.

SET 1: 18 Reps. _____ RPE

SET 2: 15 Reps. _____RPE

SET 3: 12 Reps. _____ RPE

SET 4: 10 Reps. _____ RPE

SET 5: 8 Reps. _____ RPE

SET 6: 6 Reps. _____ RPE

SET 7: _____Reps. at_____lbs. _____RPE

Comments:

LOW CALORIE DIETING PHASE

The purpose of this phase is to mimic the type of diet a bodybuilder would consume in preparation for competition. This phase will last 4 days during which you will be asked to come in EVERY morning to receive your daily food. We asked that you follow our instructions in preparing and eating this food and that you consume only the food that is given to you.

The workout during this time correlates to days 4 through 8 in your exercise protocol sheets. You will notice that on days 4 and 8 you don't have to workout but instead are asked to come into the lab to perform the flat bench press test. On these days please DON'T EAT ANYTHING FOR 12 HOURS before your appointment time, and DO NOT WORKOUT FOR 18 HOURS BEFORE the test. Instructions for the test itself will be given to you on testing day.

If you experience and pain or discomfort during this study please don't hesitate to alert one of the examiners of your problem.

Day 5: _____

NAME: _____

Please do not add/delete any reps, sets, wts., or ex.**

Legs/Calves/Biceps

	Weight (lbs)	*Sets*	*Reps*	*Actual Reps. Perf.*
Squats		4	10-12	
Leg Press		3	12-15	
Leg Extension		4	8-15	
Leg Curls		4	8-15	
Donkey Calf Raises		4	12-20	
Preacher Curl		3	12-20	
Dumbbell Curls		2(each arm)	12-20	
Crunches		4	50+	

Stationary Cycling for 30 min. at heart rate of _____ bpm

COMMENTS:

Day 6:

Back/Chest

	Weight (lbs)	*Sets*	*Reps*	*Actual Reps. Perf.*
Pull-Ups	body weight	3	failure	
Lat Pull-downs		4	8-15	
Bent-over Rows		4	8-15	
Incline Bench Press		3	12-15	
Dips	body weight	2	12-15	
Crunches		3	50+	

Stationary Cycling for 30 min. at heart rate of _____ bpm

Day 7: _____ **Please do not
NAME: _____ add/delete any reps., wt.,sets, or ex.**

Shoulders/Triceps

	Weight (lbs)	*Set*	*Reps*	*Actual Reps. Perf.*
Military Press		3	8-12	
Side Lateral Raises (shoulders)		2	12-15	
Front Lateral Raises		2	12-15	
Rear Lateral Raises (sitting)		2	12-15	
Shrugs		2	12-15	
Tricep Cable Pushdowns		2	20-15	
Tricep Kickbacks (dumbbell)		2(each arm)	12-15	
Tricep Extensions (lying using E-Z curl bar)		2	12-15	
Crunches		4	50+	

Stationary Cycling for 30 min. at heart rate of
bpm

COMMENTS:

Day 8:

DO NOT EXERCISE (for 18 hours before your appt. time), REPORT TO LAB FOR FLAT BENCH PRESS TESTING.
(MAKE SURE YOU DON'T EAT ANYTHING 12 HOURS BEFORE TESTING)

**********It is important that you follow this workout and document this workout on the sheets provided until the end of the study. PLEASE DO NOT DO ANY ADDITIONAL EXERCISES OR DELETE ANY OF THE PRESCRIBED EXERCISES LISTED ABOVE. For some reason if you do not do the exact repetition or set listed above, please explain why in the space provided at the end of each workouts. *******

LOW CALORIE DIET

The food given to you in this bag contains EVERYTHING you should eat for one day (except non-caloric beverages). Please follow instructions in food preparation and DO NOT delete or add any other foods. If you experience any abnormal symptoms or discomforts while on this diet, please contact one of the examiners.

Your diet basically consists of:

BREAKFAST
2 cups of oatmeal

LUNCH
10 ounces of tuna fish
1 cup of rice

DINNER
1.5 cups of spaghetti
1 cup of tomato sauce

SNACK
1.333 tablespoons of peanut butter
4 rice cakes

-The exact amount might differ for you because the amount of food given is based on body weight. Please try to eat your food as designed above (3 meals and 1 snack), and remember to eat only the food you are given.

FOOD/BEVERAGES YOU CAN CONSUME
lemon juice, dry herbs (oregano, basil, cinnamon) water (unlimited amount)
diet soft drinks
coffee (no cream, artificial sweeteners only)
tea (artificial sweeteners only)
sugarless gum (no more than 3 sticks/day)

-If there is something else that you think would be okay to eat during this week, please check with the examiners first.

-Please don't consume any supplements during these four days and make sure to DRINK LOTS OF WATER (at least 6 glasses/day). Staying hydrated will help you from feeling tired and dizzy.

-You might feel fatigue from the diet but let us know if you experience any UNUSUAL SYMPTOMS.

!!!!!!!!!!!!!!!!!!IMPORTANT!!!!!!!!!!!!!!!!!!!!!!
TUNA FISH AND TOMATO SAUCE ARE PERISHABLE FOODS. THEY NEED TO BE REFRIGERATED IMMEDIATELY AFTER RECEIVING THEM. DO NOT EAT THEM IF THEY HAVE BEEN OUT FOR LONGER THAN ONE HOUR.

LOW CALORIE DIET CHECK-OFF

Please check off the food after you have eaten them. Also, add any beverages, seasonings, or permitted food that you consumed with that meal.

DAY

BREAKFAST

_____Oatmeal
_____ Beverage (Specify)
_____Other (Specify)

LUNCH

_____Tuna Fish
_____Rice
_____Beverage (Specify)
_____ Other (Specify)

DINNER

_____Spaghetti
_____Tomato sauce
_____Beverage (Specify)
_____Other (Specify)

SNACK

_____ Peanut Butter
_____ Rice Cakes
_____ Beverage (Specify)
_____ Other (Specify)

COMMENTS

COOKING OATMEAL

Stovetop

1) Stir the package of oats into cups of briskly boiling water.
2) Cook this mixture for 1 minute, stirring occasionally.
3) Cover; remove from heat. Let stand until desired consistency.

Microwave

1) Combine cups of water with the oatmeal in a microwavable dish.
2) Microwave on high for 1 1/2 - 2 minutes
3) Remove and mix well

PLEASE DO NOT ADD ANY EXTRAS TO YOUR OATMEAL SUCH AS SUGAR, RAISINS, ETC.. CINNAMON IS OKAY, AND YOU CAN ADD ARTIFICIAL SWEETENER IF YOU WANT, BUT NO SUGAR.

COOKING RICE

Stovetop

1) Measure cups of water; bring to a boil
2) Stir rice into water; remove from heat
3) Let rice stand until all water is absorbed, (around 5 minutes)

Microwave

1) Combine cups of water and rice in microwavable dish.
2) Microwave on high for 2-3 min. or until water boils.

DO NOT ADD ANY EXTRAS TO RICE (Such as Butter), EXCEPT DRY SPICES SUCH AS PEPPER, BASIL, ETC.

COOKING SPAGHETTI

Stovetop

1) Bring 2-3 quarts of water to boil.
2) Add spaghetti; stir to separate
3) Boil spaghetti uncovered for about (9-13 minutes)
4) Drain and serve immediately.

