THE EFFECT OF DIFFERENT LEVELS OF DEXTROSE INTAKE ON ENDURANCE RUNNING

By

PAUL SHIMON
B.S., Texas A&M University, 1970

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Health, Physical Education and Recreation

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1975

Approved by:

William B. Zuti
Major Professor

ACKNOWLEDGEMENTS

I would like to express sincere gratitude to Dr. William Zuti for his assistance and guidance in this study. Appreciation is extended to Dr. Charles Corbin for his encouragement and assistance. I would like to thank Dr. John Merriman for his generous aid and insight. Thanks also to Dr. Joe Smith for his help and assistance with graphs and Dr. Ken Kemp for his assistance in statistical analysis.

Acknowledgement goes to Dr. Larry Noble for his advise and Dr. John Spangler for his encouragement. Thanks also to Steve White, Mike Wittlieff and Pat Murray for their help in the collection of data. Appreciation is extended to the Cramer Company for their generous supply of Dextrose used in this study.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Chapter I

INTRODUCTION

The distance runners performance is influenced by many factors; training, weather, and natural ability to name a few. Coaches and athletes are especially concerned with establishing techniques which will improve endurance performance. There have been an abundant number of athletes who have claimed special diets have helped them be what they are today. For example, runners have claimed that a colorless special drink containing electrolytes called ERG had a great deal to do with improving their endurance. Recently a technique has come into favor with distance runners, in events exceeding 60 minutes, namely, "carbohydrate loading". Carbohydrate loading is done by increasing normal glycogen storage.

Muscle glycogen is the major fuel used by the body during exercise. Normally, the greater the muscle glycogen content during exercise, the longer the individual's ability to sustain prolonged endurance activity. Consumption of carbohydrates increases the muscle glycogen. A number of studies (9, 10, 11, 22, 26, 29, 33, 34) have been made to evaluate the effects of loading carbohydrates (storing muscle glycogen) on performing prolonged exercise.

Those favoring the carbohydrate loading regimen suggest first depleting the glycogen stores in the body by reducing carbohydrate intake to a minimum and consuming fats and proteins in their place. Further depletion of the glycogen stores is accomplished by exercising the muscles which are going to be used in competition. The purpose of depleting the glycogen stores through dietary and exercise control is to set the exercised muscles up for storing. The glycogen stores will be low when heavy exercise and a reduced carbohydrate diet have been followed for several days. The carbohydrate loading phase follows for the next few days until competition, as carbohydrates are added to the normal diet, enabling the muscles to store more fuel glycogen, when the carbohydrates are added. During the loading phase of the diet, exercise is greatly reduced in order to allow retention of the glycogen in the muscles, which was previously depleted through exercise.

THE NEED FOR THE STUDY

There are a large number of distance runners currently using carbohydrate loading regimens prior to competition, as stated in several nationally published magazines, namely Runner's World and Sports Illustrated. There have been a number of studies done on the effects of carbohydrate loading regimens; however, none have been done evaluating the levels of carbohydrate supplement added to a normal diet after depletion.

STATEMENT OF THE PROBLEM

The purpose of this study was to determine which of the following diet and exercise regimens was most efficient through reduction of heart rate, requirement of less oxygen consumption and increase of respiratory quotient during performance of a sustained 90 minute treadmill run. This consisted of 1) A normal diet which was seven days of recorded dietary intake preceding the controlled treadmill run, 2) a regimen consisting of three days of carbohydrate depletion and 60 minutes of running per day to further deplete stores of glycogen, followed by three days of normal diet plus 500 Calories of Dextrose and no running, 3) a regimen consisting of three days of carbohydrate depletion and 60 minutes of running per day to further deplete stores of glycogen, followed by three days of normal diet plus 1000 Calories of Dextrose and no running.

LIMITATIONS OF THE STUDY

Certain limitations were present in this study and should be pointed out to the reader:

1) Activity and dietary regimen were followed at home by the subjects and may have varied slightly between testing sessions.

2) There was the possibility of the subjects becoming more effecient on the treadmill between testing sessions.

3) The amount of sleep, work, and rest that the individual received may affect heart rate; however, activity was recorded in order for the subjects to have periods between testing sessions vary as little as possible.

4) The daily routine of subjects prior to testing may vary which may produce changes in resting heart rates; however, subjects rested standing for five minutes prior to physiological testing.

5) Subjects ran at approximately 50% of their maximum oxygen uptake (VO_2) therefore; this study is limited to rates of less than 50% maximum VO_2.

DEFINITIONS OF TERNS

Carbohydrates

Primarily sugars and starches which, when broken down by enzymes are converted to glycogen which is stored in three areas; 1) in blood as blood glucose, 2) in the liver as liver glycogen and 3) in the muscles as muscle glycogen.

Depletion of Carbohydrates

The initial phase of the dietary regimen, namely the first three days, in which a bare minimum of carbohydrates are consumed, maximum consumption should not exceed 50 Calories.

Dextrose

A sugar derived synthetically from starch, which in this study were consumed orally in tablet form by subjects as the carbohydrate supplement added to the normal diet following three days of carbohydrate depletion. In this study the Dextrose was produced commercially by the Cramer Company.

Dietary Regimen

In this study refers to three days of depletion of carbohydrates, then three days of adding carbohydrates in the form of Dextrose to the normal diet.

Glycogen

Rich source of energy supply, in this study refers to carbohydrate stores in the working muscles.

Loading Carbohydrates

Phase of the dietary regimen, specifically the second three days, in which either 500 or 1000 Calories of Dextrose are added to the normal diet.

Normal Diet

In this study refers to 7 days of recorded dietary intake preceding the control treadmill run. This diet was also followed during the loading phase of the diet.

Oxygen Consumption (VO_2)

Volume of oxygen extracted from the inspired air expressed in liters per minute which increases roughly linearly with an increase in work load.

Respiratory Quotient (RQ)

RQ is the ratio of carbon dioxide volume produced, divided by the oxygen volume utilized, expressed as a percent which shows that participation of the fat and carbohydrate metabolism. An RQ of 1.00 would mean carbohydrates are being burned, a .85 would mean 50% fat and 50% carbohydrate are being burned and an RQ of .70 would mean fat is being burned as fuel. The caloric value of oxygen varies with respiratory quotient and is not taken into consideration; at most this represents a seven percent difference.

Standard Temperature Pressure, Dry (STPD)

STPD is the value which is used to express the volume of oxygen extracted at $0^{o}C$, 760 mm HG from the inspired air volume corrected from ambient air and expressed in liters per minute.

Chapter II

REVIEW OF LITERATURE

This chapter reviews the research related to carbohydrate loading. Studies are presented which are related to carbohydrate loading diets and activity procedures preceding physiological testing and physiological parameters studied during testing, specifically heart rate, oxygen consumption, respiratory quotient and overall performance. The studies will include two main areas: 1) studies examining the effect of carbohydrate intake on performance, 2) studies illustrating the effect of depletion prior to carbohydrate loading.

Effect of Carbohydrate Intake on Endurance Performance

The main fuel utilized during exercise is muscle glycogen, which is derived from the consumption of carbohydrates, (5, 26, 38) and plays an increasingly important role as duration of work or exercise increases. Muscle glycogen is especially important in those muscles involved in continuous prolonged endurance, as it is the most efficient fuel; however, glycogen cannot be stored in the muscles for any length of time since working muscles become depleted of glycogen following exercise. Carbohydrates are essential to the diets of athletes desiring maximal performance in sporting events involving duration, where large quantities of the efficient fuel glycogen are employed, such as long-distance bicycle racing, cross-country skiing and long-distance running (6, 15, 16, 20, 24).

A study which points out what elimination of muscle glycogen does to performance was conducted by Pernow and Saltin (35), in which four healthy male subjects worked for 1-1.5 hours with one leg until exhaustion, after one hour of rest identical work was performed with the other leg. The subjects were then administered a low carbohydrate diet and the experimental procedure was repeated. The capacity for prolonged work was reduced when on the low carbohydrate diet, with work load reduced from 788 KPM to 588 KPM and work time reduced from 55 minutes to 28 minutes. The mean RQ was .97 for the left leg and .96 for the right leg on normal diet, after the reduced carbohydrate diet it was .77 and .84 for the left and right leg respectively. The investigators found that by reducing carbohydrates and lowering muscle glycogen that the ability to perform prolonged exercise was seriously impaired.

The relationship of carbohydrates to endurance performance was demonstrated by Christensen and Hansen (13), who showed that the feeding of a carbohydrate-rich diet for several days enabled subjects to perform heavy exercise twice as long as on a normal diet pedaling at the same workload. A low carbohydrate diet in which less than five percent of the subject's diet was derived from carbohydrates had the effect of decreasing the subject's ability to perform heavy exercise. It was concluded that there is a severe restriction of the capacity for prolonged exercise when carbohydrates are excluded from the diet.

A similar study was conducted by Bergstrom et al (10), who tested nine physical education students. These subjects worked to exhaustion at 75% of their maximal oxygen uptakes on bicycle ergometers. Subjects were tested three times, once on a normal diet, once on a fat-plus-protein diet and once on a predonimantly carbohydrate diet. Heart rates and respiratory quotients were taken at rest, after 30 minutes and at the end of work; differences for the three diets' heart rate were small and insignificant, however RQ averaged .81 for the normal diet, .74 for protein and fat diet and .94 for the carbohydrate diet. The average work time was less (59 minutes) for the fat and protein diet than either the normal diet (126 minutes) or the high carbohydrate diet in which subjects averaged 189 minutes for the bicycle ergometer ride. It was concluded that the glycogen content of the muscles was a determinant for the capacity to perform prolonged work.

Another investigation involving muscle glycogen was conducted in regard to severity of work and type of diet by Pruett (36). Nine healthy men aged 22 to 33 were tested on three diets each consisting of 3000 Calories. The standard diet consisted of 72 grams of protein, 100 grams of fat and 420 grams of carbohydrate. The high fat diet was 72 grams of protein, 200 grams of fat and 180 grams of carbohydrate. The high carbohydrate diet was 72 grams of protein, 30 grams of fat and 620 grams of carbohydrate. The exercise regimen consisted of riding a bicycle for 45 minutes, resting for 15 minutes, then running on a treadmill for 15 minutes until six repetitions of this were completed or exhaustion ensued. No heart rates were reported; however, sample air was taken at .5 hours of work and analyzed for O_2, CO_2, and RQ in order to determine the severity of load and assess percentage of carbohydrates and fat utilized during each exercise period. The average contribution of carbohydrates to total energy at 50% max. VO_2 was 40% on the standard diet, 35% on the high fat diet and 50% on the carbohydrate diet. The conclusion drawn for this study was that glycogen stores in the muscles may be the major limiting factor in prolonged exhaustive work.

Hermansen (24) studied the effects of glycogen on prolonged work by testing 10 trained and 10 untrained men on a bicycle ergometer, averaging 77% of their max. VO_2. Subjects rode for 20 minutes, then rested 15 minutes and repeated this until exhaustion occured. The trained subjects showed higher VO_2, lower heart rates and lower RQ's. A close relationship was found between carbohydrates consumed and glycogen used during work; it was concluded that glycogen stores in exercising muscles limit the capacity for prolonged severe work.

In an investigation involving competition and the importance of carbohydrate intake, McKechnie and associates (31), in a study designed to determine the effect of spontaneous carbohydrate intake studied 27 athletes on three different occasions running at a distance of 21.5 miles. The first race was a control in which subjects ate their normal diet. After the race subjects were divided into two groups matched by running times. Half of the group avoided carbohydrates and half of the group stayed on a normal diet for one week before the race. For two weeks preceding each race competitors kept accurate records of all food consumed so that carbohydrate intake could be determined; this record also acted as a reminder regarding dietary restriction. Training records were also kept for each individual and examined for the distance run in training the week before each race. Results showed that it took subjects a significantly longer time to complete the distance on a reduced carbohydrate diet than a diet which contained carbohydrates.

Several summaries of the review of literature in this area have been written by Bergstrom and Hultman (7), Costill (16) and Van Handel (42). These reviews concluded that 1) lack of carbohydrates in the diet is a limiting factor in endurance work and 2) there is a positive relationship between muscle glycogen concentration and exercise tolerance in man. From these studies it may be concluded that a distance runner wishing to achieve maximal performance should include carbohydrates in his diet.

The Effect of Depletion Prior to Carbohydrate Loading

In discussing the relationship of carbohydrates to performance the recently acclaimed procedure, namely, the depletion phase, must be reviewed. Carbohydrate depletion can be accomplished through exercise, consumption of a low carbohydrate diet, or both. These tend to lower the glycogen content of the muscles, setting them up for greater storage capacity.

A study conducted by Ahlborg and colleagues 1) involved the quantity of muscle glycogen while riding a bicycle ergometer. They concluded that the capacity for prolonged work is directly correlated to the glycogen stores in working muscles. In order to increase the storing capacity of the muscles involved in the event, Astrand (4) recommends first exercising those muscles to exhaustion one week prior to competition, then following a diet of low carbohydrates while continuing training and finally adding carbohydrates to the normal diet for three days with no heavy exercise. Following Astrand's process the storage capacity for glycogen would be increased. To demonstrate how dynamic this effect on performance can be, he tested nine subjects who worked on bicycle ergometers on four different dietary regimens at the same workload until exhaustion. Using three days of a normal diet, the average ride was 114 minutes. After three days of an all fat and protein diet, the average ride was 57 minutes. After three days of carbohydrate-rich diet the average ride was 167 minutes. With a seven day carbohydrate-rich diet plan involving depletion through heavy exercise and low carbohydrate intake, then adding carbohydrates, the average ride was 240 minutes. The conclusion was that depletion of the stores of glycogen in the muscles sets them up for greater storage capacity when carbohydrates are added.

