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REHYDRATION USING A GLUCOSE POLYMER/FRUCTOSE
ELECTROLYTE SOLUTION FOLLOWING PROLONGED HEAVY EXERCISE

The Ohio State University

PH.D. 1981

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REHYDRATION USING A GLUCOSE POLYMER/FRUCTOSE
ELECTROLYTE SOLUTION FOLLOWING PROLONGED
HEAVY EXERCISE
DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

William Allan Norris, B.S., M.S.

* * * * *

The Ohio State University

1981

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To my parents who have supported me in all
my endeavors,

To Marie, for her love and devotion

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Thank you.

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TABLE OF CONTENTS

	Page
DEDICATION	ii
ACKNOWLEDGEMENTS	iii
VITA	iv
LIST OF TABLES	vii
LIST OF FIGURES	viii
 Chapter	
I. Introduction	1
Statement of the Problem	3
Definitions of Terms	3
Limitations	6
II. Review of the Literature	7
Literature Related to Fluid Loss	
During Exercise	8
Literature Related to Glucose	
Ingestion and Performance	10
Literature Related to Gastric	
Emptying of Glucose	14
Literature Related to Blood	
Modifications During Exercise	16
Summary	19
III. Methods and Procedures	20
Design of the Study	20
Selection of Subjects	21
Cardiorespiratory Determinations	22
Fluid Ingestion	23
Blood Analysis	24

	Page
IV. Results	30
Blood Analysis	31
Cardiorespiratory Determinations	45
V. Discussion	59
VI. Summary and Conclusions	64
Recommendations for Further Study	65
BIBLIOGRAPHY	67

LIST OF TABLES

Table		Page
1	Physical Characteristics of Subjects	26
2	Research Protocol for Treatment and Conditions	27
3	Protocol for Blood Collection	28
4	Subject Weight Loss During Testing Session .	29
5	Blood Hematocrit Data	33
6	Blood Triglyceride Data	35
7	Blood Free Fatty Acid Data	37
8	Blood Glucose Data	39
9	Blood Insulin Data	41
10	Blood Lactate Data	43
11	$\bar{V}E$ Respiratory Data	47
12	$\bar{V}O_2$ l/min Respiratory Data	49
13	$\bar{V}CO_2$ l/min Respiratory Data	51
14	$\bar{V}O_2$ ml/kg-min Respiratory Data	53
15	$\bar{R}$ Values	55
16	Heart Rate Data	57

LIST OF FIGURES

Figure		Page
1	Hematocrit	34
2	Triglycerides	36
3	Free Fatty Acids	38
4	Glucose	40
5	Insulin	42
6	Lactate	44
7	$\bar{V}E$	48
8	$\bar{V}O_2$ l/min	50
9	$\bar{V}CO_2$ l/min	52
10	$\bar{V}O_2$ ml/kg-min	54
11	$\bar{R}$ Values	56
12	Heart Rate	58

CHAPTER I

INTRODUCTION

Proper hydration of the athlete or any individual performing prolonged hard work has been a concern of researchers for many years. Work performance can be seriously hindered by sweat losses greater than 5% of body weight. As fluids are lost, there is a reduction in the stroke volume of the heart. An elevated heart rate is required to compensate for the reduced blood volume and to maintain a regulatory cardiac output. In order to control this loss of body water and maintain a normo-hydrated state, fluids must be ingested at regular intervals.

This replacement of fluids, however, may not always be possible during the course of an athletic event such as soccer where they may play for 45 continuous minutes or during distance races of 10, 20, 30, and 40 kilometers that have become increasingly popular. The loss of body water through exercise can be seriously compounded by high temperatures and humidity during the performance. If loss of body fluids is not to be a limiting factor in an activity, then the intracellular and extracellular fluids need to be replenished in an effort to restore water, electrolytes, and foodstuffs that have been utilized during that performance.

In quest of the ideal fluid to rehydrate and nourish the athlete, many compositions have been tried (16, 19, 25). A review of previous research dealing with ergogenic fluids for rehydration indicates that the liquid composition should manifest certain characteristics. The composition should be readily absorbed by the stomach and cleared at approximately the same rate as water. It should enhance the carbohydrate fuel supply in the body, as carbohydrates are the predominant energy source for physical activity. The fluid should replace electrolytes that are lost from the strenuous activity and also be palatable to promote its usage ad libitum.