DO NOT ADD ANY EXTRAS TO THE SPAGHETTI EXCEPT FOR THE PROVIDED TOMATO SAUCE. YOU MAY ADD DRY SPICES (Basil, Tarragon, Pepper) BUT NO CHEESES OR OTHER EXTRAS.

Appendix C

INFORMED CONSENT
HUMAN SUBJECT FORM
MEDICAL SCREENING FORM

REQUEST FOR APPROVAL OF RESEARCH PROPOSAL

IN THE DIVISION OF HPER

Submitted to

Charles Baffi, Ph.D.

Chairman, Division Human Subjects Committee

By

Janet Walberg-Rankin, Ph.D., Lynette Poland,

Tina Randall

Co-investigators

TITLE:

Bodybuilders and Low Calorie Diets: The Effects of Carbohydrate Supplementation on Muscle Endurance and Perception of Fatigue

JUSTIFICATION OF PROJECT:

The purpose of this project is to determine if the type of dietary supplement given to bodybuilders on a weight reduction diet (similar to what they would do to prepare for a competition) will affect (1) muscle endurance on multiple-bout resistance exercises, and (2) psychological status and perception of effort. Bodybuilders training for a competition attempt to maintain their large muscle mass while reducing body fat to minimal levels. One of the

methods these athletes use in order to lose body fat is caloric restriction in addition to an intense daily workout. When consuming such low calorie diets, bodybuilders often feel fatigued, irritable, hungry and are generally unable to perform as well during training sessions (Costill, et al, International Journal of Sports Medicine, 1988: 9 pages 1-18). We would like to test the possible benefits of two (carbohydrate or protein) dietary supplements taken just prior to a resistance weight training lifting session. We hypothesize that the carbohydrate supplement will improve both the performance of a lifting session and reduce the perception of effort during exercise. This is suggested by evidence showing increased endurance and decreased perception of fatigue in individuals using carbohydrate supplements during aerobic exercise. Historically, carbohydrate supplements have been discounted as useful for anaerobic exercise, such as resistance weight training, since body carbohydrate stores are not depleted and therefore not thought to be limiting. However, since carbohydrate stores are reduced by caloric restriction, this nutrient may be limiting in athletes doing anaerobic work while dieting for weight loss. Results of this study would be beneficial to weightlifters, and especially bodybuilders preparing for a competition. If a carbohydrate supplement

enhances their mental performance and psychological status, it may help improve the quality of their workouts.

PROCEDURES:

Subjects will include approximately 24 experienced male weightlifters from 18 to 25 years of age recruited from the Virginia Tech campus and surrounding areas. They will be screened for contraindications to weight loss and multiple bout resistance training activities including, but not limited to, diabetes, heart conditions, orthopedic limitations or injuries, and major organ malfunctions. Subjects will be divided into an experimental, a placebo, and a control group.

The study will begin with a two day maintenance period. An exchange diet where all foods are divided into seven categories (e.g. milk, fruits) will be prescribed for each subject. The diet will consist of 55% carbohydrate, 30% fat, and 15% protein and approximately 40kcal/kg/day. Maximal strength for 20 lifts will be tested in order to develop an exercise prescription based on individual capacity. Subjects will be lifting weights with two different body parts each day on a six day rotation. This lifting regimen is one typical of bodybuilders. Aerobic activities will consist of 30 minutes of stationary

bicycling in a heart rate range between 55 - 70% of their maximum heart rate (determined using an age adjusted maximum heart rate formula).

The four day treatment period will start immediately after the maintenance period. The subjects will be lifting on the same routine prescribed to them during the maintenance period. Subjects will record weights lifted, sets and repetitions in each lifting session. Subjects will be randomly monitored to assure compliance to the exercise prescription.

During the treatment period, subjects will be prescribed a diet of 21 kcal/kg body weight consisting of 55% carbohydrate, 15% fat, and 30% protein. Subjects will be given their food for consumption. The diet will consist of tuna, pasta, spaghetti sauce, rice cakes, oatmeal, potatoes, and other similar items typical of a dieting bodybuilder.

One preliminary test session will include the calculation of percent body fat and weight of each subject. Percent body fat will be calculated using calipers that measure the width of a fold of skin on the chest, thigh, and abdomen. These numbers are then put in an equation determining the percentage. Weight will be measured using a standard step-on scale.

A test of muscle performance will be completed four times (two practice trials, one at the end of the maintenance period, and one at the end of the treatment period). The performance test will follow a typical bodybuilding workout lasting approximately one hour. Thus the test will be assessing performance and fatigue rate at the end of an hour weight lifting session. The performance measure will consist of multiple sets using the bench press. All sets will have a weight at 55% of the subject's maximum. The first set will consist of 15 repetitions, the second set of 12 repetitions, the third set of 10 repetitions, and the final set continuing on until volitional fatigue. Each subject will have fasted for 12 hours prior to each performance and the exercise session will occur in the morning 24 hours after the last workout. Subjects will consume their respective supplement 60 minutes before testing.

The carbohydrate supplement of 300 kcal will be consumed in liquid form 60 minutes prior to each performance measure by the experimental group. The placebo group will consume a commercial supplement of the same caloric value used by bodybuilders which is composed mainly of protein. The control group will receive nothing and will be asked to continue their normal diet and exercise routine and to

maintain their body weight. The control group will be recording both their exercise routine and diet.

In addition to examining muscle performance, we will look at effects of dieting and the supplement consumption on mood and perception of effort. Subjects will be given a mood questionnaire (Profile of Mood States consisting of 65 questions rating different mood states on a 5 point scale) immediately prior to the workout before each performance measure and after each performance measure session. The subject will be asked to rate their perception of effort (Borg's Rating of Perceived Exertion scale utilizing the numbers 6-20) between each set during the performance measures.

Since fatigue and mood can be affected by blood lactate, each subject will also have blood lactate levels measured prior to and just after each performance test. This will require withdrawal of less than half a teaspoon of blood with each test (25ul per sample). A lancet will be used to prick to the finger and the blood will be collected in a capillary tube. This will then be immediately analyzed using a lactate analyzer.

RISKS AND BENEFITS:

Risks to the human subjects include hunger, fatigue, and irritability while on the low calorie diet. Muscle soreness and fatigue may result from the muscle performance test. There may be a slight risk of strains, sprains, tendonitis, and bursitis while performing the prescribed workouts, strength testing, and performance measures. However, these activities are regularly performed by these athletes so risks are minimized.

Risks of blood collection include temporary pain upon finger pricking and possible tenderness of the pricked finger after completion. One person experienced in these procedures will be performing all of the testing. Risks will be limited by use of rubber gloves, disinfection of the finger being pricked, and by following all OSHA regulations regarding blood sampling.

Benefits to the human subjects include having their percent of body fat calculated and knowledge of the effects of dietary supplements on performance and mood. The results of this study may directly help these athletes in future competition and in preparing workout sessions.

CONFIDENTIALITY/ANONYMITY:

Results of this study will remain confidential. Without written consent of each subject, the results of this research will not be released by the investigators to anyone other than persons working on the study. Names will be removed from the information provided by each subject; only a subject number will identify each weight lifter during data analysis and any written reports of the investigation. The researchers will be the only persons having access to the subject's identity.

CONSENT:

An informed consent form will be signed by each subject after he has read it in the presence of the investigator and asked any questions that he might have. Subject's will be informed that they are free to withdrawal at anytime during the course of this study without penalty.