In regard to competition and the importance of depletion, Karllson and Saltin (26) tested 10 trained distance runners on two 30-kilometer races, with three weeks recovery between the two races on the following two diets. 1) A normal mixed diet and 2) a carbohydrate loading diet regimen involving three days of exercise and carbohydrate depletion, followed by three days of carbohydrate loading with no heavy exercise. Subjects were divided into two diet groups for the first race and reversed conditions for the second race. The normal diet subjects averaged 143 minutes for the race, while men on the carbohydrate loading regimen averaged 135 minutes, which was an eight minute per man improvement. The improvement for all of the men occured during the latter two-thirds of the race, as the carbohydrate loaders were able to maintain their pace, while the non-loaders slowed an average of 16 minutes compared with their carbohydrate loading performance, indicating that the effect of the loading begins to take place after about 60 minutes. The conclusion was that the special regimen was superior to the normal diet in terms of performance.

Another study along these lines was carried out by Bergstrom and associates (11) involving the testing of nine male physical education students who served as subjects. They were tested at the same relative workload on a bicycle ergometer and rode until exhaustion occurred. Following a mixed diet the subjects' average work time was 126 minutes; a fat and protein diet resulted in a ride of 59 minutes on the average and a carbohydrate diet produced an average riding time of 189 minutes. Both the fat and protein and the carbohydrate diet involved a glycogen depletion phase. In summarizing the results heart rates and oxygen consumption differences on the various diets were small and not significant, however the mean RQ's were higher after the carbohydrate and mixed diets than the protein and fat diet. The investigators concluded that the long term work capacity can be varied by administering different diets after glycogen depletion.

In summarizing their research on the type of nutrition that an athlete should have for maximal sports performance Bergstrom and Hultman (7) stated that for a really beneficial effect to occur in events with heavy exercise involving long duration, it would be of value to increase the glycogen stores in muscle groups performing the heaviest work. This is achieved by first depleting muscles of glycogen through exercise and a diet of low carbohydrates for two or three days, then adding carbohydrates to the diet and performing no heavy work during the three days preceding competition.

Summary

The literature review can be summarized by stating that carbohydrates are essential to the endurance athlete looking for maximal performance in a prolonged bout of activity. Furthermore a carbohydrate loading regimen prior to major competition will probably result in an even greater maximization of an individual's performance. There have been no studies that this investigator could find which have examined the quantity of carbohydrate consumed during the loading phase of a carbohydrate loading regimen preceding physiological endurance testing.

Chapter III

PROCEDURES

This study was designed to investigate the effects of varying dietary regimens on heart rate, oxygen consumption, sweat loss and respiratory quotient during endurance running. This chapter presents information concerning procedures used in conducting the research. Specifically this chapter includes sections on selection of subjects, dietary information, testing procedures, collection of data and treatment of data.

Selection of Subjects

The adult men studied in this investigation were experienced volunteer runners selected from the noon hour runners at Kansas State University, Manhattan, Kansas, on the basis that they could run on a treadmill for 90 minutes. Four adult males with an age range from 19 to 38 served as subjects. This investigation was conducted in the spring of 1975.

Dietary Information

In order to control the subjects normal diets it was necessary that subjects keep accurate records, recording quantity and item, for all food and beverages consumed. The record served as a dietary check, used during the experimental weeks in order for the subjects to keep their individual diets constant. (See Figure 1).

Subjects were instructed as to types of food to consume during the experimental loading plans. The food to consume during the depletion phase consisted of mainly fats and proteins. During the loading phase subjects followed their normal diet and consumed an additional 500 or 1000 Calories of Dextrose. Subjects were asked to eat the same types and amount of food for both experimental trials. (See Appendix C and D for lists of foods). The levels of Dextrose added to the diet was the only difference between the two experimental trials.

Name ____________________ Date ____________________

Day of Week ____________________ Meal

Quantity	Item	Calories
	Snacks to Next Meal	
	Total	
Initial	Time	

Figure 1. Dietary Record

Testing Procedures

Just before testing in the Exercise Physiology Laboratory the barometric pressure and wet and dry bulb temperatures were recorded in order to determine partial pressure of water (12). Time schedules of treadmill testing were arranged so that they were given at the same time of day for each treadmill run. The subjects were tested on a Quinton model 643 treadmill. The testing was completed in a three week period to reduce changes that could occur from training or detraining.

Subjects practiced running on the treadmill prior to testing to become familiar with the treadmill and laboratory equipment and select a treadmill speed which they would run near 50% of their maximum capacity.

Subjects ran a control and two experimental conditions. The control condition consisted of seven days of normal running and recorded diet preceding the 90 minute treadmill run. The subjects were then randomly assigned to two experimental conditions. The first experimental condition consisted of three days of essentially as little carbohydrate consumption as possible, with fats and proteins as the main diet, followed by three days of their normal diet, plus 500 Calories of Cramer Dextrose tablets. The second experimental condition was the same as the first except that 1000 Calories of Dextrose were taken. Each subject ran a control condition, then two ran the 1000 Calorie Dextrose condition. Upon completion of this, subjects reversed conditions.

In order to help deplete glycogen stores, subjects had only a minimum of carbohydrate, 50 Calories intake per day being the maximum, for the three days of depletion. Subjects performed a daily run of at least 60 minutes during these three days to complete the glycogen stores depletion. During the three days of the loading phase the subjects performed no exercise in order for the glycogen stores to be replenished in the muscles. All activity was recorded so that the individuals could keep caloric expenditure constant. The activity form was used so that the subjects could perform the same amount and type of exercise for both experimental weeks. (See Figure 2 for the diet and activity regimen).

	SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
DIET	All day normal	Free CHO	Free CHO	Free CHO Supper Normal	Normal plus CHO suppl. (finish all of bag before bed)	Normal plus CHO suppl.	Normal plus CHO suppl. with breakfast
ACTIVITY	OFF	RUN 60 min.	RUN 60 min.	RUN before supper 60 min.	NO RUN	NO RUN	TEST NOON

Figure 2. Activity and Diet for Experimental Plans

Collection of Data

Each subject emptied bowels and bladder and was weighed nude just before testing and again after testing on a Homs full capacity beam bench scale with blank tare, model 300 t, in order to determine sweat loss. Sampling of the subjects heart rate, expired air, CO_2, and O_2 were taken five minutes after the subject was prepared for the treadmill run, in order for a representative resting sample. Samples were measured at the intervals listed in Table I. These intervals were measured using a Gra Lab Universal electric timer. The intervals were identified for the purpose of evaluating when the effects of the Dextrose took place.

A Bioplar modified lead II was used to record the electrocardiogram (ECG), in order to measure cardiac efficiency. Recordings of the

Table I

INTERVALS FOR SAMPLE TAKING

Minutes		Minutes
resting	(after 5 minutes standing)	49-50
4-5	(after start of run)	54-55
9-10		59-60
14-15		64-65
19-20		69-70
24-25		74-75
29-30		79-80
34-35		84-85
39-40		89-90
44-45		

ECG ventricular contractions were measured by timing 30 R spikes. A Hewlett-Packard model 7803B oscilloscope was attached to a Physio-Control model 073-01 electrocardiograph for the purpose of ease in counting pulse beats. The readings from the oscilloscope were converted to beats per minute by using a conversion table (See Appendix F). The subject was prepared for testing by placing the negative electrode on the upper portion of the sternum, the positive electrode was placed below the pectoralis major at approximately the fifth intercostal space. The ground electrode was placed in the same position as the positive electrode, but on the right side. Before the electrodes were placed in position, the skin was cleansed with alcohol to remove excess dirt and oil and scraped to remove the horny layer of skin in order for a good contact to be made. Adhesive washers were placed over electrode heads to hold them tightly in place. "New Skin", a liquid adhesive manufactured by the Natcon Company, was placed over areas where tape was to be placed to help secure electrodes which were taped to eliminate excessive movement with "Dermicel", a tape manufactured by Johnson and Johnson Company.

Ventilated air was taken using open-circuit procedure described in Consolazio, Johnson and Pecora (14), with a Parkinson Cowan ventilometer and Collins triple J valve mouthpiece attachment. The intake of the ventilometer was set via the triple J valve and mouthpiece (See Figure 3). The triple J valve was set up so that the expired air went into the sampling chamber and then to the sampling bags. When the bags were filled with sampled air, they were taken to the previously calibrated oxygen analyzer for analysis of oxygen content. The bags were then attached to the carbon dioxide analyzer for analysis of carbon dioxide. The gas was then converted to STPD value from the barometric pressure, wet and dry bulb temperatures and pressure of water. A piece of white athletic tape was placed over the subject's nose to prevent the nose clip from sliding off because of perspiration. A nose clip was attached to prevent exhalation through the nose during air collection.

Samples of ventilated air were taken using a Neptune Pressure Dyna pump model 4K, and analyzed on a Beckman oxygen analyzer model E2, for percentage of oxygen. Carbon dioxide was analyzed on a Beckman medical gas analyzer model LB-1. Every two or three samples analyzers were calibrated to insure accurate readings.

Treatment of Data

The means of the four subjects were taken on heart rate, oxygen consumption and respiratory quotient to determine the average for each testing session. Comparisons were made on the mean for each testing session. Comparisons were made on the means for each variable on the different experimental conditions.

Data were examined using a split plot ANOVA to determine the more efficient level of Dextrose in terms of performance. The .05 alpha level was used as the criterion for statistical significance.

In order to study the individual response to each of the physiological parameters, a case study approach was chosen. It was necessary to examine subjects individually since they ran at different treadmill speeds and varied in age and estimated maximum heart rate.

Chapter IV

RESULTS AND DISCUSSION

In this study heart rate, oxygen consumption and respiratory quotient were examined during a 90 minute treadmill run following seven days of recorded food and exercise for three dietary regimens. This chapter presents the results obtained and a discussion of those results. The results will include 1) means of the data, 2) ANOVA of the data and 3) a case study of each subject including detailed examination of the individual response of the subjects to the diets on each of the variables.

RESULTS

The means of the variables including heart rate, oxygen consumption and respiratory quotient are presented in Table II. The means are presented for the purpose of comparing the effects of the dietary regimens.

Heart Rate Means

The subject's heart rate during the normal diet condition averaged five beats higher than during the 500 Calorie or 1000 Calorie dietary conditions indicating a more rapid rate of fuel supply during the experimental condition. This was expected since the loading effect should have made the heart more efficient during the experimental conditions as the heart was being supplied with the efficient glycogen fuel.

Oxygen Consumption and Respiratory Quotient Means

There was no difference in performances during the different dietary conditions for oxygen consumption indicating that the amount of oxygen used during the different dietary conditions was approximately similar. The performances during the different dietary experimental conditions for respiratory quotient were close indicating that the percent of fat and carbohydrate utilization was relatively similar.

Table II

HEART RATE, OXYGEN CONSUMPTION AND RESPIRATORY QUOTIENT MEANS

	Normal	500 Calorie+	1000 Calorie+
HR	154	150	149
VO_2	2.8362	2.7409	2.7168
RQ	.8223	.8417	.8607

Split Plot Analysis of Variance of HR, VO_2, and RQ

Heart rate, oxygen consumption and respiratory quotient were examined using a split plot ANOVA as described by LeClerg, Leonard and Clark (29). This analysis differs from a regular ANOVA in that it is divided into two parts corresponding to main and subplots each with their own error term. This design was chosen because it was felt that the subplots time, diet x time and subject x time were important factors to consider for the purpose of determining more specifically where significant differences may occur. With this design the error term is reduced for subplots, resulting in increased precision of measurement. A split plot ANOVA was performed for heart rate as shown in Table III, a significant difference was found for time. The results of the oxygen consumption split plot ANOVA as shown in Table IV indicate no significant difference among treatments. Analysis of the respiratory quotient measurements by split plot ANOVA as shown in Table V, indicate that there were no significant differences. The dietary regimens showed no significant difference among the variables because they were not affected significantly during the treadmill run.

The following explanation applies to Tables III through V. The source is the factor analyzed. Error (a) is the variability expected between diet and subject interaction during the same time periods, used to test for diet effects. Error (b) is the variability expected where subplots (factors below error (a)) received the same diet condition and time of diet, represented as the subplot mean square (ms). The diet x time affect represents the variations in diet differences unaccounted for by pure subject differences. The subject x time interaction represents the variation in subject differences unaccounted for by pure time differences. Factors below error (a) show more specifically where the significant differences for diet and subjects took place. The subjects were significant factors which was expected since the treadmill speed varied for each subject.

Table III

SPLIT PLOT ANALYSIS OF VARIANCE FOR HEART RATE

Source	ss	df	ms	F
Diet	1050.75	2	525.37	2.32
Subjects	32929.65	3	10976.21	4.86*
Error (a)	1356.19	6	226.03	
Time	841.26	17	49.49	5.26*
Diet x Time	454.27	34	13.36	1.54
Subject x Time	740.55	51	14.52	1.42
Error (b)	960.08	102	9.41	
Total	38331.76	215		

*Significant at .05 level.

Subject and time differences were accounted for due to different treadmill speeds of each subject.

Table IV

SPLIT PLOT ANALYSIS OF VARIANCE FOR OXYGEN CONSUMPTION

Source	ss	df	ms	F
Diet	.57	2	.29	3.36
Subjects	3.89	3	1.30	22.74*
Error (a)	1.03	6	.17	
Time	.25	17	.01	.01
Diet x Time	.61	34	.02	.48
Subject x Time	.90	51	.02	.70
Error (b)	1.28	102	.01	
Total	8.53	215		

*Significant at .05 level.