Due to carbohydrates supplying the major source of energy for intense work, many different amounts and concentrations of glucose have been evaluated in order to fuel this metabolic demand. Previous research has indicated that those mixtures which have delivered a significant supply of calories to the digestive tract have also been high in osmolality and delayed gastric emptying (16, 19, 24, 26). Recent work (27, 38), however, demonstrated that a polymerized form of glucose can supply a significantly greater amount of carbohydrate to the blood glucose pool and still empty from the gut faster than glucose. The effectiveness of a polymerized glucose solution during exercise has yet to be evaluated and must respond favorably to the aforementioned criteria of delivering an optional

carbohydrate load without compromising rapid absorption and clearance by the stomach.

Statement of the Problem

The purpose of this study was to compare a 7% polymerized glucose solution with water in order to evaluate its effect on rehydration and recovery following prolonged heavy exercise. Each subject was monitored four times with one week between each evaluation. The six subjects ran for 60 minutes on the treadmill at a speed and grade that would elicit a metabolic rate of 67% $\dot{V}O_{2\max}$. Immediately following the run, the subjects began drinking 1.2 liters of the test solution during a 75-minute recovery period. The polycose and water fluids were utilized during a walking and a resting recovery.

Parameters evaluated during this study were $\dot{V}O_{2\max}$, $\dot{V}_E$, $\dot{V}O_2$ l/m, $\dot{V}CO_2$ l/m, R, $\dot{V}O_2$ ml/kg/min, RPE, Heart Rate, and blood adaptation in glucose, insulin, hematocrit, triglycerides, lactate, and free fatty acids.

Definitions of Terms and Symbols

1. Glucose polymer/fructose electrolyte solution - Polymerized glucose is an oral carbohydrate solution prepared by a controlled hydrolysis of corn starch and contains a variety of polymer lengths. The approximate

distribution of these polymer lengths is tabulated below:

<u>Chain Length</u>	<u>Percentage</u>
Free glucose	2%
2-4 glucose units	15-20%
5-10 glucose units	30-36%
10 or more glucose units	42-52%

The solution has an average molecular weight of 1000, about 5 times that of free glucose. The increased molecular weight results in an osmolality that is one-fifth that of an isocaloric glucose solution. The polymers are linked predominately by alpha 1-4 glucosidic bonds with limited beta 1-6 branching.

Polymerized glucose is rapidly absorbed. Amylase and pancreatic and intestinal maltases quickly hydrolyze the polymer to free glucose. These enzymes are widely distributed on the mucosal brush border in the small intestine. After hydrolysis, the glucose is rapidly absorbed into the portal blood.

The experimental solution used in this study formed a 7% concentration comprised of 2% fructose (to enhance the organoleptic characteristics) and 5% polycose. The delivered calories are shown below:

5% polycose =	60 g polycose =	240 calories
2% fructose =	24 g fructose =	96 calories
<hr/>		
7% solution	84 grams of carbohydrate	336 calories delivered

Comparison of polycose to a typical glucose ingestion is shown below:

<u>Total CHO in Solution</u> (g/100 ml)	<u>Osmolality of Solution</u> (mOsmal/L)	
	<u>Polycose</u>	<u>Glucose</u>
5	56	304
10	111	602
20	231	1325
40	534	3000

The mineral content of the 7% test solution used for the restoration of lost electrolytes is portrayed below:

	<u>mEq/L</u>
Na	10.0
K	5.0
Cl	10.0
Mg	2.0
Ca	2.0

(POLYCOSE Product monograph. 1977. Ross Laboratories, Columbus, Ohio.)

2. R - Respiratory exchange ratio ($\dot{V}CO_2/\dot{V}O_2$).
3. RPE - Rating of perceived exertion, the Borg Scale.
4. Rest-Recovery - The period following prolonged heavy exercise in which no activity is performed for 75 minutes.

5. Walk-Recovery - The period following prolonged heavy exercise in which the subject rested for 10 minutes, walked at 40% $\dot{V}O_2$ max, and then rested for 15 minutes.

6. Rehydration - Ingestion of 1.2 liters of either water or glucose polymer/fructose solution.

7. $\dot{V}CO_2$ l/m - Carbon dioxide production in liters per minute.

8. $\dot{V}_E$ - Volume of expired gas per minute.

9. $\dot{V}O_2$ l/m - Oxygen consumption in liters per minute.