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants
of Investigative Projects

Title of Project: Bodybuilders and Low Calorie Diets: The Effects of Dietary Supplementation on Muscle Endurance and Perception of Fatigue

Principle Investigators: Lynette Poland and Tina Randall, masters student directors; Janet Walberg-Rankin, faculty director

I. THE PURPOSE OF THIS RESEARCH/PROJECT

You are invited to participate in a study about the effects of dietary supplementation on the quality of a training session while an athlete is consuming a low calorie diet. This study involves experimentation for the purpose of:

1. determining if dietary supplements can affect muscle performance during weight lifting sessions.
2. determining if dietary supplements affect psychological status during training sessions.

This study involves 24 subjects.

II. PROCEDURES

The procedures to be used in this research are as follows:

1. You will be asked to consume a weight maintenance diet for 3 days. You will be asked to eat certain foods you provide for yourself. This will be based on foods you typically consume. It's purpose is to ensure that you are not gaining or losing body weight and that all subjects are consuming similar diets prior to the treatment.

2. Then, you will be asked to consume a low calorie diet for 4 days during which time food for your consumption will be provided to you each morning by the experimenters with specific directions for preparation. You will be requested to fill out food intake records during these four days. No other food can be consumed during this period.

3. A weight-lifting routine will be prescribed for you based on your strength and must be followed for a total of seven days (three days maintenance and four days of low calorie consumption). Required aerobic activities will consist of 30 minutes of stationary bicycling within 65-75% of your maximum heart rate each day of this study. You will be requested to fill out records of your workouts.

4. You will perform four total multiple-bout resistance exercises tests--two practice sessions, one test after the maintenance period, and one test after the diet treatment

period. The performance session will consist of a bench press test. You will lift seven sets on the bench press at 60% of your maximum strength. The first set will have 18 repetitions, the second will have 15, the third 12, the fourth 10, the fifth 8, the sixth 6, and the final set you will do repetitions until you cannot complete a full lift.

5. You will be given a liquid dietary supplement 15 minutes prior to each performance measurement.

6. You will fill out a mood questionnaire consisting of 65 questions (approximately 10-15 minutes required to complete) before and after each exercise performance measurement.

7. You will be asked to report your perception of effort sporadically throughout each performance measurement.

The time and conditions required for you to participate in this project are as follows:

1. Initial meeting for orientation and health screening; lasting approximately 60 - 90 minutes.

2. Daily recording of food intake and weightlifting routines.

3. Daily food pickup during the four day diet treatment period.

4. Two to three hours designed to determine maximum strengths of major muscle groups used for prescribing weightlifting routines.
5. Choosing pre-specified time for your workout (your own discretion) so that the investigators can do sporadic check-ins. 6. Four mornings--two practice sessions, one after the maintenance period, and one after the diet treatment period--during which time you will be asked to fill out questionnaires and perform your bench press test. These sessions will last approximately 1 hour each.
7. Before each of the mornings discussed in #6, consumption of a supplement 15 minutes prior to performance measures.
8. Your guarantee that you have not used any form of steroids within the past six months.

The possible risks or discomforts to you as a participant may be:
1. Hunger, fatigue, and irritability while on the four day low calorie diet.
2. Muscle soreness and fatigue from the muscle performance tests and strength tests. There is a slight risk of strains, sprains, tendonitis, and bursitis from the muscle performance tests, strength tests, and prescribed lifting workouts.

VI. APPROVAL OF RESEARCH

This project has been approved, as required, by the Institutional Review Board for projects involving human subjects at Virginia Polytechnic Institute and State University.

VII. SUBJECT'S RESPONSIBILITIES

I know of no reason I cannot participate in this study. I have the following responsibilities:

1. To advise the researchers of any pre-existing medical problems that may affect my participation, such as, but not limited to, diabetes, heart conditions, muscle, bone, or joint problems, and major organ malfunctions. Should you have any questions regarding a particular condition, please feel free to ask any investigator.
2. To advise the researchers of any medical problems that might arise in the course of this experiment, such as signs of strains, sprains, tendonitis, or bursitis; or any signs and/or symptoms of illness.
3. To refrain from the consumption of alcoholic beverages throughout the entire duration of the study.
4. To refrain from the consumption of caffeine and use of tobacco at least 4 hours prior to each muscle performance test.

Safeguards that will be used to minimize your risk or discomfort include:

1. A telephone is available which would be used to call the hospital for emergency service.
2. The investigators are trained in basic first aid and CPR.

III. BENEFITS OF THIS PROJECT

Your participation in the project will provide the following information that may be helpful:

1. Knowledge of benefits of dietary supplementation on your performance while eating low calorie diets.
2. Having your body fat percentage and body weight calculated.

No guarantee of benefits has been made to encourage you to participate.

You may receive a synopsis or summary of this research when completed.

IV. EXTENT OF ANONYMITY AND CONFIDENTIALITY

The results of this study will be kept strictly confidential. At no time will the researcher release the results of the study to anyone other than individuals working on the projects without your written consent. The

information you provide will have your name removed and only a subject number will identify you during analyses and any written reports of the research.

V. FREEDOM TO WITHDRAWAL

Your are free to withdrawal from this study at any time without penalty.

There may be the following circumstances under which the investigator may determine that you should not continue as a subject of this project:

1. Failure to comply with prescribed lifting sessions and/or diet regimens.
2. Illness.

5. To refrain from exercise 18 hours prior to each performance measure.

6. To adhere to the prescribed diets and workouts.

7. To refrain from any other dietary supplements and steroid use throughout the duration of this study.

VIII. SUBJECT'S PERMISSION

I have read and understand the informed consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project.

If I participate, I am free to withdraw at any time without penalty. I agree to abide by the rules of this project.

Signature of Participant:

_____

Signature of Investigator:

_____

Date: _____

Should I have any questions about this research or its conduct, I will contact:

Lynette Poland	961-0332
Investigator	
Tina Randall	552-7649
Investigator	
Janet Walberg-Rankin, Ph.D.	231-6355
Faculty Advisor	
Ernest Stout	231-9359
Chairman of the University Review Board	

MEDICAL HISTORY
Poland/Randall Thesis

** All information is private and confidential **

Name: _____

Address: _____

Home Phone: _____

Social Security Number: _____

Date of Birth: _____

Family Physician: _____

Physician's Address: _____

Physician's Phone Number: _____

Sex: Male ___ Female ___

I. Have you ever been diagnosed with or suffer from problems related to the heart, lungs, or circulatory system (i.e. - chest pain, shortness of breath, heart disease, hypertension, asthma)

YES ___ NO ___

If yes, please explain:

_____

_____

II. Have you ever been diagnosed with or suffer from problems relating to the skeletal/muscular system (i.e. - broken bones, bursitis, tendonitis, sprains, strains)

YES ___ NO ___

If yes, please explain:

_____

_____

III. Have you been treated by a physician for anything other than the common cold in the past six months?

YES ___ NO ____

If yes, please explain:

_____

_____

Do you have or have you been diagnosed with
Diabetes YES ___ NO ___
Anemia YES ___ NO ___
Periods of dizziness or fainting spells
YES ___ NO ___

List any medications (prescription and/or over-the-counter) you are now taking and their use:

_____

_____

List any allergies (including drugs):

_____

_____

Do you currently use any tobacco products (including smokeless)?
YES ___ NO ___
If yes, please describe:

_____

_____

Are you currently taking steroids? yes ___ no ___
Have you ever taken steroids? yes ___ no ___
If yes, please give dates and duration:

_____

Have you been under more stress than normal during the past six
months (i.e. - death in the family, moving homes)
YES ___ NO ___
If yes, please explain:

_____

_____

Please explain any other medical conditions that your consider important for us to know:

_____

_____

GENERAL DATA SHEET
Poland/Randall Thesis

Name: _____

Address: _____

_____

Home Phone Number: _____

Work Phone Number (if appropriate): _____

In an emergency, please contact: _____
Relationship: _____
Phone Number: _____

Please list your class schedule:
Monday Tuesday Wednesday Thursday Friday

Please list your work schedule (if appropriate):
Monday Tuesday Wednesday Thursday Friday Satur

Are there any other times during the week that you are unavailable?
Monday Tuesday Wednesday Thursday Friday Satur

Do you forsee leaving town any time during February or March?
Yes ___ No ____
If yes, please state dates:

_____

EXERCISE HISTORY/HABITS
Poland/Randall Thesis

Are you currently weightlifting? Yes ___ No ___

How many years: _____

How many days per week: _____

How many minutes does each lifting session typically last:

_____

Please decribe your rotation schedule:

_____

_____

_____

_____

_____

On the back of this page please describe what exercises you perform for each rotation in your cycle.

Where do you workout? _____

What type of equipment do you generally use?

_____

Have you ever participated in a bodybuilding competition?
Yes ___ No ___
If yes, please list them below:

Name	Dates	Finishing Place

Do you do any type of aerobic exercise? Yes ___ No ___

Please list the aerobic activities (e.g. - running, biking, swimming) you participate in and the frequency and duration of each:

_____

_____

_____

Do you participate in any other forms of exercise?
Yes ___ No ___
If yes, please list with the frequency and duration of each:

_____
_____
_____

Do you ever feel faint, dizzy, or nauseous while working out?
Yes ___ No ___
If yes, please explain circumstances and frequency:

_____
_____
_____

Do you have any conditions that would limit your participation in either the weightlifting or aerobic portion of this study (i.e. (i.e. - orthopedic injuries, time constraints, etc...)

_____
_____
_____

Have you ever been advised by a doctor not to engage in either weightlifting or aerobic activities? Yes ___ No ___
If yes, please explain:

_____
_____
_____

Do you see any reasons other than those listed above for which you should not participate in this study?
Yes ___ No ___
If yes, please explain:

_____
_____
_____

Do you have access to a stationary bicycle? Yes ___ No ___

DIET HISTORY
Poland/Randall Thesis

Name:

_____

Current Weight: _____

How long have you been at this weight? _____

Are you currently trying to gain/lose weight?
Yes ___ No ___
If so, state reason and duration:

_____

_____

If you have had a weight fluctuation within the past year, explain how and why it occurred:

_____

_____

_____

Number of meals you usually eat per day: _____

Do you ever drink alcoholic beverages? Yes ___ No ___
If yes, how many drinks per week? _____

Briefly explain your current diet regimen (i.e. - types of food you most commonly eat and drink):

_____

_____

_____

_____

_____

_____

Do you have any food allergies, please explain (BE SPECIFIC!):

_____

_____

_____

_____

_____

Are you currently taking any dietary supplements?
Yes ___ No ___
If yes, list and explain their use:

_____

_____

_____

Have you taken any dietary supplements within the last six months? Yes ___ No ___
If yes, list and explain their use:

Do you ever feel weak or faint when you haven't consumed an adequate amount of food? Yes ___ No ___

Do you feel you can complete this study knowing that you will probably not be consuming your usual amount of food?
Yes ___ No ___

Do you think you will have problems complying with the dietary regimen prescribed to you? Yes ___ No ___

Do you have a refrigerator to store any foods that may require refrigeration? Yes ___ No ___

94-030

REQUEST FOR APPROVAL OF
INVESTIGATION INVOLVING HUMAN SUBJECTS

Principal Investigator(s) Lynette Poland and Tina Randal(M.S. stud.) Janet Walberg Rankin (advisor) Department Health and Physical Ed

Project Title: Bodybuilders and low calorie diets: the effects of dietary supplementation on ~~muscle endurance and perception of fatigue~~

Source of Support: Departmental Research [X] Sponsored Research [ ] Proposal No. _____

1. The criteria for "expedited review" by the Institutional Review Board for a project involving the use of human subjects and with minimal risk* is one or more of the following. Please initial all applicable conditions and provide a substantiating statement of protocol.

[ ] a. Collection of:

1) hair or nail clipping in a non-disfiguring manner;
2) deciduous teeth;
3) permanent teeth if patient care indicates need of extraction.

[ ] b. Collection of excreta and external secretions: sweat, unicanulated saliva, placenta removed at delivery, amniotic fluid obtained at time of rupture of the membrane.

[ ] c. Recording of data from subjects 18 years or older, using noninvasive procedures routinely employed in clinical practice. Exemption does not include exposure to electromagnetic radiation outside the visible range.

[/] d. Collection of blood samples by ~~venipuncture~~ finger prick (not exceeding 150 ml 8 week period, and no more than twice a week) from subjects 18 years or older, in good health and not pregnant.

[ ] e. Collection of supra- and subgingival dental plaque and calculus, provided the procedure is no more invasive than routine scaling of the teeth.

[ ] f. Voice readings.

[X] g. Moderate exercise by healthy volunteers who are accustomed to this level of exercise

[ ] h. Study of existing data, documents, records, pathological specimens or diagnostic specimens.

[ ] i. Research on drugs or devices for which an investigational exemption is not required.

2. If the project involves human subjects who are exposed to "more than minimal risk" and are not covered by the criteria above (1 to 9), the IRB review must involve the full IRB board. Please check if the research involves more than minimal risk** __ and provide a substantiating statement of protocol.

3. Human subjects would be involved in the proposed activity as either: Minors and or Children*___, Fetuses___, Abortuses___, Pregnant Women___, Prisoners___, Mentally Retarded___, Mentally Disabled___.

Note that if children are involved in the research as human subjects, they may have to provide consent as well as their parents.

Whether or not the project may undergo "expedited review" or must be reviewed by the full Institutional Review Board, it is necessary that the required informed consent forms also be reviewed. These should be submitted with the proposal. However, if there is insufficient time to meet the sponsor's deadline, submittal can be delayed up to thirty days after submittal of the proposal without jeopardizing the IRB certification to the prospective sponsor.

*Minimal risk means that the risks of harm anticipated in the proposed research are not greater, considering the probability and magnitude, than those encountered in daily life or during performance of routine physical or psychological examinations or tests.

**Subject at risk is an individual who may be exposed to the possibility of injury as a consequence or participation as a subject in any research, development or related activity which departs from the application of those established and accepted methods necessary to meet his needs, or which increases the ordinary risks of daily life, including the recognized risks inherent in a chosen occupation or field of science.

This is to certify that the project identified above will be carried out as approved by the Human Subject Review Board, and will neither be modified nor carried out beyond the period approved below without express review and approval by the Board.

Janet Walberg Rankin 12-8-93 — Richard [illegible] 12/10/93

Principal Investigator Date — Departmental Reviewer Date

The Human Subjects Review Board has reviewed the protocol identified above, as it involves human subjects, and hereby approves the conduct of the project for 12 months, at which time the protocol must be resubmitted for approval to continue.