The subject differences were accounted for due to the different treadmill speeds of each subject.

Table V

SPLIT PLOT ANALYSIS OF VARIANCE FOR RESPIRATORY QUOTIENT

Source	ss	df	ms	F
Diet	.05	2	.03	.93
Subjects	.51	3	.17	5.98*
Error (a)	.17	6	.03	
Time	.04	17	.00	1.59
Diet x Time	.06	34	.00	1.06
Subjects x Time	.10	51	.00	1.06
Error (b)	.16	102	.00	
Total	1.09	215		

*Significant at .05 level.

The subject difference was accounted for due to the different treadmill speeds of each subject.

Case Study

The heart rate, oxygen consumption and respiratory quotient of each subject were examined for trends in order to determine which diet would be most advantageous for the subject to follow prior to competition, for the purpose of obtaining a better performance.

Heart rate. The means for all subjects are graphed in Figure 3. Means for the individual subjects are graphed in Figures 4-9. Subject number 1 averaged 12.5 beats higher on the normal condition than the experimental diets, indicating that he had a more rapid rate of fuel supply during the experimental conditions. There was no difference between the two experimental conditions showing that the amount of loading did not matter. Subjects 2 and 3 showed no significant difference among the three dietary conditions for heart rate. Subject number 4 elicited 5-6 beats higher on the 1000 Calorie diet than the normal or 500 Calorie diet indicating that for cardiac efficiency the 1000 Calorie diet was the least efficient.

Oxygen consumption. The means for all subjects are graphed in Figure 8. The means for individual subjects are graphed in Figures 9-12. Subject number 1 averaged lower on the 1000 Calorie diet than the 500 Calorie or normal diet condition especially from 20 to 70 minutes indicating that less oxygen was required during this time period for the same workload. The other subjects showed no significant differences for oxygen consumption during the treadmill run.

Respiratory quotient. The means for all subjects are graphed in

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.

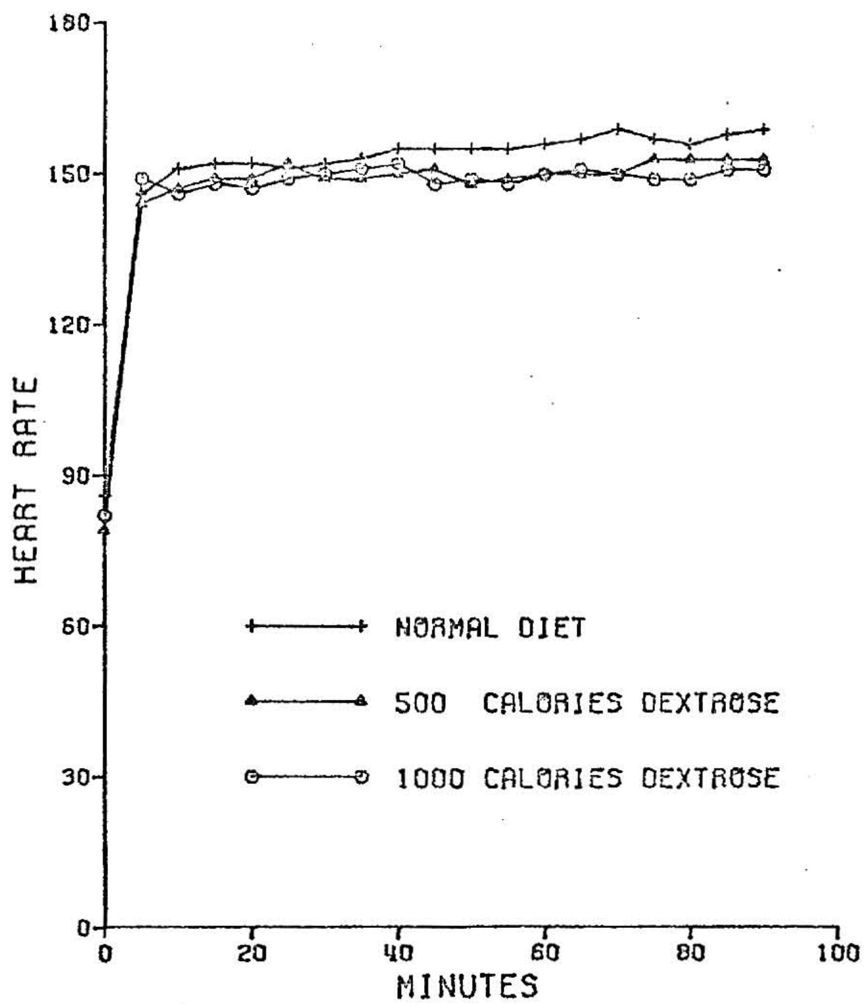

Figure 3. Heart Rate Means

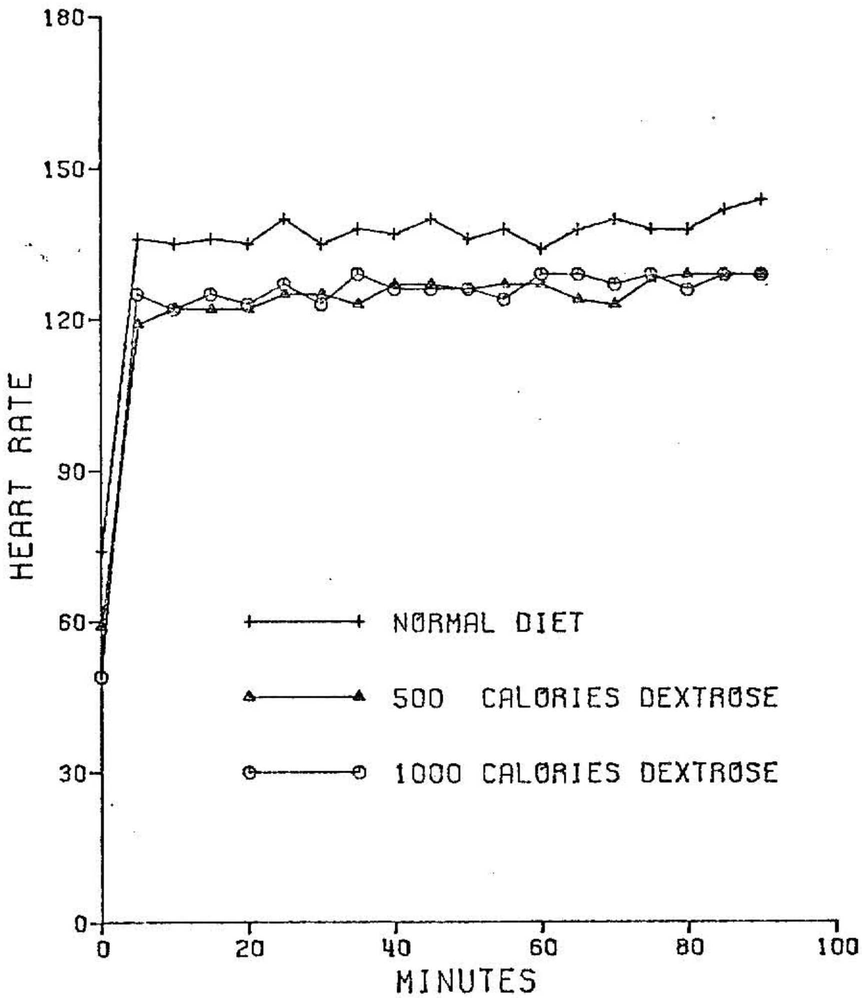

Figure 4. Subject 1 Heart Rate Responses.

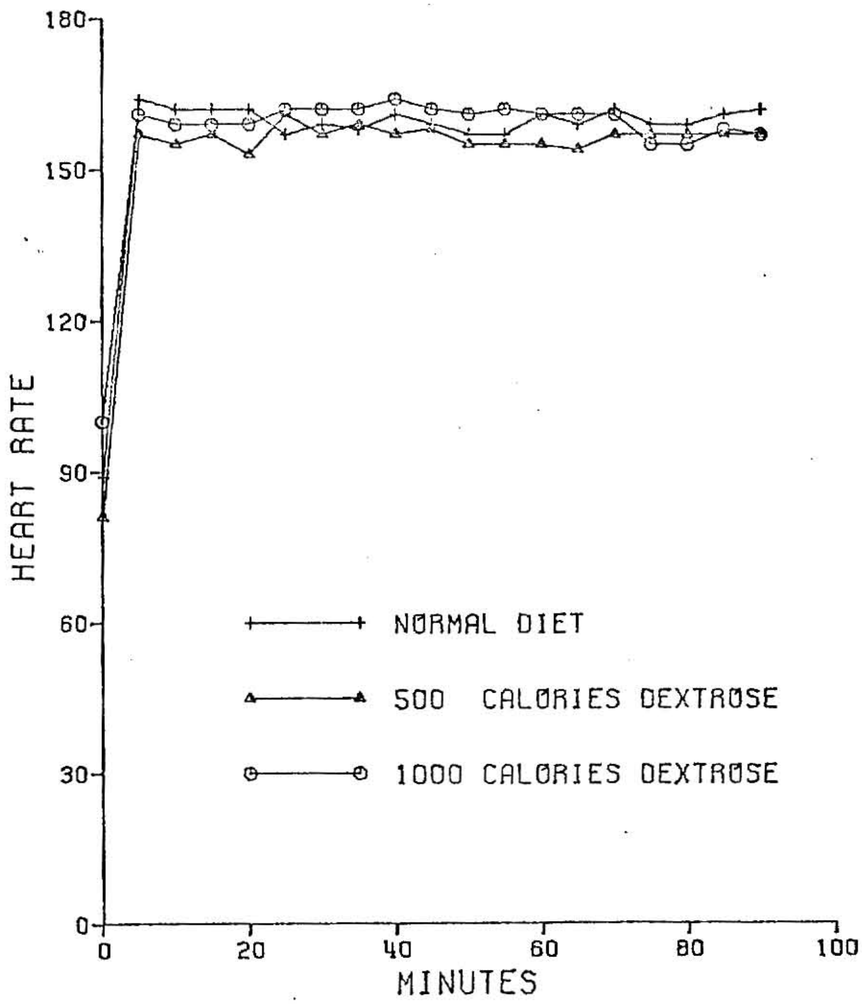

Figure 5. Subject 2 Heart Rate Responses.

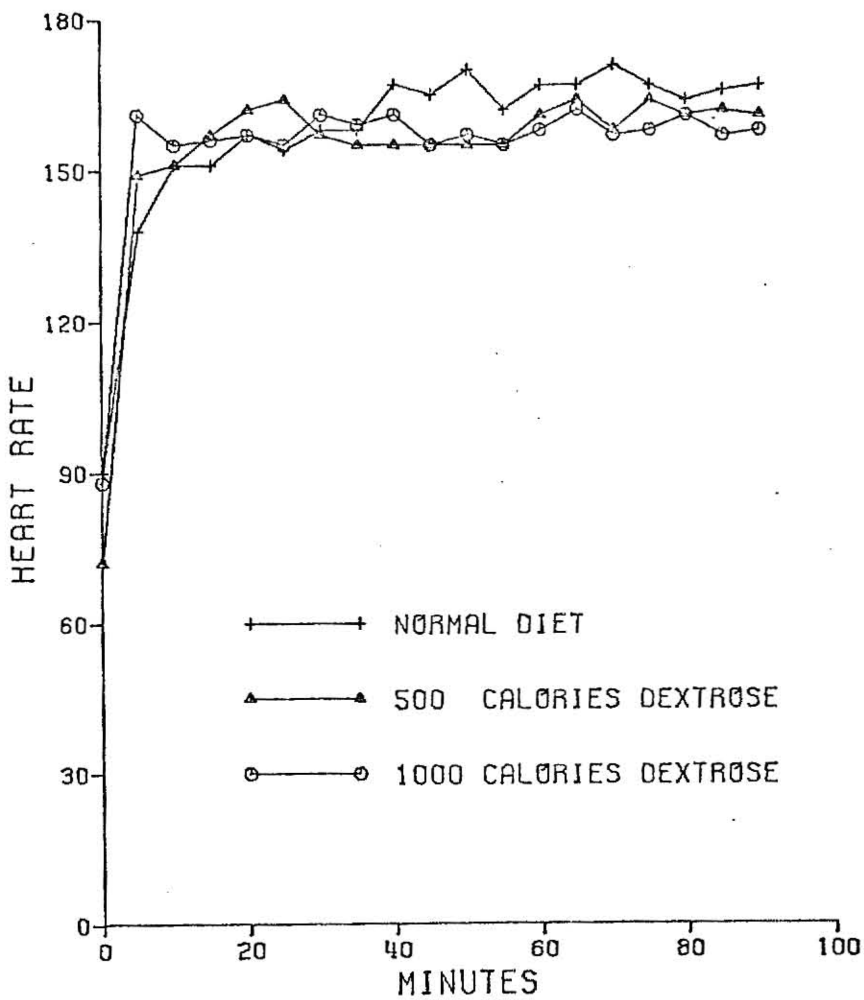

Figure 6. Subject 3 Heart Rate Responses.