10. $\dot{V}O_2$ ml/kg/min - Oxygen consumption in liters per minute.

11. $\dot{V}O_2$ max - Maximal volume of oxygen consumed per minute during exercise.

Limitations

This study involved six graduate students at The Ohio State University who were in good physical shape for the performance of two continuous hours of aerobic work. Subjects exercised 12 hours post-absorptive and were aware of the experimental or control fluid they were ingesting. The subjects were not asked to alter their typical exercise regimens or diets due to the randomized testing protocol.

CHAPTER II

REVIEW OF LITERATURE

Due to the voluminous quantity of research dealing with enhancement of performance, only those studies with definite application to the stated problem of this dissertation are cited. Glucose ingestion and its effect on performance has been presented by many authors (2, 6, 8, 11, 13, 14, 16, 25, 26, 38, 45, 53). Although glucose is used to replete energy stores of carbohydrate in the body, its restriction of use for high intensity work and fluid hydration categorize it as a questionable ergogenic aid. Proper rehydration is also of critical importance to the athlete during prolonged hard work if he is to limit the rise in core temperature and maintain a plasma volume that will not restrict performance. Literature emphasizing this concern is also cited in this chapter. In order to evaluate the metabolic adaptations during performance, several blood parameters have been monitored to evaluate internal modifications due to rehydration and glucose ingestion. Previous studies that describe techniques in blood sampling and alterations in blood concentrations are presented.

The experimental treatment in this study is not only of concern in enhancing the supply of blood glucose in the body, but also that it will not restrict fluid emptying from

the stomach. Glucose ingestions in high concentrations not only move very slowly out of the gut but also require additional water from the body's fluid compartments to dilute the concentrate. Research dealing with gastric emptying properties of glucose solutions is also presented here.

Literature Related to Fluid Loss during Exercise

A great deal of information has been written on fluid loss during activity (15, 17, 20, 31, 39, 45, 47, 55). The loss of body water not only reduces electrolyte and plasma volume levels, but also promotes a rise in core temperature (31, 45, 47). The following research studies these areas.

Pitts, Johnson, Consolazio, 1944 (45)

Six healthy young men who were fully acclimatized marched on inclined treadmills in conditions of hot dry heat and hot moist heat. Heart rate, sweat rate, and rectal temperatures were monitored during the evaluation of water, salt, and glucose for fluid replacement. It was noted that constant fluid replacement with water was able to regulate the core temperature and that salt replacement via a saline solution was able to aid in the control of sweating. The addition of glucose to water produced no appreciable effect; however, glucose in larger doses produced nausea.

Pugh, Corbett, Johnson, 1967 (47)

Weight loss, sweat rates, and core temperatures were recorded on 75 runners following a marathon run. The top finishers were those runners who also had the highest core temperatures and had lost the highest percentages of body weight when compared with the other finishers. It was concluded that heat elimination is a limiting factor for many runners and the successful runners are those who can dissipate and tolerate the elevated temperatures.

Costill, Kammer, Fisher, 1970 (15)

A protocol of three two-hour runs was employed to evaluate the conditions of no fluid replacement, water ingestion, and glucose-electrolyte ingestion on four marathon runners. The glucose-electrolyte solution was able to sustain blood glucose and R values while regulating the core temperature. Gastric residues were equal for water and glucose-electrolyte ingestion while metabolic parameters of $\dot{V}O_2$, $\dot{V}_E$, and heart rate were similar for all conditions.

Gisolfi and Copping, 1974 (31)

Six highly conditioned men ran for 1.5 and 2.5 hours at 75% of their $\dot{V}O_2$ max in a hot environment. Hydration before and during the run was compared along with temperatures of the water ingested and core temperatures

of the athletes. The results indicated that the internal temperature increase is related to the percent of water lost and not to the temperature of the ingested fluid. Core temperature is controlled to a greater extent by drinking fluids during the run rather than before.

Literature Related to Glucose Ingestion and Performance

The use of glucose to extend work time and nourish muscular activity has been well-documented (2, 6, 8, 11, 13, 14, 16, 25, 26, 38, 45, 53). The use of glucose, however, has not always been widely promoted for exercise due to its slow absorption rate. Glucose in high concentrations could prove to be a limiting rather than a beneficial factor.