[signature] 2/8/94

Board Chairman, Authorized Reviewer Date

Appendix D

RAW DATA AND STATISTICAL ANALYSES

EXAMPLE OF WORKOUT ROUTINE

BREAKDOWN OF SUPPLEMENT

DIETARY STATISTICS

This data was analyzed to see if there was a significant difference among groups for intake during MAINT exchange diet.

Summary ANOVA for Caloric Intake During MAINT phase

Source	SS	df	MS	P
Group	249856	2	124927.9	.88
Error	1.4358^{07}	15	957250.6	
Total (Adj)	1.4608^{07}	17		

Summary ANOVA for *Protein Intake During MAINT phase

Source	SS	df	MS	P
Group	2978.9	2	2989.5	** .00
Error	255.6	15	17.038	
Total	6234.5	17		

*Protein intake is calculated as a percentage of total caloric intake.

** Duncan Multiple Range shows differences between CONT and experimental groups (CARB, PROT)

Summary ANOVA for *Fat Intake During MAINT phase

Source	SS	df	MS	P
Group	71.29	2	35.644	.39
Error	525.2	15	35.010	
Total	598.4	17		

*Fat intake is calculated as a percentage of total caloric intake.

Summary ANOVA for *Carbohydrate Intake During MAINT phase

Source	SS	df	MS	P
Group	6119.8	2	3059.9	**.00
Error	127.9	15	8.53	
Total	6247.8	17		

*Carbohydrate intake is calculated as a percentage of total caloric intake.

** Duncan Multiple Range Test shows that the CONT group was different from the experimental groups (CARB, PROT)

NOTE- EXPER phase was not analyzed because the subjects were given their food and had the same diets.

RAW DATA FOR AVERAGE CALORIC INTAKE (KCAL), % CARBOHYDRATE INGESTION, % PROTEIN INGESTION, and % FAT INGESTION DURING MAINTENANCE PHASE

SUBJ	GROUP	ENERGY	CARB	PROT	FAT
1*	CONT	3302	61	19	20
2*	CONT	5283	37	43	20
3*	CONT	1817	51	37	11
4	CONT	4411	13	49	38
5	CONT	1179	22	50	29
6	CONT	5313	19	64	17
7	CONT	2431	25	60	15
8	CONT	1828	17	63	20
9*	PROT	3911	61	15	23
10	PROT	2296	64	14	21
11	PROT	2732	57	16	27
12	PROT	2810	59	15	27
13	PROT	2879	63	14	22
14	PROT	2874	61	17	21
15	PROT	3380	66	18	17
16	CARB	2986	64	15	20
17	CARB	3151	63	16	21
18	CARB	3197	62	15	22
19	CARB	2145	66	17	17
20	CARB	2485	63	18	19
21	CARB	2107	67	22	12
22	CARB	3127	58	18	23

CONT= CONTROL GROUP
PROT= PROTEIN GROUP
CARB= CARBOHYDRATE GROUP

*= these subjects were dropped from analysis because they did not complete the designated 69 repetitions in sets 1-6.

DAILY WORKOUT ANALYSIS

The volume that each subject lifted during the daily workout was analyzed to determine if there were any difference among groups during the workout.

Summary T-Tesst for *Volume of Workout-
MAINT and EXPER Phases

	MAINT	EXPER
Mean	31759.23	27861.53
SEM	2946.61	3574.1
Equal Var. T-Value	.841447	.841447
Equal Var. Prob	.4063	.4063

* Volume per cycle= (wt*repD1 X wt*repD2 X wt*rep D3)
(weight in KG)

RAW DATA FOR WEIGHT LIFTING VOLUMES
(Kilograms lifted* repetitions)

*SUBJECT	GROUP	MAINT	EXPER
1*	CONT	58012	77272
2*	CONT	58012	77272
3*	CONT	17378	21699
4	CONT	15348	6894
5*	CONT	9986	0
6	CONT	27909	3211
7	CONT	6990	7539
8	PROT	37235	37287
9*	PROT	36308	36470
10	PROT	35845	25398
11	PROT	31815	29167
12	PROT	33617	32783
13	PROT	54590	52462
14	PROT	40605	36722
15	CARB	30398	30211
16	CARB	41227	40919
17	CARB	29687	31620
18	CARB	33426	33805
19	CARB	29012	30924
20	CARB	35661	34308
21	CARB	46556	40396

CONT= CONTROL GROUP
PROT= PROTEIN GROUP
CARB= CARBOHYDRATE GROUP

Values indicate three day totals for each phase (Day 1 legs/calves/biceps +Day 2 back/chest + Day 3 shoulders/triceps)

* these subjects were dropped from anlysis because they either did not complete the designated 69 repetitions in sets 1-6, or one subject data set was not available for analysis becuase this subject did not perform any exercises during this period.

BODY COMPOSITION ANALYSIS

Body weight was analyzed to determine if there was any significant difference among groups and time with body weight.

Summary ANOVA for BW (kg) among Group and Time

Source	SS	df	MS	F	P
Group	47.79	2	23.89	.09	.912
Test	27.49	2	13.75	.15	.862
Interaction (Group X Test)	175.22	4	43.81	.27	.894
Residual	8475.32	53	159.92		

Group- CONT, CARB, PROT
Test- Baseline, Pre-test, Post-test

Summary ANOVA for body fat among Group

Source	SS	df	MS	F	P
Group	20.7	2	10.4	.704	.5103
Residual	220.6	15	14.7		

Group- CONT, CARB, PROT

RAW DATA FOR BODY WEIGHT (KG)

SUBJECT	GROUP	BASELINE	PRE TEST	POST TEST
1*	CONT	148	145.5	147
2*	CONT	95	96.9	96.4
3*	CONT	64.6	65	65.7
4	CONT	90.2	88.2	88.2
5	CONT	63.3	74	74.9
6	CONT	75.9	74.6	75
7	CONT	89.4	88.8	89.5
8	CONT	79.6	80	80.4
9*	PROT	70.5	68.7	65.1
10	PROT	75.2	75.9	74.3
11	PROT	80.8	80.5	79.4
12	PROT	74.2	73.5	71.3
13	PROT	110	110.4	108
14	PROT	74.6	74.7	73
15	PROT	90	90.7	89
16	CARB	63.1	62.8	62.3
17	CARB	87	83.7	86.8
18	CARB	67.4	67.7	67.5
19	CARB	88	85.7	84.7
20	CARB	100	99.1	100
21	CARB	83	83.4	82.5
22	CARB	90.5	91.5	88.2

CONT= CONTROL GROUP
CARB= CARBOHYDRATE GROUP
PROT= PROTEIN GROUP

*= these subjects were dropped from analysis because they did not complete the designated 69 repetitions in sets 1-6.

RAW DATA FOR
PERCENT BODY FAT

SUBJ	GROUP	BODYFAT %
1*	CONT	28.8
2*	CONT	11.6
3*	CONT	7
4	CONT	12.5
5	CONT	9.8
6	CONT	7.6
7	CONT	17.4
8	CONT	14.3
9*	PROT	9.6
10	PROT	13.4
11	PROT	16
12	PROT	9.8
13	PROT	10.5
14	PROT	14.3
15	PROT	13.4
16	CARB	11.8
17	CARB	4.7
18	CARB	11.6
19	CARB	4.7
20	CARB	17.4
21	CARB	8.9
22	CARB	14.3

CONT= CONTROL
PROT= PROTEIN
CARB= CARBOHYDRATE

*= these subjects were dropped from analysis because they did not perform the designated 69 repetitions in sets 1-6

ANALYSIS OF FLAT BENCH PRESS DATA

Note- 4 subjects were dropped from original pool of 22 because they did not complete the designated 69 repetitions asked of them during the flat bench press test.