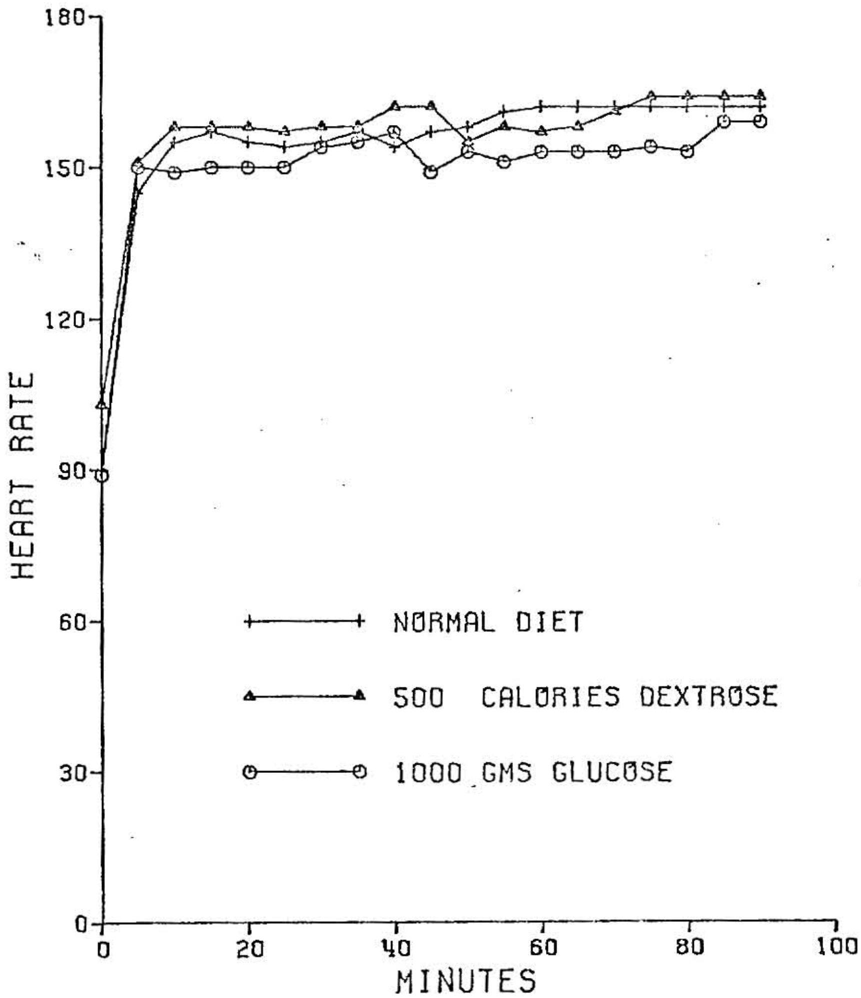

Figure 7. Subject 4 Heart Rate Responses.

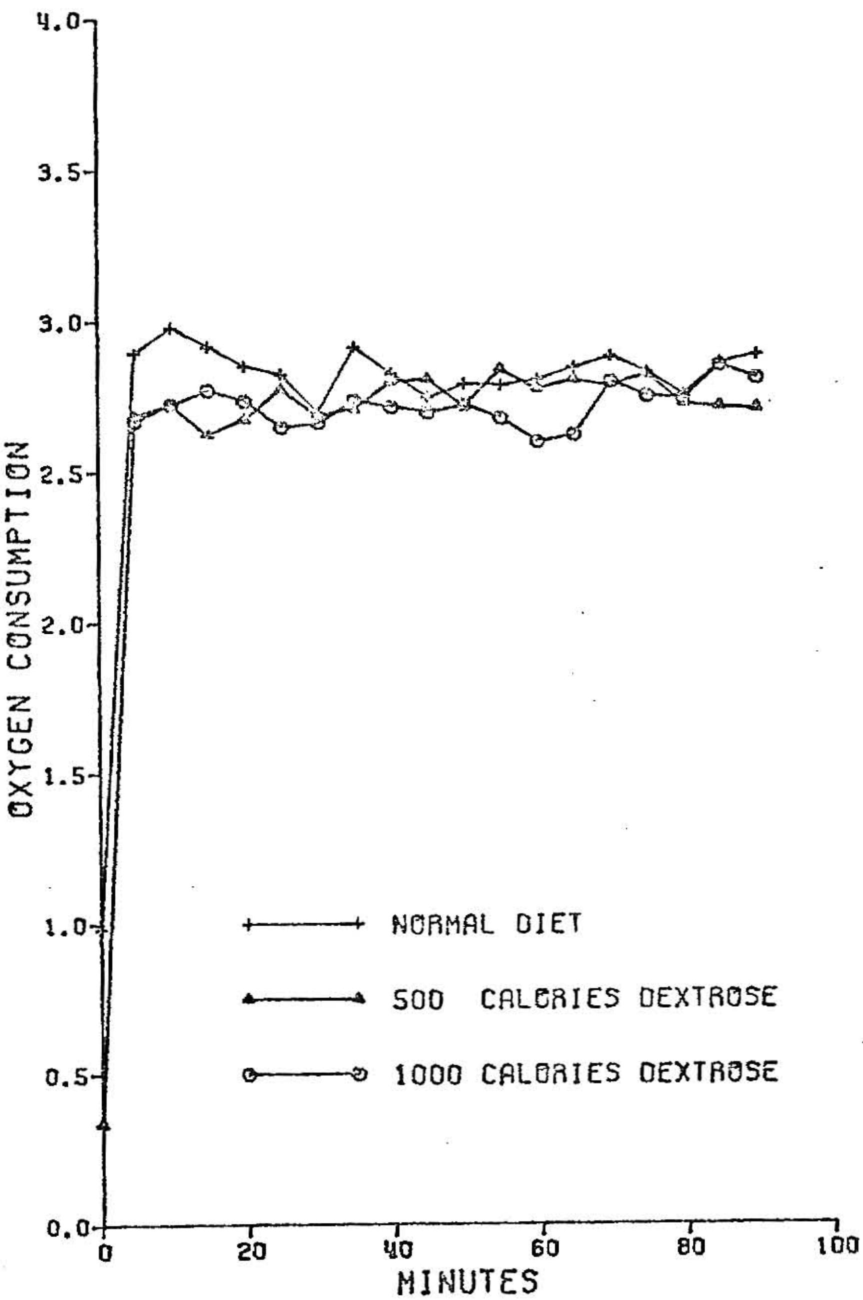

Figure 8. Oxygen Consumption Means.

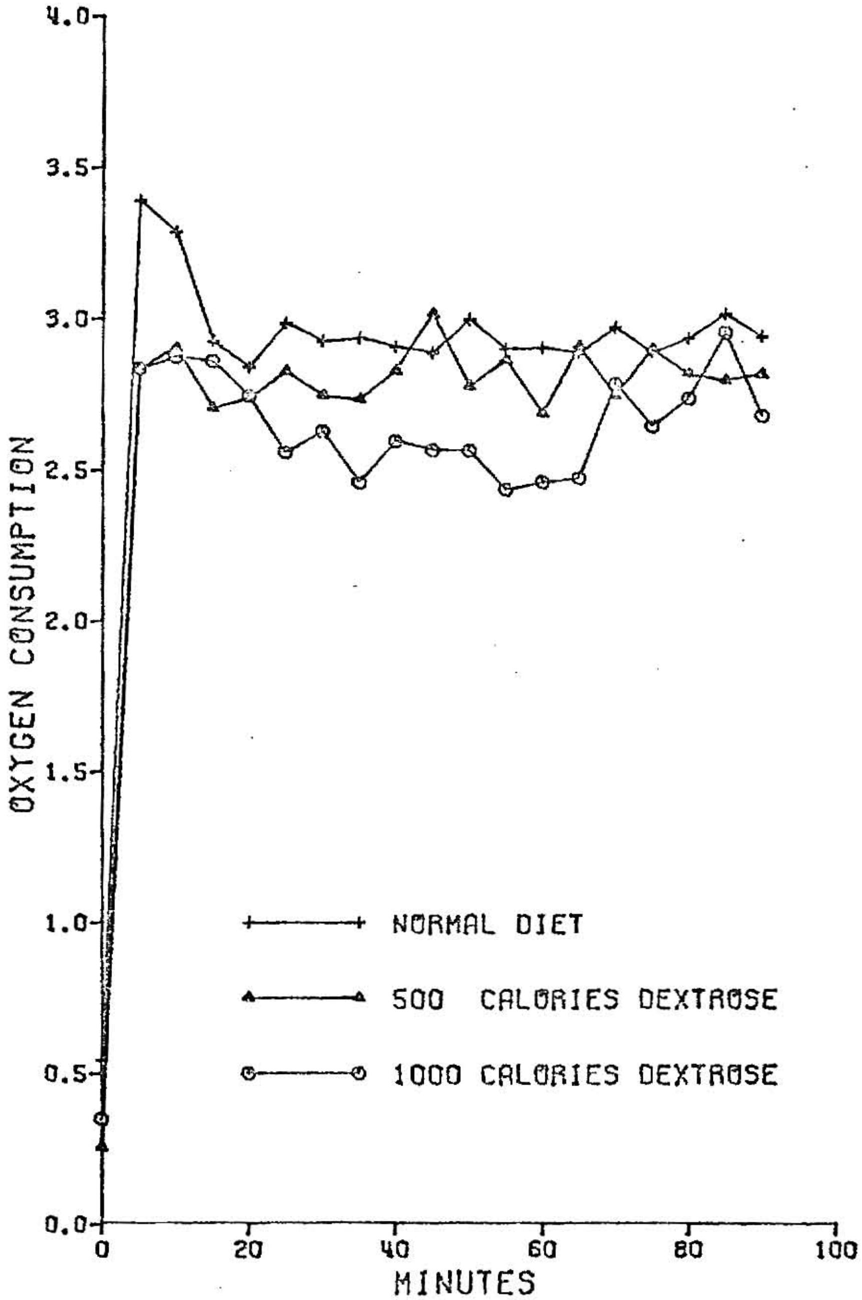

Figure 9. Subject 1 Oxygen Consumption Responses.

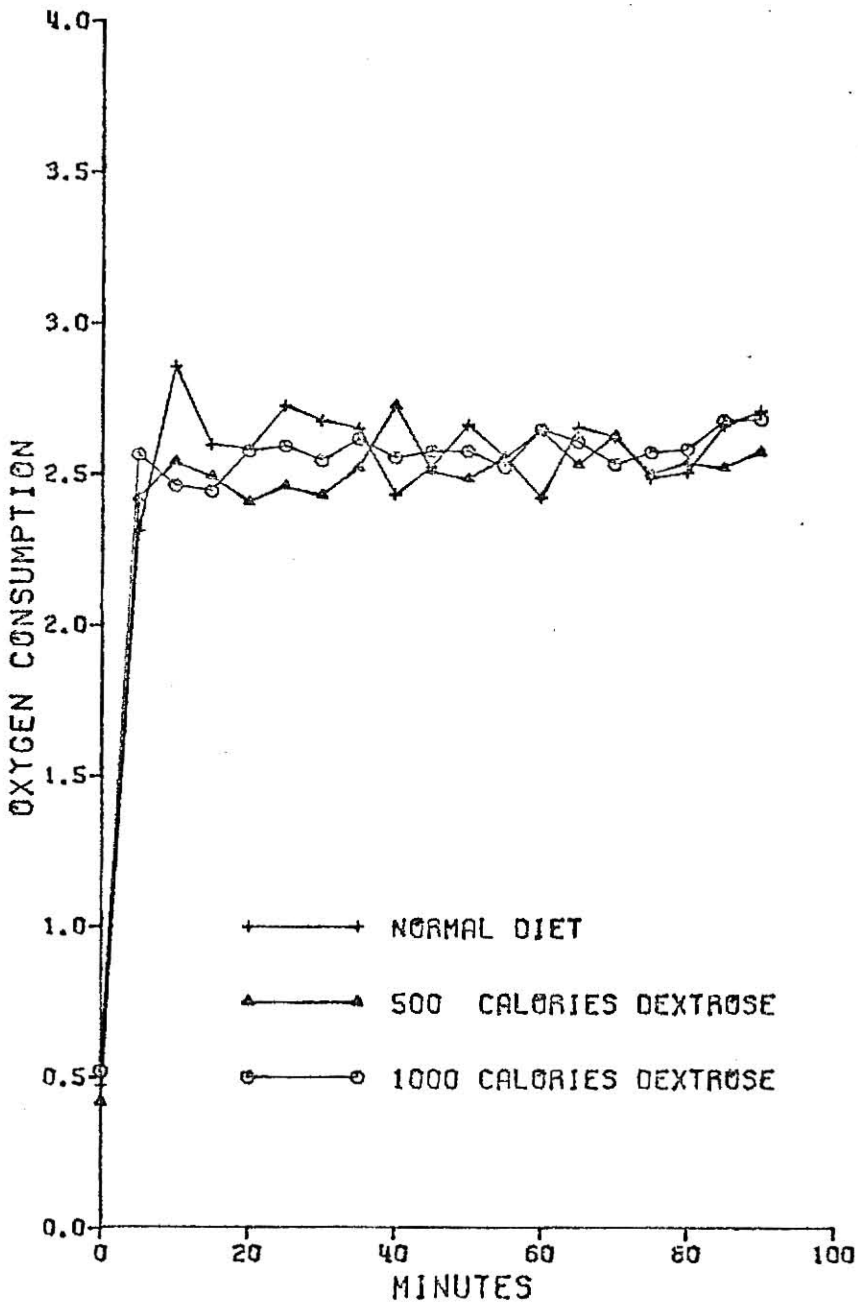

Figure 10. Subject 2 Oxygen Consumption Responses.