Hermansen, Pruett, Osnes, Giere, 1970 (33)

Two female and three male college students participated in this analysis of blood glucose and plasma insulin concentrations during and after maximal exercise of very short duration. These responses were compared with changes in blood sugar and plasma insulin induced by glucose infusion. Blood glucose increased after intermittent running by 109% and 118% following glucose infusion. Insulin value increased 273% following exercise and 179% after the infusion. Peak insulin values lagged 10 minutes behind peak glucose levels during the exercise phase but both variables showed no time difference during the resting infusion.

Costill, Bennett, Branam, Eddy, 1973 (13)

An aqueous solution of glucose was tagged with labeled glucose- ^{14}C was monitored at rest and during prolonged physical activity (60-72% $\dot{V}\text{O}_2$ max). The seven male subjects ran or cycled for 30 minutes before and 60 minutes following the glucose feeding. It appeared that exercise had little affect on this amount of glucose ingestion as ^{14}C appeared in the serum and expired in 5-7 minutes post-ingestion. Glucose was utilized 6.5 times faster during exercise than at rest and from minutes 30 to 75 post-ingestion the liver appeared to decrease its contribution to blood glucose levels. Any metabolic gains derived from this ingestion would not be realized until 20-30 minutes following ingestion.

Ahlborg, Felig, 1976 (2)

Four hours of bike ergometry at 30% $\dot{V}\text{O}_2$ max was used to evaluate the effects of a 200-gram glucose ingestion (at 90 minutes of exercise) and no food intake on performance. Arterial glucose rose 35%, free fatty acids and glycerol fell 60-70%, and a two-to three-fold increase in insulin was observed following glucose ingestion. Plasma glucagon showed a four-fold increase in the controls but did not increase in the glucose group. A two-fold uptake of glucose was seen in the exercising legs and splanchnic glucose output increased an identical amount in the glucose

ingestion group in spite of a 70-100% reduction of gluconeogenic precursors (lactate, pyruvate, and glycerol).

Ahlborg, Felig, 1977 (3)

A glucose ingestion of 200g was administered 50 minutes prior to four hours of cycling at 30% $\dot{V}O_2$ max. A control group cycled without a food supplement. As in their earlier work, the authors noted a 35% use in arterial glucose, glycerol reduction of 60-70%, a two-to three-fold rise in insulin, and a greater uptake of glucose by exercising muscles all in the glucose-fed subjects. Through the use of a pre-exercise ingestion, it was observed that glucagon decreased 60-75% and that arterial free fatty acids showed a gradual rise after approximately 2 hours of performance. In comparison with the authors' previous work, the free fatty acids played a greater role in energy supply during the final phase of exercise while hyperinsulinemia and relative hypoglucagonemia were present at the onset of activity.

Ivy, Costill, Fink, Lower, 1979 (38)

Nine trained cyclists performed 2 hours on a bike ergometer to evaluate treatments of caffeine (250 mg before and 250 mg during exercise), glucose polymer (90 g during exercise), and no intake. The caffeine ingestion increased work production significantly over the control values and fat oxidation was elevated 31% during the final hour of

performance. The glucose polymer was not able to elevate total work production above the control levels but did significantly maintain glucose and insulin levels. Carbohydrate utilization was substantially greater during the final ten minutes and work production surpassed that performed during the initial ten minutes when the polymerized glucose was used. These values, combined with a reduction in fatigue rate, made it unclear as to minimal change in total work production for this treatment.

Bonen, Malcolm, Kilgour, MacIntyre, Belcastro, 1981 (8)

Following a 36-44 hour fast, combined with exhaustive exercise to deplete glycogen stores, subjects performed in groups of glucose ingestion 15 minutes before, glucose ingestion during, no glucose, and no exercise. With no glucose ingestion, blood glucose decreased during exercise and lactate and R values remained low. In the pre-exercise glucose group lactate values doubled and R values significantly increased; however, blood glucose levels declined during performance and did not elevate until recovery. When glucose was ingested during performance, insulin and glucose value showed a steady increase during recovery from their stable exercise levels. Ingestion during intense performance maintain an increased utilization of carbohydrate energy from its exogenous source, whether it is enhanced by muscle glycogen or not, and fat metabolism is reduced even when FFA concentrations are elevated.

Literature Related to Gastric Emptying of Glucose

For a glucose solution to be effective, it needs to deliver a significant carbohydrate load to the system without delaying gastric emptying. The higher concentrations will tend to draw water into the stomach rather than send it out.