Summary ANOVA for *Volume in Last Set

Source	SS	df	MS	F	P
Group	85400	2	42700	.183	.835
Subject	3508015	15	233868	.366	
Test	7890	2	3645	.366	.697
Interaction (group X test)	105916	4	26479	2.456	.067
Residual	4027720	30			

* Volume= Total reps lifted in last set X wt. lifted (KGS.)

Group- CONT, PROT, CARB
Test- Baseline, Pre-test, Post-test

Summary Advanced ANOVA for Repetitions Performed in Last Set of Test

Source	SS	df	MS	F	P
Group	136.14	2	68.07	1.29	.305
Subject	793.12	15	52.87		
Test	5.09	2	2.55	1.06	.358
Interaction (group X test)	22.13	4	5.53	2.31	.081
Residual	71.83	30	19.37		

Group- CONT, PROT, CARB
Test- Baseline, Pre-Test, Post-Test

RAW DATA FOR ENDURANCE TEST: FLAT BENCH PRESS VOLUME
(kilograms lifted * total repetitions performed in set 7)

SUBJECT	GROUP	BASELINE	PRETEST	POSTTEST
1*	CONT	900	800	800
2*	CONT	909	636	818
3*	CONT	1018	727	727
4	CONT	924	1001	924
5	CONT	1088	1088	1024
6	CONT	1409	1409	1278
7	CONT	1100	660	825
8	CONT	952	748	952
9*	PROT	1314	1022	584
10	PROT	1144	1045	1045
11	PROT	1596	1596	1525
12	PROT	950	850	850
13	PROT	949	1022	730
14	PROT	825	975	975
15	PROT	1250	1050	1150
16	CARB	950	1000	1050
17	CARB	955	955	1152
18	CARB	975	900	975
19	CARB	857	804	737
20	CARB	1491	1491	1491
21	CARB	1507	1780	1780
22	CARB	712	890	1157

CONT= CONTROL GROUP
PROT= PROTEIN GROUP
CARB= CARBOHYDRATE GROUP

*= these subjects were dropped from analysis because they did not complete the designated 69 repetitions in sets 1-6.

RAW DATA FOR NUMBER OF REPETITIONS PERFORMED IN SET 7 OF FLAT BENCH PRESS TEST

SUBJECT	GROUP	BASELINE	PRETEST	POSTTEST
1*	CONT	9	8	8
2*	CONT	10	7	9
3*	CONT	14	10	10
4	CONT	12	13	12
5	CONT	17	17	16
6	CONT	20	20	18
7	CONT	20	12	15
8	CONT	14	11	14
9*	PROT	18	14	8
10	PROT	22	20	20
11	PROT	26	26	25
12	PROT	19	17	17
13	PROT	13	14	10
14	PROT	11	13	13
15	PROT	25	21	23
16	CARB	19	20	21
17	CARB	15	15	18
18	CARB	13	12	13
19	CARB	13	12	11
20	CARB	16	16	16
21	CARB	17	20	20
22	CARB	8	10	13

CONT= CONTROL GROUP
CARB= CARBOHYDRATE GROUP
PROT= PROTEIN GROUP

*= these subjects were dropped from analysis because they did not complete the designated 69 repetitions in sets 1-6.

RAW DATA FOR VOLUME PERFORMED DURING THE PRACTICE TRIAL

SUBJ	GROUP	PRACTICE VOLUME
1*	CONT	7410
2*	CONT	6455
3*	CONT	5527
4	CONT	5796
5	CONT	5346
6	CONT	5496
7	CONT	4855
8	CONT	5455
9*	PROT	6259
10	PROT	4804
11	PROT	5584
12	PROT	4200
13	PROT	5527
14	PROT	5925
15	PROT	4350
16	CARB	4250
17	CARB	5473
18	CARB	5925
19	CARB	5273
20	CARB	8293
21	CARB	4391
22	CARB	3559

Volume= total reps X kg lifted

*= these subjects were dropped from analysis because they did not complete the designated 69 repetitions in sets 1-6

Subject Sample of Daily Weightlifting Volumes

Subject 20
Maintenance Phase

3/17/94- Legs/calves/biceps

EXERCISE	SET 1	SET 2	SET 3	SET 4	TOTAL
Leg press	1063	1063	1004	1004	4417
Leg extension	1791	1654	1791		5236
Leg curls	640	640	591	541	3307
Calf raises	413	413	413	413	1654
Preacher curl	669	669	630		1969
Dumbbell curl	295	295	295	295	1181
				TOTAL	17764

3/18/94- Back/chest

EXERCISE	SET 1	SET 2	SET 3	SET 4	TOTAL
Pull-ups	866	866	780		2512
Lat pull-downs	827	827	827	827	3308
Bent-over rows	827	827	732	661	3032
incline bench	945	945	945		2935
dips	2598	2598	2598		5197
				TOTAL	16887

3/19/94- Shoulders/triceps

EXERCISE	SET 1	SET 2	SET 3	SET 4	TOTAL
Military press	650	650	650		1949
Side lat. raise	148	148			295
Front lat. raise	148	148			295
Rear lat. raise	248	230			478
Shrugs	3240	2991			6230
Tricep pushdown	630	630			1260
tricep kickbacks	110	110	102	102	425
tricep extension	413	413			827
				TOTAL	11760

TOTAL WORKLOAD FOR MAINT= 46406

Note- Calculations are in workload (kg wt. lifted X reps)

Experimental Phase

4/21/94-Legs/calves/biceps

EXERCISE	SET 1	SET 2	SET 3	SET 4	TOTAL
Squats	1205	1104	1104	1104	4518
Leg press	2067	2067	2067		6201
Leg extension	2067	2067	2067	2067	3307
Leg curls	640	640	541	591	2411
calf raises	413	441	413	413	1681
preacher curl	630	630	630		2008
dumbbell curl	335	335	315	295	1280
				TOTAL	2141

4/22/94- Back/chest

EXERCISE	SET 1	SET 2	SET 3	SET 4	TOTAL
Pull-ups	874	874	780		2528
Lat pull-down	827	827	827	827	3307
Bent-over rows	717	661	661	551	3031
Incline bench	945	945	882		2772
Dips	1299	1299	1299		2598
				TOTAL	14236

4/34/94- Shoulders/triceps

EXERCISE	SET 1	SET 2	SET 3	SET 4	TOTAL
Military press	476	476	433		1386
Side lat.	148	148			295
Front lat.	148	148			295
Rear lat.	230	248			478
Shrugs	2976	2976			1260
Tricep pushdown	630	630			1260
Tricep kickback	118	118	118	118	472
Tricep extension	413	413			827
				TOTAL	40396

Total workload EXPER phase= 76038

SUMMARY OF SUPPLEMENTS

Carbohydrate Supplement

Kroger's Sport Shot	
Serving	8 oz.
kcal	70
protein	0
Carbohydrate	18 g
fat	0 g
sodium	110 mg
potassium	15 mg

Ingredients: high fructose corn syrup, citric acid, sodium benzoate, natural flavors, sodium chloride, sodium citrate, monopotassium phosphate, gum arabic, brominated vegetable oil, ester gum, sodium chloride, dyes

Protein Supplement

Challenge's 95% Isolated Soy Protein	
Serving	1 ounce
calories	100
protein	24 g
carbohydrate	0
fat	0
sodium	275 mg
potassium	75 mg

Ingredients: Supro (isolated soy protein), lecithin, aspartame, papain, and natural flavors

References

Bangsbo, J., Norregaard, L., & Thorsoe, F. (1992). The effect of a carbohydrate diet on intermittant exercise performance. International Journal of Sports Medicine, 13, 152-157.