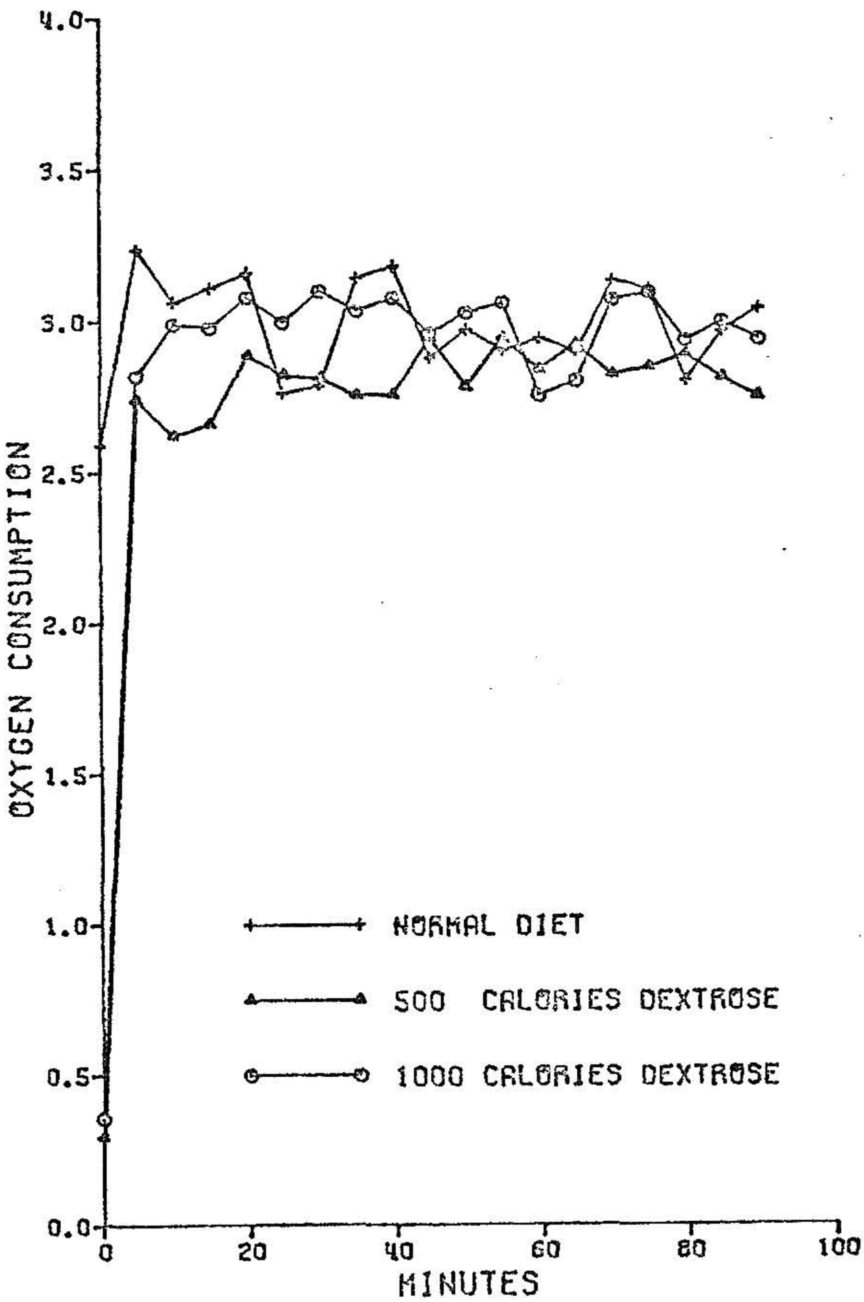

Figure 11. Subject 3 Oxygen Consumption Responses.

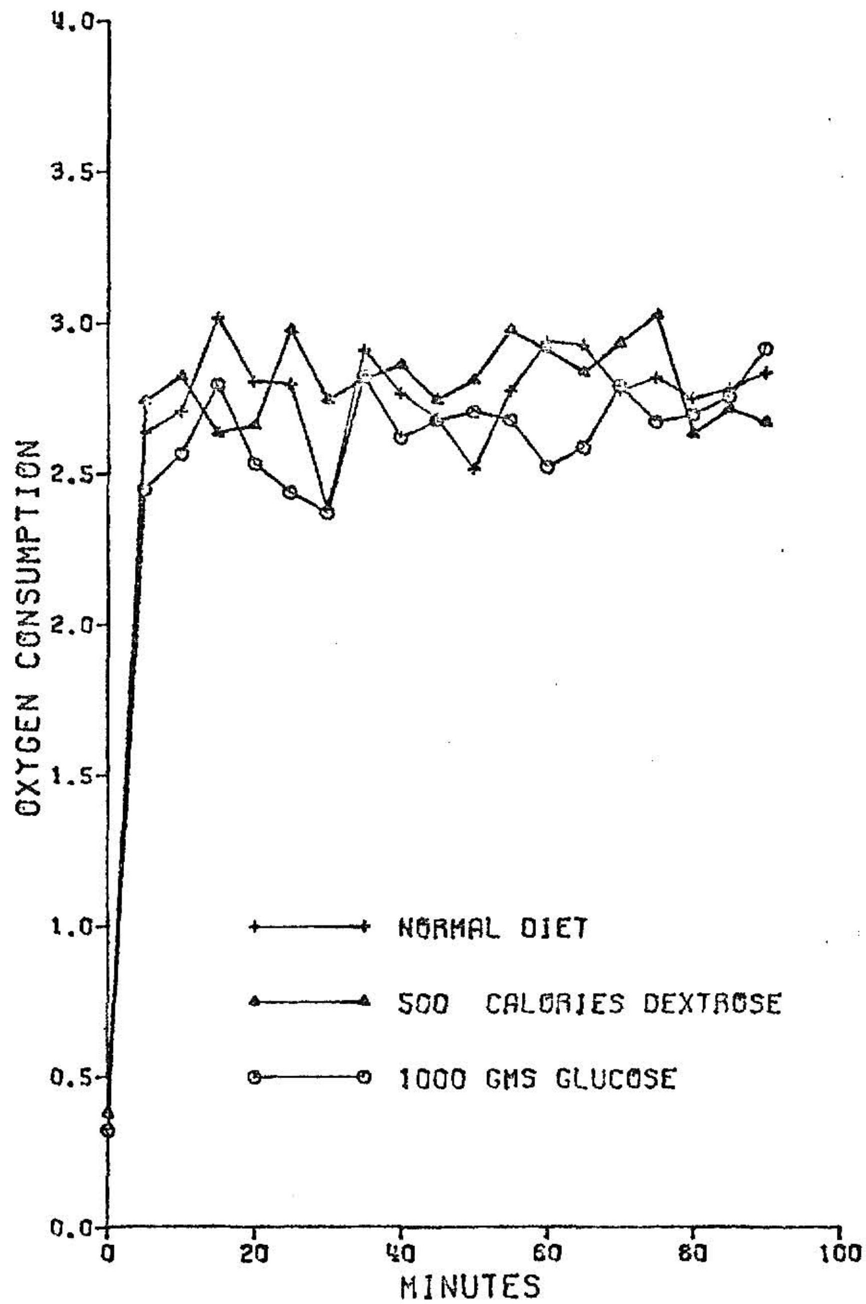

Figure 12. Subject 4 Oxygen Consumption Responses.

Figure 13. The means for individual subjects are graphed in Figures 14-17. Subject number 1 showed no significant difference. Subject number 2's RQ was higher from the 25 to 70 minute time periods on the 1000 Calorie diet, however no difference between the normal and 500 Calorie diet appear to exist for this subject. Subject number 3 averaged higher on the 5000 Calorie diet from 30-90 minutes, however differences were small and not statistically significant. Subject number 4 showed no significant differences during the treadmill run among the dietary conditions.

DISCUSSION

The purpose of this study was to determine the extent to which a normal diet, a depletion period preceding 500 Calories above a normal diet, and a depletion period preceding 1000 Calories above a normal diet affected the variables heart rate, oxygen consumption and respiratory quotient during a 90 minute treadmill run.

Results of the split plot ANOVA showed that none of the variables heart rate, oxygen consumption or respiratory quotient were affected significantly by the diet. This was in contrast to other studies in which the depletion effect prior to loading was significantly advantageous (1, 26, 29, 47). Bergstrom (10) found similar results in that no significant differences were found between heart rate or VO_2. The diets in that study consisted of a normal mixed diet, a fat plus protein diet following depletion and a carbohydrate diet following depletion. In this study the subjects varied significantly on all three variables, which is understandable since the subjects ran at different

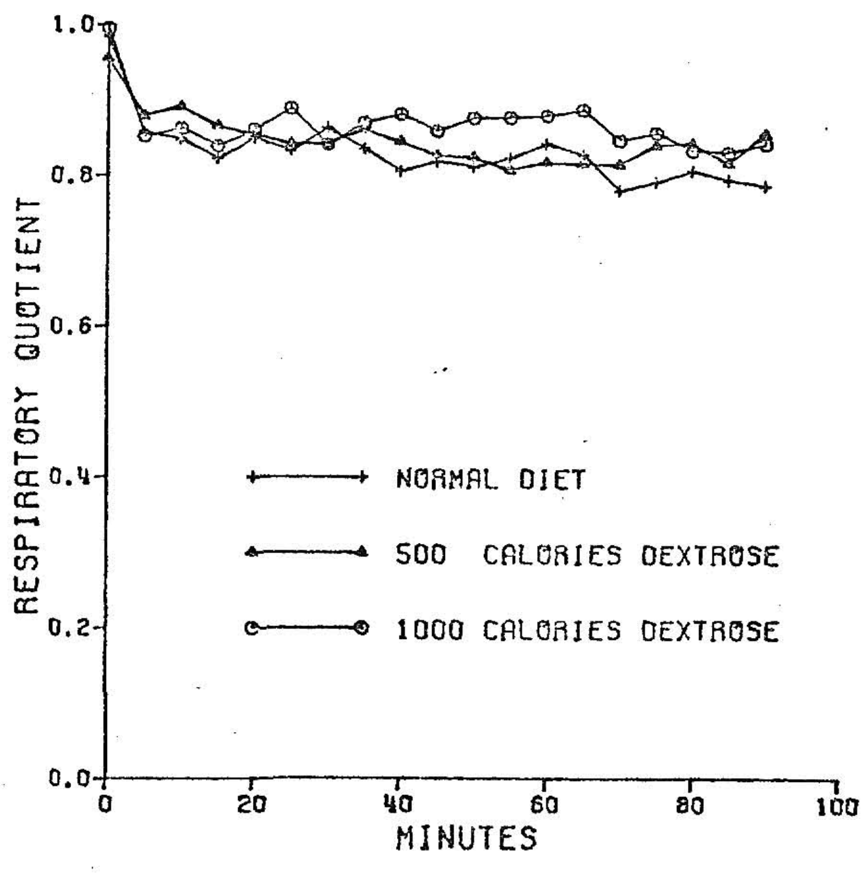

Figure 13. Respiratory Quotient Means.

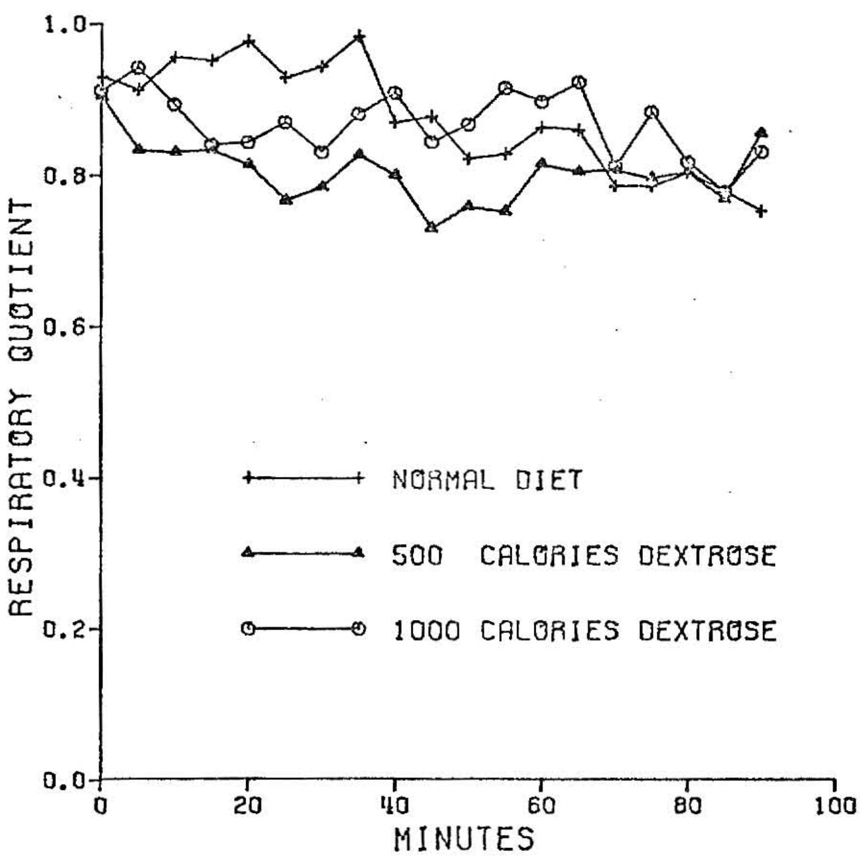

Figure 14. Subject 1 Respiratory Quotient Responses.