Fordtran, Saltin, 1967 (25)

One hour of treadmill running at 70% $\dot{V}O_2$ max was used to evaluate gastric emptying in four males and one female. The subjects drank 750 ml both at the start of and during exercise. Two solutions were compared--13.3% glucose and 0.3% sodium chloride and water which contained a volume marker. The glucose solution was not significantly slowed in its clearance between rest and exercise. Exercise did not demonstrate any limiting effects on glucose, water, electrolytes, and bicarbonate. Glucose ingestion (100 g) and salt (2.25 g) can be used effectively to delay fatigue and will be readily absorbed by the gut without a compromise of internal water.

Costill, Saltin, 1974 (17)

Fifteen men served as subjects and their own controls in a gastric emptying study that evaluated various glucose concentrations, various volumes ingested, temperature of the solute, and during rest and exercise. At rest, even

small amounts of glucose retard gastric emptying. Fluids of 20°C or less showed the best clearance from the stomach, and volumes of 600 ml or less achieved the maximum rate of clearance. Exercise did not affect the rate of gastric clearance until the intensity exceeded 70% $\dot{V}O_2$ max indicating that very intense work would retard clearance of any ingested glucose solute regardless of its minimal concentration.

Coyle, Costill, Fink, Hoopes, 1978 (19)

Three sports drinks were compared for gastric emptying rates and delivery of water, carbohydrate, and electrolytes 15 minutes after ingestion. A nasal-gastric tube was placed in the twelve subjects who drank 400 ml of the test solutions and were aspirated fifteen minutes later. The volumes of Brakettime, Body Punch, and water emptied in 15 minutes were not significantly different, while 35 to 40% more Gatorade remained uncleared. At the 15 minute clearance period, Brakettime, Body Punch, and Gatorade delivered 1.9, 4.5, and 6.8 g of carbohydrate to the stomach. Electrolyte efflux could not be evaluated due to rapid chemical exchanges across the gastric wall.

Foster, Costill, Fink, 1980 (27)

Solutions of glucose and a glucose polymer in concentrations of 5, 10, 20, and 40% were analyzed 30 minutes after ingestion for gastric residue and carbohydrate

delivery. Fifteen subjects drank 400 ml of each solute in determining that as concentrations increase, there is a likewise increase in gastric residue. The glucose polymer was able to clear the stomach significantly faster than the lowest concentration of glucose and induced a minimal rate of gastric secretion. The 5% glucose polymer approaches the gastric emptying rate for water and supplies significant more carbohydrate to the system than glucose. The combination of 69% more fluid and 33% more carbohydrate indicate polymerized glucose as a much more viable fuel source in an athletic drink.

Literature Related to Blood Modifications during Exercise

The following studies look at the effects glucose and exercise have on different blood parameters. Intensity plays an important role during exercise as to the amount of glucose that will be cleared by the digestive system.

Issekutz, Miller, 1962 (37)

This early study monitored the effects of exercise and lactate infusion on free fatty acid concentrations. Dogs were run on treadmills in order to evaluate the exercise and the infusion variables. The plasma free fatty acid levels were observed to rapidly decrease during exercise. However, upon statistical analysis, this drop in FFA was

due to the rising lactate levels and not the exercise, indicating a strong interrelationship between lactate and FFA.

Pruett, 1970 (46)

Four trained young men performed a series of bicycle ergometer evaluations to monitor exhaustive exercise and the relationship of blood glucose and insulin. Insulin secretion was inhibited during exercise while glucose output was increased. During a recovery period immediately post-exercise, the insulin level rose and decreased the glucose levels to concentrations below resting levels. When exercise ensued, this correlation repeated its previous pattern.

Wahren, Felig, Ahlborg, Jorfeldt, 1971 (53)

The blood parameters of glucose, lactate, pyruvate, glycerol, and insulin were recorded in 25 subjects at rest and during 40 minutes of leg ergometry. Glucose uptake in the exercising tissue ranged from a 7-fold increase during light work to a 20-fold increase at heavy workloads. Splanchnic glucose production reached levels of a 3 to 5 times that of resting values. The authors indicated that blood glucose becomes increasingly vital over time in exercise, even though insulin levels decreased, glucose uptake at the periphery increased, and the hepatic output of glucose through glycolysis provides a necessary source

of substrate.