Bergstrom, J., Hermansen, L., Hultman, E., and Sultin, B. (1967). Diet, muscle glycogen and physical performance. Acta Physiological Scandinavia, 71, 140-150.

Burke, L.M., Collier, G. R., Hargreaves, M. (1993). Muscle glycogen storage after prolonged exercise: Effect of the glycemic index of carbohydrate feedings. Journal of Applied Physiology, 1019-1023.

Bonen, A., Malcolm, S. A., Kilgour, R. D., MacIntyre, K. P., and Belcastro, A. N. (1981). Glucose ingestion before and during intense exercise. Journal of Applied Physiology, 766-771.

Burke, L. M., and Read, R. S. (1993). Dietary supplements in sport. Sports Medicine, 15 (1), 43-65.

Cheetham, M. E., Boobis, L. S. Brooks, S., and Williams, C. (1986). Human muscle metabolism during sprint running. Journal of Applied Physiology, 54-60.

Coggan, A., and Coyle, E. (1988). Effect of carbohydrate feedings during high intensity exercise. Journal of Applied Physiology, 65, 1703-1709.

Cole, K. J., Grandjean, P. W., Sobsaak, R. J., and Mitchell, J. B. (1993). Effect of carbohydrate composition on fluid balance, gastric emptying, and exercise performance. International Journal of Sport Nutrition, 3, 408-417.

Coyle, E. F., Coggan, A. R., Hemmert, M. K., Ivey, J. (1986). Muscle glycogen utilization during prolonged strenuous exercise when fed carbohydrate. American Psysiological Society, 165-172.

Coyle, E. F., Coggan, A. R., Hemmert, M. K., Lowe, R.

C., Walters, T. J. (1985). Substrate usage during prolonged exercise following pre-exercise meal. Journal of Applied Physiology, 59, 429-433.

Costill, D. (1988). Carbohydrates for exercise: dietary demands for optimal performance. International Journal of Sports Medicine, 9, 1-18.

Coyle, E. F., Hagberf, J. M., Hurley, B. F., Martin, W. H., Ehsani, A. A., and Holloszy, J. O. (1983). Carbohydrate feeding during prolonged strenuous exercise can delay fatigue. American Physiological Society, 230-235.

Davis, P. G., and Phinney, S. D. (1990). Differential effects of two very low calorie diets on aerobic and anaerobic performance. International Journal of Obesity, 56, 109-114.

Dudley, G. A. (1988). Metabolic consequences of resistive-type exercise. Medicine and Science in Sport and Exercise, 20, S158-S161.

Elliot, D., Goldberg, L., Keohl, K., & Catlin, D. (1987). Characteristics of anabolic-androgenic steriod free competitive male and female bodybuilders. Physician and Sports Medicine, 15, 169-178.

Fielding, R. A., Costill, D. L., Fink, W. J., King, D. J., Hargreaves, M., and Kovaleski, J. (1985). Frequency of carbohydrate feedings and muscle glycogen use. Medicine and Science in Sports and Exercise, 17, 472-476.

Exchange list for meal planning, The American Diabetes Association, 1989.

Freischlag, J. (1984). Weight loss, body composition, and health of high school wrestlers. Physician and Sports Medicine, 12, 121-126.

Gaitanos, G. C., Williams, C., Boobis, H., and Brooks, S. (1993). Human muscle metabolism during intermittent maximal exercise. Journal of Applied Physiology, 712-719.

Greenhaff, P., Gleeson, M., & Maughan, R. (1987).

The effects of dietary manipulation on blood acid-base status and the performance of high intensity exercise. European Journal of Applied Physiology, 56, 331-337.

Greenhaff, P., Gleeson, M., & Maughan, R. (1988). The effects of a glycogen loading regime on an acid-base status & blood lactate concentrations before and after a fixed period of high intensity exercise in man. European Journal of Applied Physiology, 57, 254-259.

Greenhaff, P., Gleeson, M., & Maughan, R. (1988). The effects of diet on muscle pH and metabolism during high intensity exercise. European Journal of Applied Physiology, 57, 531-539.

Greenhaff, P., Gleeson, M., & Maughan, R. (1988). Diet induced metabolic acidosis and the performance of high intensity exercise in man. European Journal of Applied Physiology, 57, 583-590.

Grunewald, K. K. and Bailey, R. S. (1993). Commercially marketed supplements foe bodybuilding athletes. Sports Medicine, 15 (2), 90-103.

Hargreaves, M., Costill, D., Coggan, A., Fink, W., and Nishibata, I. (1984). The effects of carbohydrate feedings on muscle glycogen utilization and exercise performance. Medicine and Science in Sports and Exercise, 16, 219-222.

Hickson, J., Johnson, T., Lee, W., and Sidor, R. (1990). Nutrition and the precontest preparation of a male bodybuilder. Journal of the American Dietics Association, 90(2), 264-267.

Horswill, C., Hickner, R., Scott, J., Costill, D., and Gould, D. (1990). Weight loss, dietary carbohydrate modifications, and high intensity physical performance. Medicine and Science in Sports and Exercise, 22 (4), 470-476.

Horton, E. S. (1982). Effects of low energy diets on work performance. The American Journal of Clinical Nutrition, 35, 1228-1233.

Housh, T. J., Johnson, G. O., McDowell, S. C., Housch,

D. J., and Pepper, M. L. (1990). The relationship between anaerobic running capacity and peak plasma lactate. The Journal of Sports Medicine and Physical Fitness, 32 (2), 117-122.

Ivy, J. L., Miler, W., Dover, V., Goodyear, L.G., Sherman, W. M., Farrell, S., and Williams, H. (1983). Endurance improved by ingestion of a glucose polymer supplement. Medicine and Science in Sports and Exercise, 15, 466-471.

Ivy, J. L., Yaspelkis, B. B., Patterson, J. G., Anderla, P. A., and Ding, Z. (1993). Carboydrate supplementation spares muscles glycogen during variant intensity exercise. Journal of Applied Physiology, 1477-1485.

Jacobs, I. (1967). Lactate concentraiton after short, maximal exercise at various glycogen levels. Acta Physiological Scandinavian, 71, 140-150.

Jacobs, I. (1981). Lactate concentration after short, maximal exercise at various glycogen levels. Acta Physiological Scandinavian, 111, 465-469.

Katz, A., Broberg, S., Sahlin K., Ans Wahren, J. (1981). Leg glucose uptake during maximal exercise in humans. American Journal of Physiology, 251, E65-E70.

Keith, R. E., O'Keefee, K. A., Blessing, D. L., Wilson, G. D. (1991). Alterations in dietary carbohydrate, protein, and fat intake and mood state in trained female cyclists. Medicine and Science in Sports and Exercise, 23, 212-218.

Keul, J., Hataalambie, G., Bruder, M., and Gottstein, H. (1978). The effect of weight lifting exercise on heart rate and metabolism in experienced weightlifters. Medicine and Science in Sports and Exercise, 10, 13-15.