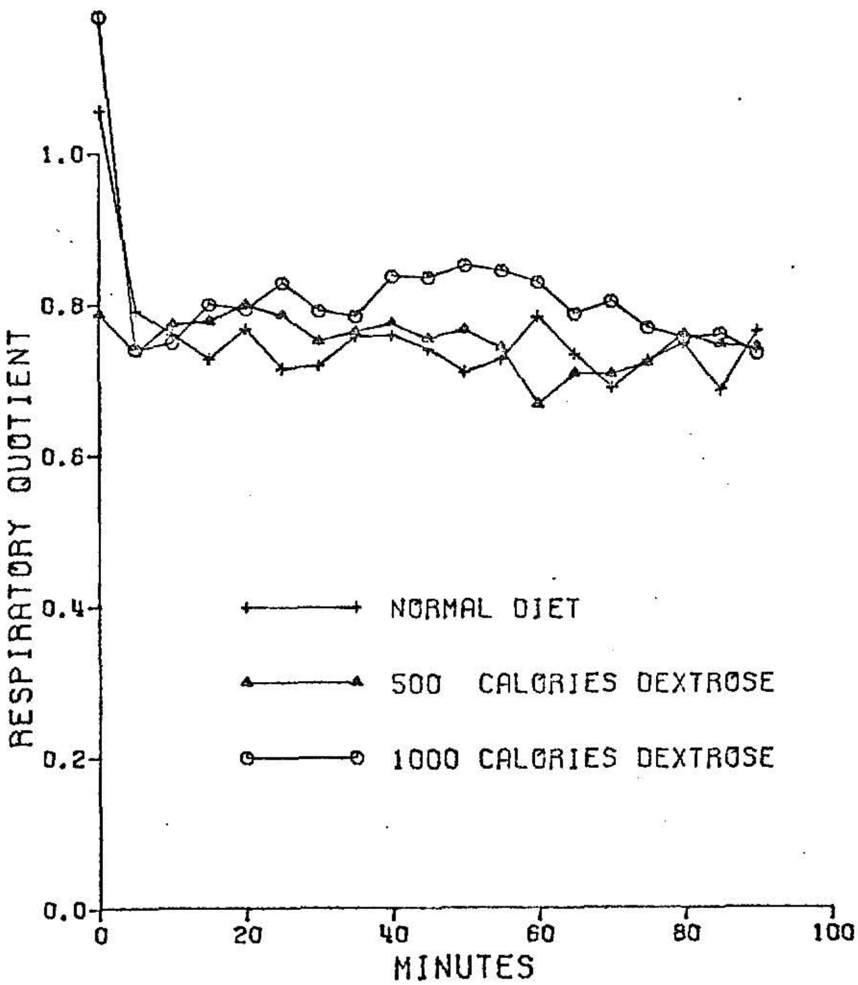

Figure 15. Subject w Respiratory Quotient Responses.

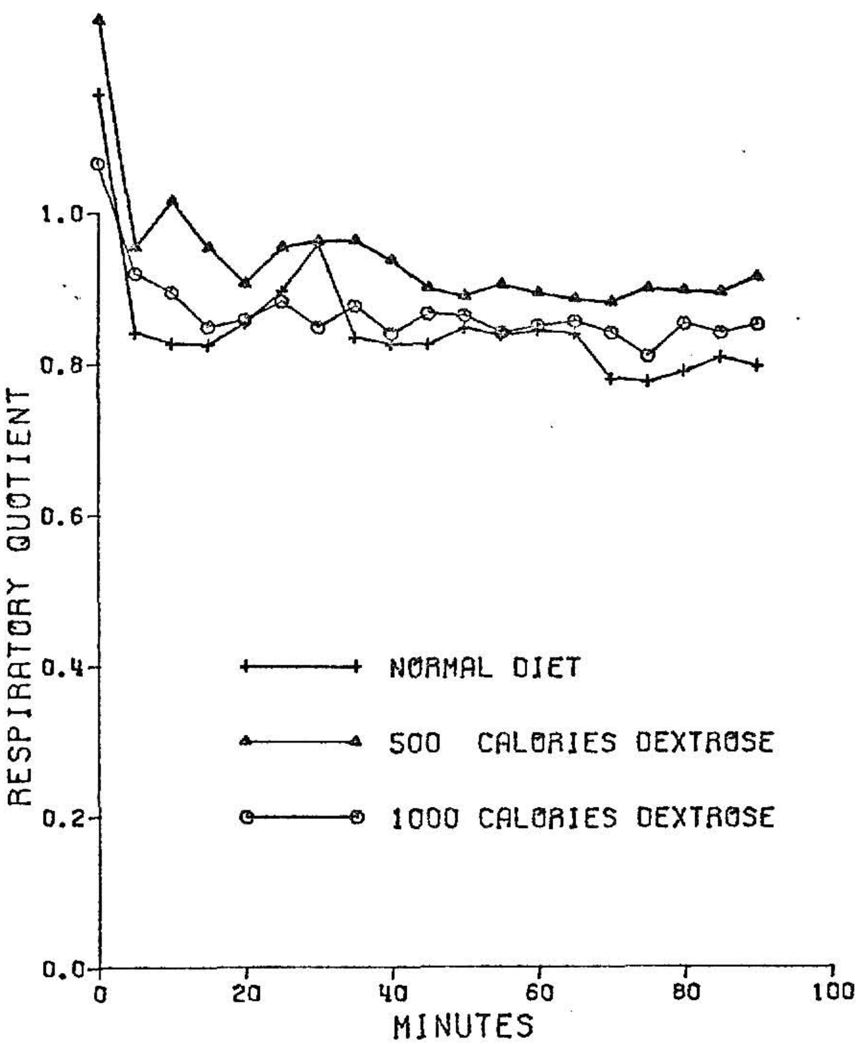

Figure 16. Subject 3 Respiratory Quotient Responses.

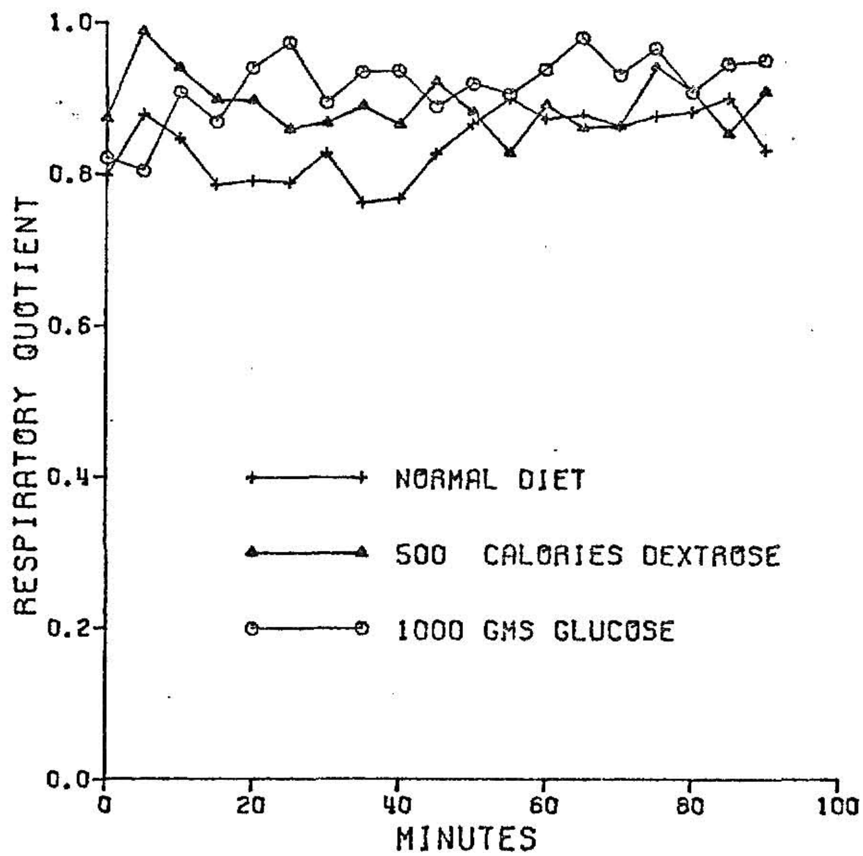

Figure 17. Subject 4 Respiratory Quotient Responses.

treadmill speeds. The reason that the subjects ran at different speeds was because their physical structures varied. See Appendix B for subjects age, height and best mile time.

One interesting observation is the difference in the resting heart rates of the subjects prior to physiological testing. Perhaps the anxiety level of the subjects varied prior to the treadmill runs. The Hawthorne effect could have taken place prior to the testing which may have created this variance.

Capacity for exercise is dependent upon maximal oxygen uptake (26). In order to minimize the inter-individual variation in workload, subjects ran at approximately 50% of max. VO_2 for each test on a treadmill. All subjects were trained and had run on a treadmill, which implies that between treadmill runs the performance should not have improved (28). The level of 50% max. VO_2 is much lower than competition in which VO_2 is 70-80% of maximum and may not have been high enough to produce a significant difference.

Among variables other than heart rate, VO_2 and RQ other researchers (15, 19, 23, 25) have found that the more muscle glycogen content just before endurance work, the longer the pace can be maintained. It has been shown that the glycogen concentration is critical for resynthesis of phosphocreatine and ATP in working muscles in man (9, 25, 27) which could mean that some other variable other than heart rate, VO_2 or RQ is affected by increasing the muscle glycogen content. Perhaps hydration content or blood glucose levels are significant factors.

There are about 2.7 grams of water stored with each gram of glycogen (3, 32). An individual can't tolerate heavy physical work or heat stress as effectively if subjected to a loss of one percent body weight (3), although remarkably neither heart rate or oxygen consumption are changed by sweat loss of up to five percent of body weight (2, 30, 37). Water losses for subjects are shown in Table VI. Three subjects retained more water on the 1000 Calorie condition, indicating less chance of dehydration. Dehydration has been shown (3, 8, 18, 33, 40, 41, 43, 44) to limit endurance performance during prolonged exercise.

The split plot ANOVA test for significance limits conclusions to the time periods included in the experiment. In speculating beyond 90 minutes, perhaps significant differences on these variables would appear. Long distance runners, especially in the marathon have been known to improve their times when on carbohydrate loading regimens (7, 15, 16, 32). For example one runner involved in this study experienced a 12 minute drop in his marathon time in races run over the same course under the same conditions after following a carbohydrate loading regimen.

The amount of loading had no significant effect on heart rate, VO_2 or RQ, therefore it may be concluded that some other variable is responsible for increased duration in prolonged endurance activities, perhaps increasing the duration or speed of the treadmill run would bring about some significant changes.

Table VI

WATER LOSSES FOR SUBJECTS

	CONTROL	500 Cal +	1000 Cal +
Subject 1			
Before	184 lb 12 oz	184 lb 13 oz	186 lb 13 oz
After	181 lb 12 oz	182 lb 05 oz	184 lb 01 oz
Net Loss	3 lb	2 lb 08 oz	2 lb 12 oz
Subject 2			
Before	146 lb 04 oz	147 lb 06 oz	147 lb 08 oz
After	142 lb 09 oz	143 lb 12 oz	144 lb 05 oz
Net Loss	3 lb 04 oz	3 lb 10 oz	3 lb 03 oz
Subject 3			
Before	145 lb 10 oz	147 lb 08 oz	149 lb 07 oz
After	140 lb 10 oz	143 lb 08 oz	145 lb 03 oz
Net Loss	5 lb	4 lb	4 lb 04 oz
Subject 4			
Before	162 lb 04 oz	160 lb 08 oz	159 lb 15 oz
After	158 lb 10 oz	157 lb 03 oz	156 lb 09 oz
Net Loss	3 lb 10 oz	3 lb 05 oz	3 lb 06 oz

Chapter V

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to determine which of the following diet and exercise regimens was most efficient through reduction of heart rate, requirement of less oxygen consumption and increase of respiratory quotient during performance of a 90 minute treadmill run. 1) A normal diet which was seven days of recorded dietary intake preceding the controlled treadmill run, 2) a regimen consisting of three days of carbohydrate depletion and 60 minutes of running per day to further deplete stores of glycogen, followed by three days of normal diet plus 500 Calories of Dextrose and no running, 3) a regimen consisting of three days of carbohydrate depletion and 60 minutes of running per day to further deplete stores of glycogen, followed by three days of normal diet plus 1000 Calories of Dextrose and no running.

The results of the data showed that the dietary regimen up to 1000 Calories does not significantly increase or decrease heart rate or oxygen consumption or raise or lower respiratory quotient during 90 minutes of running at 50% of max. VO_2. This leads to the conclusion that some other variable must be responsible for the improvement of endurance performance of runners using carbohydrate diets.

The following recommendations were based on the results and conclusions of this study. Further research is needed in regard to adding ideal amounts of carbohydrates to a normal diet following depletion of glycogen stores, a similar study more closely controlled with stricter control on diet might produce different results. There is the need for studies using different training schedules while on the carbohydrate depletion phase of the diet. There is a need for a study involving the amount of glycogen that the runner depletes prior to loading of carbohydrates and the effect in regard to competition. Other possibilities include a similar study using more subjects, an endurance run of longer than 90 minutes, a study involving more trials. It is recommended that in future studies subjects run at a faster rate than 50% of maximum VO_2, perhaps 70-90%, in order to more closely simulate racing conditions.

REFERENCES CITED

1. Ahlborg, B., et al. "Muscle Glycogen and Muscle Electrolytes During Prolonged Physical Exercise," Acta Physiologica Scandinavica, 70:129-142, 1967.

2. Astrand, P. O. and B. Saltin. "Plasma and Red Cell Volume After Prolonged Severe Exercise," Journal of Applied Physiology, 19:829, 1964.

3. Astrand, P. O. and K. Rodahl. Textbook of Work Physiology. McGraw Hill Book Company, 1970.

4. Astrand, P. O., et al. "Blood Lactates After Prolonged Severe Exercise," Journal of Applied Physiology, 18:619-622, 1963.

5. Bergstrom, J. and E. Hultman. "The Effect of Exercise on Muscle Glycogen and Electrolytes in Normals," Scandinavian Journal of Clinical Laboratory Investigations, 19:218-228, 1966.

6. Bergstrom, J. and E. Hultman. "Muscle Glycogen Consumption During Cross Country Skiing," International Physiologica, 31:91-95, 1973.