Paul, Holmes, 1975 (44)

In prolonged exercise in dogs, 50 to 90% of the energy may derive from plasma free fatty acids. Intramuscular energy substrates and carbohydrates present a major portion of energy production at the beginning of exercise. Their role decreases as time dictates and FFA become the preferred fuel. The previous training, work intensity, initial content of muscle and liver glycogen and rate or mobilization of FFA from adipose tissue all regulate the degree of endurance during prolonged work.

Costill, Coyle, Dalsky, Evans, Fink, Hoopes, 1977 (14)

Seven men performed treadmill work to evaluate the effects of free fatty acids and insulin on glycogen utilization. Glucose was ingested on a separate occasion for similar analysis. The increased free fatty acids decreased the glycogen usage by 40%. Carbohydrate oxidation and glycogen utilization were enhanced along with insulin levels which had reduced glucose values below their resting levels.

Brodan, Hajek, Kuhn, Andel, 1979 (10)

Rapid oscillations of glucose and free fatty acid samples were analyzed by time and body site collections to correlate their errors of variance. Oscillations are

present for glucose and free fatty acids at all times and gradually follow a time period pattern. These patterns are most noticeable at rest, and a relative change in this pattern is seen with exercise, glucose ingestion, or fasting. Uneven concentrations, mutual interactions, and feedback regulations all assist in this oscillation.

Summary

Two major concerns of the athlete during prolonged exercise are adequate hydration and repletion of carbohydrate stores. A reduction in either or both of these two ergogenic supplements can cause a significant reduction in efficiency and performance.

If glucose is to be used during exercise, it appears that it should be in its polymerized form and contain electrolytes. An aqueous solution of glucose polymer would have the required composition for supplying fluid and electrolytes to the stomach and being able to clear them to the fluid compartments as quickly as water. The glucose supply can move readily into the serum to elevate blood glucose values and serve as a fuel supply without compromising the effectiveness of the fluid and electrolyte replenishment. This combination of fuel and fluid should prove beneficial during actual competition, but also immediately post-exercise to enhance recovery.

CHAPTER III

METHODS AND PROCEDURES

This study was undertaken to evaluate the effects of rehydration using a polycose-based electrolyte solution following prolonged heavy exercise. All metabolic determinations were recorded in the Laboratory of Work Physiology at The Ohio State University.

Design of the Study

The evaluation of the subjects was comprised of five exercise bouts. During the initial evaluation, all subjects completed a treadmill run to exhaustion in order to determine the participants' maximal oxygen consumption ($\dot{V}O_2$ max). Four sessions were then performed to compare the effects of a glucose polymer/fructose solution (polycose) to water for rehydration purposes during a walking or a rest recovery. These sessions were performed on four separate days with one week between each session. A randomized Latin Square protocol for fluid ingestion (water or polycose) and recovery (rest or exercise) is portrayed in Table 2.

Each subject reported to the laboratory 12 hours post absorptive with the exception of having ingested 4.5 ml of water per kilogram of body weight one hour prior to reporting. After the resting determinations were collected, each subject ran for 1 hour on the treadmill at a speed and grade that would elicit an oxygen consumption ($\dot{V}O_2$) approximately 67% of the $\dot{V}O_2$ max. Upon completion of the run, all subjects were further evaluated during recovery for 75 minutes.

During the recovery period, subjects performed either an exercise recovery that consisted of a fast walk at 40% $\dot{V}O_2$ max or a rest recovery for which they remained seated. During the 75-minute walking recovery period, the initial 10 minutes were used to insert, secure, and draw blood through a catheter. The subject then walked for 50 minutes at 40% $\dot{V}O_2$ max and upon termination of the walk was seated for the final 15 minutes of the recovery period. The protocol for metabolic evaluations was identical for both recoveries. The exercise intensity of 67% $\dot{V}O_2$ max and walking recovery intensity of 40% $\dot{V}O_2$ max were determined from the data collected at the maximal pretest effort.

Selection of Subjects

Six physically trained men were selected for this study on the basis of their aerobic fitness ($\dot{V}O_2$ ml/kg/min)

and their ability to perform satisfactorily on the treadmill while blood samples were being collected. Some of their physical characteristics are presented in Table 1. Five of these subjects participated in a previous investigation evaluating a 5% and 7% concentration of the experimental solute by way of gastric emptying.