Kleiner, S. M., Bazzarre, T. L., and Ainsworth, B. E. (1994). Nutritional status of nationally ranked elite bodybuilders. International Journal of Sports Nutrition, 4, 54-69.

Kleiner, S. M., Calabrese, L. H., Fieder, K. M.,

Naito, H. K., and Skibinski, C. I. (1989). Dietary influences on cardiovascular disease risk in anabolic steriod -using and nonusing bodybuilders. Journal of the American College of Nutrition, 8, 109-119.

Lambert, C. P., Flynn, M. G., Boone, J. B., Michaud, T. J., Rodriguez-Zayas, J. (1991). Effects of carbohydrate feeding on muliple-bout resistance exercise. Journal of Applied Sports Science Research, 5 (4), 192-197.

Lavoie, J. M., Bonneau, M. C., Roy, J. Y., Brisson, G. R., Helie, R. (1987). Effects of dietary manipulations on blood glucose and hormonal responses following supramaximal exercise. European Journal of Applied Physiology, 56, 109 -114.

Lugo, M., Sherman, W. M., Wimer, G. S., and Garleb, K. (1993). Metabolic responses when different forms of carbohydrate energy are consumed during cycling. International Journal of Sport Nutrition 3, 198-207.

Manore, m., Thompson, J., and Russo, M. (1993). DIet and exercise strategies of a world-class bodybuilder. International Journal of Applied Physiology, 46, 211-219.

Mason, W. L., McConnel, G., and Hargreaves, M. (1993) Carbohydrate ingestion during exercise: liquid versus solid feedings. Medicine and Science in Sports and Exercise, 25, 966-969.

Maughan, R., and Poole, D. (1981). The effects of a glycogen loading regime on the capacity to perform anaerobic exercise. European Journal of Applied Phyiology, 60 (4), 1164-1169.

McCartney, N., Spriet, L. L., Heigenhauser, G., Kouralchik, J., Sutton, J., and Jones, N. (1986). Muscle power and metabolism in maximal intermittant exercise. Journal of Applied Physiology, 60 (4), 1164-1169.

McMurray, R. G., Proctor, C. R., and Wilson, W. L. (1991). Effect of caloric deficit and dietary manipulation on aerobic exercise. International Journal of Sports Medicine, 12, 167-172.

McRussell, D., Leiter, L. A., Whitwell, J., Marliss,

E. B., and Jeejeebhoy, K. N. (1983). Skeletal muscle function during hypocaloric diets and fasting: A comparison with standard nutritional assessment parameters. The American Journal of Clinical Nutrition, 37, 133-138.

McRussell, D., Walker, P. M., Leiter, L. A., Sima, A., Tanner, W. K., Milkle, D. A., Whitwell, J., Marliss, E. B., and Jeejeebhoy, K. N. (1984). Metabolic and structural changes in skeletal muscle during hypocaloric dieting. The American Journal of Clinical Nutrition, 39, 503-513.

Melby, C. Scholl, C., Edwards, G., Bullough, R. (1993). Effect of acute resistance exercise on post exercise energy expenditure and resting metabolic rate. Journal of Applied Physiology, 1847-1853.

Millard-Stafford, M. L., Cureton, K. J., Ray, C. A. (1988). Effect of glucose polymer diet supplement on responses to prolonged sucessive swimming, cycling, and running. European Journal of Applied Physiology, 58, 327-333.

Murdoch, S. D., Bazzarre, T. L., Snider, I. P., and Goldfarb, A. H. (1993). Differences in the effects of carbohydrate food form on endurance performance to exhaustion. International Jouranl of Sports Nutrition, 3, 41-54.

Neuffer, P., Costill, D., Flynn, M., Kirwan, J., Mitchell, J., and Houmard, J. (1987). Improvements in exercise performance: effects of carbohydrate feeding and diet. Journal of Applied Physiology, 62, 983-968.

Newton, L. E., Hunter, G., Bammon, M., Roney, R. (1993). Changes in psychological state and self-reported diet during various phases of training in competitive bodybuilders. Journal of Strength and Conditioning Research, 7 (3), 153-158.

Pascoe, D., Costill, D., Fink, W., Robregs, R., and Zachwieja, J. (1993). Glycogen resynthesis in skeletal muscle following resistance exercise. Medicine and Science in Sports and Exercise, 25, 349-362.

Russell, D., Walker, P., Leiter, L., Sima, A., Tanner, W., Mickle, D., and Jeejeebhoy, K. (1984). Metabolic and structural changes in skeletal

muscle during hypocaloric dieting. American Journal of Clincial Nutrition, 39, 503-513.

Sandoval W. M., and Heyward, V. (1991). Food Selection patterns of bodybuilders. International Journal of Sport Nutrition, 1, 61-68.

Saris, W. M., Goodpaster, B. H., Jeukendrup, A. E., Browns, F., Halliday, D., and Wagenmakers, J. M. (1993). Exogenous carbohydrate oxidation from different carbohydrate sources during exercise. Journal of Applied Physiology, 2168-2172.

Scott, C., Carpenter, R., Taylor, A., and Gordon, N. (1991). Effect of a macronutrient composition of an energy-restrictive diet on maximal muscle performance. Medicine and Science in Sports and Exercise, 814-818.

Sherman, W. M., Costill, D. L., Fink, W. J., and Miler, J. M. (1981). Effect of exercise-diet manipulation on muscle glycogen and its subsequent utilization during performance. International Journal of Sports Medicine, 2, 114-118.

Sherman, W. M., Peden, M. C., and Wright, D. A. (1991). Carbohydrate feedings one hour before exercise improves cycling performance. American Journal of Clincal Nutrition, 54, 866-870.

Stone, M., and O'Bryant, H. (1987). Weight Training: A Scientific Approach, Minneapolis, MN: Burgess International Group.

Tsintzas, K., Liu, R., Williams, C., Cambell, I., and Gaitanos, G. (1993). The effects of carbohydrate ingestion on performance during a 30 kilometer race. International Journal of Sport Nutrition, 3, 127-139.

Walberg, J., Ruiz, V., Tarlton, S., Hinkle, D., Thye, F. (1988). Exercise capacity and nitrogen loss during a high or low carbohydrate diet. Medicine and Science in Sports and Exercise, 20, 35-43.

Weissman, C., Goldstein, S., Askanzi, J., Rosenbaum, S., Milic-Emili, J., and Kinney, J. M. (1986). Semi-starvation and exercise. Journal of Applied Physiology, 2035-2039.

Yaepelkis, and Ivey (1991). Effect of carbohydrate supplementation an dwater on exercise metabolism in the heat. Journal of Applied Physiology, 71, 680-687.

Zachwieja, J. J., Costill, D. L., Fink, W., J. (1993). Carbohydrate ingestion during exercise. Effects on muscle glycogen resynthesis after exercise. International Journal of Sport Nutrition, 3, 418-430.

VITA

Lynette Charlene Poland was born to Charles and Betty Poland on Feburary 23, 1969 in Leesburg, Virginia. She graduated in June of 1987 from Broad Run High School and from there went to Virginia Tech to complete her degree in Exercise Science in May of 1992.

Before completion of her thesis she was awarded $300 in research money for this project through the Graduate School. She plans to graduate from Virginia Tech in May 1994, with a master's degree in Cardiac Rehabilitation and Adult Fitness.

Lynette Charlene Poland