7. Bergstrom, J. and E. Hultman. "Nutrition for Maximal Sport Performances," Journal of American Medical Association, 221:999, 1972.

8. Bergstrom, J. and E. Hultman. "A Study of the Glycogen Metabloism During Exercise in Man," Scandinavian Journal of Clinical Laboratory Investigations, 19:218-228, 1967.

9. Bergstrom, J. and E. Hultman. "Synthesis of Muscle Glycogen in Man After Glucose and Fructose Infusion," Acta Medica Scandinavica, 82:93-107, 1967.

10. Bergstrom, J., et al. "Diet, Muscle Glycogen and Physical Performance," Acta Physiologica Scandinavica, 71:140-150, 1967.

11. Bergstrom, J., et al. "Effect of Nicotinic Acid on Physical Working Capacity and on Metabolism of Muscle Glycogen in Man," Journal of Applied Physiology, 26:170-176, 1969.

12. Carpenter, T. Tables, Factors and Formulas for Computing Respiratory Exchange and Biological Transformations of Energy. Washington, D.C.: Institute of Washington Publications, 1964.

13. Christensen, E. and O. Hansen. "Arbeitsfahrigheit and Uhrnahrung," Scandinavian Archives of Physiology, 81:160-171, 1939.

14. Consolazio, Pecora and Johnson. Physiological Measurements of Metabolic Functions in Man. New York: McGraw Hill Book Company, 1963.

15. Costill, D. "Physiology of Marathon Running," Journal of the American Medical Association, 221:1024, 1972.

16. Costill, D. "Muscular Exhaustion," The Physician and Sports Medicine, 36-41, 1974.

17. Costill, D. and E. Fox. "Energetics of Marathon Running," Medicine Science in Sports, 1:81-86, 1969.

18. Costill, D., et al. "Fluid Ingestion During Distance Running," Archives of Environmental Health, 21:520-525, 1970.

19. Costill, D., et al. "Muscle Glycogen Utilization During Exhaustive Running," Journal of Applied Physiology, 31:353-356.

20. Costill, D., et al. "Muscle Glycogen Utilization During Prolonged Exercise on Successive Days," Journal of Applied Physiology, 31:834, 1971.

21. Gleser, M. and J. Vogel. "Endurance Exercise: Effect of Work-Rest Schedules and Repeated Testing," Journal of Applied Physiology, 31:735-739, 1971.

22. Gollnick, P., et al. "Glycogen Depletion Pattern in Human Skeletal Muscle Fibers After Heavy Exercise," Journal of Applied Physiology, 34:615-618, 1973.

23. Hedman, R. "The Available Glycogen in Man and Connection Between Rate of Oxygen Intake and Carbohydrate Usage," Acta Physiologica Scandinavica, 40:305-321, 1957.

24. Hermansen, L., et al. "Muscle Glycogen During Prolonged Severe Exercise," Acta Physiologica Scandinavica, 71:129-139, 1967.

25. Hultman, E. and J. Bergstrom. "Muscle Glycogen Synthesis in Relation to Diet Studied in Normal Subjects," Acta Physiologica Scandinavica, 182:109-177, 1967.

26. Karllson, J. and B. Saltin. "Diet, Muscle Glycogen and Endurance Performance," Journal of Applied Physiology, 31:203-206, 1971.

27. Kelsay, J., et al. "Diets High in Glucose or Sucrose and Young Women," The American Journal of Clinical Nutrition, 27:926-936, 1974.

28. Kollias, J., et al. "Cross Country Running; Treadmill Simulation and Suggested Effectiveness of Supplemental Treadmill Training," Journal of Sports Medicine, 7:148-154, 1967.

29. LeClerg, Leonard and Clark. Field Plot Techniques. Minneapolis: Burgess Publishing Company, 1962.

30. MacKay, E. and M. Bergman. "The Relation Between Glycogen and Water Storage in the Liver," Journal of Biological Chemistry, 96:373-380, 1932.

31. McKechnie, J., et al. "The Effect of Dietary Sucrose on Performance of Marathon Runners," South African Medical Journal, 44:723-731, 1970.

32. Mahurin, J. "Glycogen Loading-Practical Application," Running, 1:4, 66-67, 1975.

33. Olsson, K. and B. Saltin. "Variation in Total Body Water With Muscle Glycogen Changes in Man," Acta Physiologica Scandinavica, 80:11-18, 1970.

34. Orava, S., et al. "Blood Glucose, Serum FFA and Serum Insulin Levels After the Intake of Carbohydrate Rich Solution Before Exercise in Man," The Journal of Sports Medicine and Physical Fitness, 14:2, 93-102, 1974.

35. Pernow B. and B. Saltin. "Availability of Substrates and Capacity for Prolonged Heavy Exercise in Man," Journal of Applied Physiology, 31:416-422, 1971.

36. Pruett, E. "Glucose and Insulin During Prolonged Work Stress in Men Living on Different Diets," Journal of Applied Physiology, 28:199-208, 1970.

37. Saltin, B. "Aerobic Work Capacity and Circulation at Exercise in Man," Acta Physiologica Scandinavica, 62:230, 1964.

38. Saltin, B. and L. Hermansen. "Glycogen Stores and Prolonged Severe Exercise," Proceedings of the Symposium of the Swedish Nutrition Foundation, 5th Uppsala, 1967.

39. Saltin B. and J. Stenberg. "Circulatory Response to Prolonged Severe Exercise," Journal of Applied Physiology, 19:833-838, 1964.

40. Senay, L. "Movement of Water Protein and Chrystalloids Between Vascular and Extravascular Compartments in Heat Exposed Men During Dehydration and Following Limited Relief of Dehydration," Journal of Physiology, 210:617-636, 1870.

41. Senay, L. and M. Christensen. "Changes in Blood Plasma During Progressive Dehydration," Journal of Applied Physiology, 24:302-309, 1965.

42. Van Handel, P. The Complete Runner. Mountain View: World Publications Company, 1974.

43. Weiner, J. and R. VanHeyninger. "Observations on the Lactate Content of Sweat," Journal of Applied Physiology, 4:734-744, 1952.

44. Wyndham, C., et al. "Changes in Central Circulation and Body Fluid Spaces During Acclimatization to Heat," Journal of Applied Physiology, 25:586-593, 1968.

APPENDICES

APPENDIX A

Subject Participation Consent Form

PHYSIOLOGY RESEARCH
Department of Health, Physical
Education, and Recreation
Kansas State University
Manhattan, Kansas

Date______________

I ____________________________ have voluntarily asked the personnel of the Department of Physical Education to study my performance on a carbohydrate loading regimen and treadmill run performed in conjunction with research. I understand that I will run for 90 minutes at the same treadmill speed, three separate times, with a week space in between each treadmill run. One treadmill run will follow one week of a normal diet, two experimental treadmill runs, one which involves no carbohydrates for three days, then adding 500 Calories of Dextrose beginning three days prior to the treadmill run. The other experimental run includes no carbohydrates in the diet for three days, then adding 1000 Calories of Dextrose beginning three days prior to the treadmill run. My weight, heart rate, oxygen consumption and respiratory quotient will be taken at five minute intervals for each 90 minute test. I will be asked to breathe into a mouthpiece apparatus for each sample.

I waive any possibility of personal damage which may be blamed upon such a program in the future and accept the responsibility for requesting this exercise. To my knowledge, I am not infected with a contagious disease, or limiting physical condition or disability, especially with respect to my heart, that would preclude the exercise and diet regimen.

I understand that I may drop out of this study at any time.

______________________________ Date____________
Subject's Signature

APPENDIX B

Personal Data on Subjects

Subject	Age	Height	Best Mile	Est. Max. H.R.	Treadmill Speed mph
1	37	6'2"	5:24	183	7.4
2	38	5'9"	5:59	182	6.5
3	28	5'11"	4:26	192	8.5
4	19	6'2"	4:51	201	7.0

APPENDIX C

Foods to Avoid During Carbohydrate Depletion

apples
apricots
bagels
barley
bananas
beans
beets
blintzes
blueberries
breads
buns
cakes
candies
carrots
cereals
cherries
cocoa
coconut
cookies
corn
crackers
cranberries
croquettes
doughnuts
eggnog
figs
flour
french toast
fruit cocktail
gelatin
grapefruit
grapes
ice cream
jams
juices
nuts
muffins
macaroni
noodles
oranges
pastries
pears
peas
pies
pineapple
plums
puddings
raisins
rhubarb
sandwiches
sauces
soft drinks
soups
strawberries
sugars
syrups
waffles
watermelon

APPENDIX D

Foods to Consume During
Carbohydrate Depletion

<u>Alcoholic Beverages</u>

Applejack

Bourbon whiskey

Brandy

Canadian whiskey

Gin

Hot buttered Rum

Martini

Rob Roy (dry vermouth)

Rum

Rye highball (soda)

Rye whiskey

Scotch highball (soda)

Scotch mist

Scotch whiskey

Slow gin

Vodka

Anchovies (canned)

Anchovy paste (1 tsp)

Bacon (broiled or fried)

Bacon (Canadian 1 slice)

Pastrami

Perch (fresh)

Pike

Pompano

Porgy

<u>Pork</u>

Chops

Roast

Salt

Shoulder

Spareribs

Tenderloin

Red Snapper

Romaine Lettuce

Bass (baked)

Bass (broiled)

<u>Beef</u>

Boiled

Braised

Corned

Hamburger

Roast

Round

Short Ribs

Steak

Stewing

Tongue (boiled)

Beef suet

Bluefish

Bouillion Cube

Butter (sweet)

Butterfish

Capers

<u>Cheese</u>

American

Cream

Liederkranz

Parmesan

<u>Salad Dressing</u>

Mayonaise

Roquefort

Vinegar and oil

<u>Salmon</u>

Broiled

Baked

Canned

Smoked (lox)

Sardines

Hollandaise

Sausage, Pork

<u>Chicken</u>

Broiled

Broiler

Canned (boned)

Fryer

Roaster

Stewing

Chives
Clams (canned)
Codfish
Cream (whipped)
Deviled meat
Duck
Eels
Eels (smoked)
<u>Eggs</u>
Raw
Boiled or poached
Dried
Fried
Omelet (plain)
Omelet (cheese)
Sesame seeds
Shad
Scampi shrimp
Sole
<u>Soft Drinks</u>
Low calorie
Soda, selzer
Water
<u>Soups</u>
Bouillion
Chicken broth
Consomme
Jellied consomme
Spices (1 tsp)

Squab
<u>Fats</u>
Bacon (1 tsp)
Chicken
Cooking
Vegetable
Finnan haddie
Flounder
Frog legs
Garlic
Gelatin (plain)
Goose
Haddock (baked)
Halibut (broiled)
<u>Ham</u>
Fresh (boiled)
Canned (boneless)
Canned (deviled)
Prosciutto
Head Cheese
Herbs
<u>Herring</u>
Kippered
Pickeled
Smoked
Horse-radish
Sturgeon
Swordfish
Sweetbreads

Tea
Tongue (canned)
Tripe
Trout (brook)
Trout (lake)
Tuna
Turkey
Turtle
Vanilla extract
<u>Lamb</u>
Breast
Chops
Ground
Roast Leg
Roast shoulder
Shish kebab
Liver spread
<u>Lobster</u>
Broiled
Canned
Creamed
Cocktail
Paste
Mackerel
Margarine (1 tsp)
Mint (1 tsp)
Mustard (dry)
<u>Oils</u>
Corn

Cottonseed

Mineral

Olive

Peanut

Salad

Veal

Chop

Cutlet

Roast

Stewing meat

White fish (steamed or smoked)

APPENDIX E

Sample Data Sheets

HEART RATE

TIME	Beats per minute	TIME	Beats per minute
RESTING		44-45	
4-5		49-50	
9-10		54-55	
14-15		59-60	
19-20		64-65	
24-25		69-70	
29-30		74-75	
34-35		79-80	
39-40		84-85	
		89-90	

VENTILATED AIR

TIME		V AIR	TIME		V AIR
		liters/min.			liters/min.
RESTING	Finish	______	49-50	Finish	______
	Start	______		Start	______
	△	______		△	______
4-5	Finish	______	54-55	Finish	______
	Start	______		Start	______
	△	______		△	______
9-10	Finish	______	59-60	Finish	______
	Start	______		Start	______
	△	______		△	______
14-15	Finish	______	64-65	Finish	______
	Start	______		Start	______
	△	______		△	______
19-20	Finish	______	69-70	Finish	______
	Start	______		Start	______
	△	______		△	______
24-25	Finish	______	74-75	Finish	______
	Start	______		Start	______
	△	______		△	______
29-30	Finish	______	79-80	Finish	______
	Start	______		Start	______
	△	______		△	______
34-35	Finish	______	84-85	Finish	______
	Start	______		Start	______
	△	______		△	______
39-40	Finish	______	89-90	Finish	______
	Start	______		Start	______
	△	______		△	______
44-45	Finish	______			
	Start	______			
	△	______			

SUBJECT:		WET BULB:	°C		
DATE:		DRY BULB:	°C	WEIGHT IN :	lbs / Kg
TESTING TIME:		PH_2O :			
TR. SPEED:	mph	P bar :	mm Hg	WEIGHT OUT:	

TIME	O_2.1	CO_2	VO_2	ml/kg	Ve	STPD cf	R.Q.
Rest							
4-5							
9-10							
14-15							
19-20							
24-25							
29-30							
34-35							
39-40							
44-45							
49-50							
54-55							
59-60							
64-65							
69-70							
74-75							
79-80							
84-85							
89-90							