All subjects were advised as to the nature and risks involved with such an investigation. Each subject signed an informed consent form which had been approved by the Human Subjects Review Committee prior to initiation of this study.

Cardiorespiratory Determinations

Upon arrival into the laboratory, each subject would have his weight recorded to the nearest kilogram. This procedure would be repeated prior to departure in order to determine water loss. A pre-exercise blood sample, resting heart rate and expired gases were collected prior to any exercise performance. Heart rates were monitored on a Hewlett-Packard 1500B electrocardiograph every five minutes during the final 15 seconds of the final minute. The collected gases were drawn through a Wilmore valve and into a Beckman OM-11 oxygen analyzer and a Beckman LB-2 carbon dioxide analyzer for gas concentration determinations. Gas volumes were measured on the inspired side with a Parkinson-Cowan CD-4 gas volume meter and recorded with a Tracewell digital display printout.

Each subject was able to familiarize himself with noseclip and mouthpiece usage while running on the treadmill on a separate day prior to his initial testing bout. The subjects were also familiarized with the protocols for gas collection, blood drawing, and fluid intake. All recovery gas collections were made using meteorological balloon sample bags and following a procedure described by Fox et al. (29) in order to determine O_2 debt. Heart rate and gas determinations were made every 5 minutes.

Fluid Ingestion

Fluid (either polycose or water) was ingested at four different time periods during the session through a one-liter plastic squeeze bottle and at a temperature of approximately 6°C . Each subject drank 400 ml at minutes 55-60 of exercise, 400 ml at minutes 10-15 of recovery, 200 ml at minutes 20-24 of recovery, and 200 ml at minutes 28-30 of recovery. In this manner, the total amount of 1.2 liters of either the experimental or control fluid could be ingested within the initial 30 minutes of recovery. The descriptive characteristics of the experimental solution are presented in Appendix A. The volume of 1.2 liters was selected to approximate the amount of fluids lost by the body in this type of activity. The initial ingestions of 400 ml were identical in volume to those used in the earlier gastric emptying study.

Blood Analysis

Blood samples were drawn by a certified medical technologist. The pre-exercise and immediate post-exercise blood samples were drawn from a prominent antecubital vein using a straight-needle with syringe attached. All other blood samples were drawn, using sterile technique, through an intravenous plastic catheter inserted into a prominent antecubital or forearm vein. The volume of blood drawn varied depending on which tests were to be run. Table 3 shows which test combinations were drawn at various times throughout each session. The entire complement of six tests was drawn only five of the ten times due to the amount of blood required.

Blood was transferred from the syringes, using sterile technique, to Vacutainer^R tubes containing appropriate anticoagulants with the exception of the lactate samples which were pipetted into tubes containing 8% perchloric acid. All serum samples were allowed to clot, centrifuged, and serum was transferred to plain plastic tubes. Serum for triglycerides was refrigerated. Serum for non-esterified fatty acids was frozen. Plasma for insulin was separated from the red blood cells via centrifugation and immediately frozen. All other blood specimens were refrigerated. Specimens were transported to the laboratory within 3-4 hours of drawing.

All blood specimens were analyzed by Consolidated Biomedical Laboratories, Inc., headquartered in Dublin, Ohio. All samples were analyzed using standard accepted techniques. Glucose was analyzed using the glucose-oxidase method (51); triglycerides, using enzyme colorimetric method (50); insulin, using double-antibody radioimmunoassay technique (7, 30); non-esterified fatty acids using colorimetric method (43); lactic acid, using spectrophotometric enzyme technique (49); and hematocrits, using the Coulter Model S Sr. automated cell counter (18). All methods were appropriately quality-controlled. The normal range established for the laboratory for each test is indicated on the appropriate figure.