APPENDIX F

Conversion For 30 Pulse Beats

Sec.	HR/min.				
22.0sec. -	82/min.	17.3sec. -	104/min.	12.6sec. -	143/min.
21.9	83	17.2	105	12.5	144
21.8	83	17.1	105	12.4	145
21.7	83	17.0	106	12.3	146
21.6	83	16.9	107	12.2	148
21.5	84	16.8	107	12.1	149
21.4	84	16.7	108	12.0	150
21.3	85	16.6	108	11.9	151
21.2	85	16.5	109	11.8	153
21.1	85	16.4	110	11.7	154
21.0	86	16.3	110	11.6	155
20.9	86	16.2	111	11.5	157
20.8	87	16.1	112	11.4	158
20.7	87	16.0	113	11.3	159
20.6	87	15.9	113	11.2	161
20.5	88	15.8	114	11.1	162
20.4	88	15.7	115	11.0	164
20.3	89	15.6	115	10.9	165
20.2	89	15.5	116	10.8	167
20.1	90	15.4	117	10.7	168
20.0	90	15.3	118	10.6	170
19.9	90	15.2	118	10.5	171
19.8	91	15.1	119	10.4	173
19.7	91	15.0	120	10.3	175
19.6	92	14.9	121	10.2	176
19.5	92	14.8	122	10.1	178
19.4	93	14.7	122	10.0	180
19.3	93	14.6	123	9.9	182
19.2	94	14.5	124	9.7	184
19.1	94	14.4	125	9.7	186
19.0	95	14.3	126	9.6	188
18.9	95	14.2	127	9.5	189
18.8	96	14.1	128	9.4	191
18.7	96	14.0	129	9.3	194
18.6	97	13.9	129	9.2	196
18.5	97	13.8	130	9.1	198
18.4	98	13.7	131	9.0	200
18.3	98	13.6	132	8.9	202
18.2	99	13.5	133	8.8	205
18.1	99	13.4	134	8.7	207
18.0	100	13.3	135	8.6	209
17.9	101	13.2	136	8.5	212
17.8	101	13.1	137	8.4	214
17.7	102	13.0	138	8.3	217
17.6	102	12.9	140	8.2	220
17.5	103	12.8	141	8.1	222
17.4	103	12.7	142	8.0	225

APPENDIX G

Raw Data

RAW DATA

Subject #1
Heart Rate

	Control	Exp. I	Exp. II
Rest	74	59	49
4-5	136	119	123
9-10	135	122	122
14-15	136	122	125
19-20	135	122	123
24-25	140	125	127
29-30	135	125	123
34-35	138	123	129
39-40	137	127	126
44-45	140	127	126
49-50	136	126	126
54-55	138	127	124
59-60	134	127	129
64-65	138	124	129
69-70	140	123	127
74-75	138	128	129
79-80	138	129	126
84-85	142	129	129
89-90	144	129	129

RAW DATA

Subject #1
Heart Rate

	Control	Exp. I	Exp. II
Rest	74	59	49

	Control	Exp. I	Exp. II
Rest	74	59	49
4-5	136	119	123

	Control	Exp. I	Exp. II
Rest	74	59	49
4-5	136	119	123
9-10	135	122	122
14-15	136	122	125

	Control	Exp. I	Exp. II
Rest	74	59	49
4-5	136	119	123
9-10	135	119	123
14-15	136	122	125

RAW DATA

Subject #2
Heart Rate

	Control	Exp. I	Exp. II
Rest	89	81	100
4-5	164	157	161
9-10	162	155	159
14-15	162	157	159
19-20	162	153	159
24-25	157	161	162
29-30	159	157	162
34-35	158	159	162
39-40	161	157	164
44-45	159	158	162
49-50	157	155	161
54-55	157	155	162
59-60	161	155	161
64-65	159	154	161
69-70	162	157	161
74-75	159	157	155
79-80	159	157	155
84-85	161	157	158
89-90	162	157	157

RAW DATA

Subject #3
Heart Rate

	Control	Exp. I	Exp. II
Rest	90	72	88
4-5	138	149	161
9-10	151	151	155
14-15	151	157	156
19-20	157	162	157
24-25	154	164	155
29-30	158	157	161
34-35	158	155	159
39-40	167	155	161
44-45	165	155	155
49-50	170	155	157
54-55	162	155	155
59-60	167	161	158
64-65	167	164	162
69-70	171	158	157
74-75	167	164	158
79-80	164	161	161
84-85	166	162	157
89-90	167	161	158

RAW DATA

Subject #4
Heart Rate

	Control	Exp. I	Exp. II
Rest	90	103	89
4-5	145	151	150
9-10	155	158	149
14-15	157	158	150
19-20	155	158	150
24-25	154	157	150
29-30	155	158	154
34-35	157	158	155
39-40	154	162	157
44-45	157	162	149
49-50	158	155	153
54-55	161	158	151
59-60	162	157	153
64-65	162	158	153
69-70	162	161	153
74-75	162	164	154
79-80	162	164	153
84-85	162	164	159
89-90	162	164	159

RAW DATA

Subject #1
VO_2

	Control	Exp. I	Exp. II
Rest	0.5430	0.25259	0.34904
4-5	3.38200	2.83507	2.83726
9-10	3.28642	2.90285	2.87272
14-15	2.92419	2.70447	2.86041
19-20	2.83947	2.73536	2.74342
24-25	2.98501	2.82613	2.55875
29-30	2.92683	2.74893	2.62904
34-35	2.93628	2.73521	2.45887
39-40	2.90834	2.83079	2.59658
44-45	2.88776	3.01808	2.56599
49-50	2.99919	2.77756	2.56496
54-55	2.90303	2.86705	2.43680
59-60	2.90676	2.68901	2.46030
64-65	2.88851	2.91401	2.47571
69-70	2.97576	2.74860	2.78780
74-75	2.89101	2.90383	2.64669
79-80	2.93974	2.82185	2.73967
84-85	3.01973	2.79933	2.95760
89-90	2.94511	2.82052	2.68228

RAW DATA

Subject #2
VO_2

	Control	Exp. I	Exp. II
Rest	0.47316	0.41739	0.52071
4-5	2.31103	2.41739	2.56458
9-10	2.85716	2.54061	2.46199
14-15	2.59726	2.49205	2.44256
19-20	2.58244	2.40750	2.57702
24-25	2.72610	2.46024	2.59323
29-30	2.67684	2.42979	2,54425
34-35	2.65203	2.52155	2.61630
39-40	2.43374	2.72850	2.55564
44-45	2.52569	2.51014	2.57640
49-50	2.66507	2.48500	2.57743
54-55	2.55776	2.55431	2.52283
59-60	2.42338	2.64644	2.64970
64-65	2.65749	2.53355	2.60998
69-70	2.62587	2.63145	2.53467
74-75	2.48970	2.50277	2.57552
79-80	2.51077	2.54118	2.58632
84-85	2.66827	2.52494	2.68168
89-90	2.71306	2.57668	2.68674

RAW DATA

Subject #3
VO_2

	Control	Exp. I	Exp. II
Rest	2.5895	0.29581	0.35623
4-5	3.23905	2.74162	2.82164
9-10	3.06508	2.62134	2.99139
14-15	3.11192	2.66135	2.98030
19-20	3.16022	2.88877	3.07920
24-25	2.76573	2.82367	2.99672
29-30	2.78844	2.81343	3.10026
34-35	3.14383	2.75444	3.03566
39-40	3.18414	2.75775	3.07870
44-45	2.88040	2.94708	2.95979
49-50	2.97291	2.78402	3.02851
54-55	2.90290	2.94679	3.06158
59-60	2.94572	2.83929	2.75483
64-65	2.89758	2.92345	2.80388
69-70	3.13429	2.82138	3.07233
74-75	3.10621	2.84812	3.09750
79-80	2.80483	2.89128	2.93808
84-85	2.96944	2.81394	3.00063
89-90	3.04574	2.75345	2.94222

RAW DATA

Subject #4
VO_2

	Control	Exp. I	Exp. II
Rest	0.32969	0.37661	0.32233
4-5	2.63834	2.74200	2.45197
9-10	2.70774	2.82322	2.56730
14-15	3.01722	2.63089	2.79658
19-20	2.80838	2.66140	2.53426
24-25	2.80011	2.97844	2.44065
29-30	3.06338	2.74479	2.37223
34-35	2.91204	2.81547	2.82474
39-40	2.76684	2.86014	2.62011
44-45	2.68681	2.74715	2.68053
49-50	2.51687	2.81098	2.70778
54-55	2.77778	2.97702	2.67980
59-60	2.93801	2.91236	2.52356
64-65	2.92665	2.83748	2.58795
69-70	2.78080	2.93748	2.7950
74-75	2.82203	3.02836	2.67562
79-80	2.75122	2.63297	2.69779
84-85	2.78324	2.71735	2.75756
89-90	2.83856	2.67347	2.91808

RAW DATA

Subject #1
R.Q.

	Control	Exp. I	Exp. II
Rest	.92959	.90416	.91121
4-5	.91168	.83350	.94218
9-10	.95580	.83096	.89360
14-15	.95102	.83342	.84035
19-20	.97754	.81384	.84313
24-25	.92922	.76662	.87008
29-30	.94386	.78444	.83096
34-35	.98400	.82753	.88152
39-40	.87048	.80036	.90959
44-45	.87890	.73086	.84456
49-50	.82237	.75929	.86818
54-55	.82940	.75344	.91611
59-60	.86487	.81644	.89837
64-65	.86066	.80588	.92367
69-70	.78751	.80843	.81236
74-75	.78751	.79786	.88450
79-80	.80539	.80588	.81839
84-85	.78004	.77084	.78004
89-90	.75464	.85780	.83350

RAW DATA

Subject #2
R.Q.

	Control	Exp. I	Exp. II
Rest	1.0563	.78819	1.7997
4-5	.79114	.73660	.74006
9-10	.76035	.77474	.74931
14-15	.82811	.77768	.79987
19-20	.76777	.79979	.79388
24-25	.71457	.78598	.82863
29-30	.71935	.75107	.79157
34-35	.75754	.76406	.78391
39-40	.75952	.77560	.83725
44-45	.74064	.75466	.83597
49-50	.71077	.76682	.85192
54-55	.72800	.74240	.84495
59-60	.78496	.66786	.83010
64-65	.73374	.70857	.78748
69-70	.69011	.70735	.80408
74-75	.72625	.72266	.76842
79-80	.74861	.76035	.75632
84-85	.68679	.74737	.76023
89-90	.76434	.74320	.73491

RAW DATA

Subject #3
R.Q.

	Control	Exp. I	Exp. II
Rest	1.15609	1.25498	1.06549
4-5	.84161	.95493	.91982
9-10	.82716	1.01638	.89542
14-15	.82563	.95331	.84848
19-20	.85401	.90683	.85859
24-25	.89636	.95437	.88258
29-30	.95985	.96357	.84848
34-35	.83552	.96396	.87738
39-40	.82637	.93803	.84036
44-45	.82637	.90139	.86658
49-50	.84790	.89034	.86464
54-55	.83787	.90624	.84179
59-60	.84444	.89551	.85140
64-65	.84035	.88766	.85711
69-70	.78072	.88258	.84179
74-75	.77695	.90074	.81096
79-80	.79040	.89800	.85401
84-85	.80944	.89582	.84179
89-90	.79781	.91614	.85320

RAW DATA

Subject #4
R.Q.

	Control	Exp. I	Exp. II
Rest	.79777	.87324	.82155
4-5	.87891	.9884	.80493
9-10	.84733	.94081	.90879
14-15	.78686	.89838	.86928
19-20	.79170	.89800	.94104
24-25	.78944	.86000	.97453
29-30	.63736	.86825	.89551
34-35	.76354	.89041	.93630
39-40	.76875	.86658	.93776
44-45	.82898	.92352	.89069
49-50	.86825	.88305	.92161
54-55	.90166	.83010	.90766
59-60	.87516	.89329	.94078
64-65	.88007	.86360	.98260
69-70	.86611	.86611	.93427
74-75	.87964	.94458	.96915
79-80	.88512	.91347	.91121
84-85	.90432	.85670	.94907
89-90	.83401	.91159	.95345

THE EFFECT OF DIFFERENT LEVELS OF DEXTROSE
INTAKE ON ENDURANCE RUNNING

by

PAUL SHIMON

B.S., Texas A&M University, 1970

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Health, Physical Education and Recreation

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1975

The purpose of this study was to determine which of the following dietary regimens was most efficient for reducing heart rate and oxygen consumption and for increasing the respiratory quotient during a 90 minute treadmill run: 1) a normal seven-day diet, 2) a regimen consisting of three days of carbohydrate depletion and 60 minutes of running per day followed by three days of normal diet plus 500 Calories of Dextrose and no running and 3) a regimen consisting of three days of carbohydrate depletion and 60 minutes of running per day followed by three days of normal diet plus 1000 Calories of Dextrose and no running. Four male subjects ranging in age from 19 to 38 were selected for this investigation on the basis that they could run for 90 minutes on a treadmill. Subjects ran a control treadmill run and then were randomly assigned to the experimental treatment and testing conditions. Each subject ran at approximately 50% of their maximum oxygen uptake. Subjects were tested for heart rate, oxygen consumption and respiratory quotient at rest and during five minute intervals throughout each 90 minute treadmill run to determine what relationship existed among variables. A split plot ANOVA was performed on all three variables to determine if there was a significant difference in response of heart rate, oxygen consumption or respiratory quotient among subject's diets. No significance was found among the responses to the diets. Individual case studies indicated no distinct trends. It was therefore concluded that some other variable was responsible for the improvement experienced by runners using carbohydrate loading regimens prior to prolonged endurance performances.