TABLE 1
PHYSICAL CHARACTERISTICS OF SUBJECTS

NO.	SUBJECT	AGE	HEIGHT (CM)	WEIGHT (KG)	% BODY FAT	$\dot{V}O_{2\max}$ (l/min)	$VO_{2\text{ml/kg/min}}$
1	PC	28	184.2	75.0	8.2	4.52	60.0
2	KK	29	177.8	69.5	11.2	3.79	52.8
3	PN	29	190.5	64.9	12.5	3.90	61.5
4	BN	29	172.7	65.9	14.6	3.52	51.9
5	DR	35	177.8	65.6	17.2	4.00	60.9
6	PT	26	188.0	72.1	11.0	4.16	63.9
$\bar{X}$		29.3	181.83	68.8	12.5	3.98	58.50
SD		3.0	6.85	4.09	3.1	.34	4.94

TABLE 2
RESEARCH PROTOCOL FOR TREATMENT AND CONDITIONS

SUBJECT	SESSION			
	1	2	3	4
P C	W-W	W-R	P-W	P-R
K K	P-R	W-W	W-R	P-W
P N	P-R	W-W	P-W	W-R
B N	W-R	P-W	P-R	W-W
D R	P-W	P-R	W-W	W-R
P T	W-W	P-R	W-R	P-W

Legend P-R: Polycose-Rest W-R: Water-Rest
P-W: Polycose-Walk W-W: Water-Walk

TABLE 3
 PROTOCOL FOR BLOOD COLLECTION

BLOOD VARIABLE	PRE EXERCISE	IMMED POST EX	RECOVERY TIME (mins)							
			5	10	15	30	40	50	60	75
HEMATOCRIT	C	C	C	C	C	C	C	C	C	C
TRIGLYCERIDE	C	C	C	C	C	C	C	C	C	C
FREE FATTY ACID	C	C	NC	NC	NC	C	NC	NC	C	C
GLUCOSE	C	C	C	C	C	C	C	C	C	C
INSULIN	C	C	NC	NC	NC	C	NC	NC	C	C
LACTATE	C	C	C	NC	NC	C	NC	NC	C	C

Legend C = Blood drawn at this time
 NC = No blood collection

TABLE 4
SUBJECT WEIGHT LOSS DURING TESTING SESSION

NO.	SUBJECT	WEIGHT LOSS (KG)			
		67% VO ₂ MAX RUN + REST RECOVERY		67% VO ₂ MAX RUN + WALK RECOVERY	
		PRE - POST WEIGHT	CORRECTED WEIGHT*	PRE - POST WEIGHT	CORRECTED WEIGHT*
1	PC	.82	1.89	1.59	2.66
2	KK	.23	1.30	.82	1.89
3	PN	.82	1.89	1.41	2.48
4	BN	.48	1.55	.93	2.00
5	DR	.41	1.48	1.05	2.11
6	PT	.82	1.89	1.48	2.55
	$\bar{X}$	.597	1.667	1.213	2.282
	SD	0.258	0.258	0.320	0.320

*Weight corrected for fluid ingestion - 1.2 liters
and blood samples drawn - 0.154 liters

CHAPTER IV

RESULTS

The purpose of this study was to determine the effects of rehydration in male athletes following prolonged heavy exercise by comparing water versus a glucose polymer/fructose based electrolyte solution. Each participant ran at a speed and grade on the treadmill that would elicit a metabolic rate of 67% $\dot{V}O_2$ max. Immediately upon completion of the exercise the subject performed either a rest-recovery or a light exercise recovery (approximately 40% $\dot{V}O_2$ max) and ingested water or the test solution. Four separate testing days were used to monitor cardiorespiratory and blood parameters. Venous blood was analyzed for lactic acid, insulin, glucose, free fatty acids, triglycerides and hematocrit, while oxygen, carbon dioxide, and heart rate values were recorded during the test.

Data are presented in this chapter for blood and metabolic parameters. Tables have been completed to display these physiological parameters and their changes during the four testing conditions. Significant differences between conditions are also presented on these tables. Figures are utilized to portray patterns and specific characteristics of each variable. An Analysis of Variance and Duncan's

Multiple Range Test were performed on both the blood and the cardiorespiratory data.

Blood Analysis

Mean data for blood analysis during the four experimental conditions (P-R, P-W, W-R, W-W) are shown in Tables 5 through 10. Table 3 shows the schedule for blood draws and the collection time for each variable. All blood variables were statistically compared for significant differences between conditions, between treatments and over time. All significant findings are indicated on their respective table and figure.

Blood Hematocrit. The values for the hematocrit are listed in Table 5 and graphed in Figure 1. There were significant differences for these mean values at minutes 0 and 15 of recovery. The experimental solution presented a negligible effect on resting and exercise recoveries.

Blood Triglycerides. The values for triglycerides are listed in Table 6 and displayed in Figure 2. The polydose values indicate a gradual increase in triglyceride values during recovery, however there are no significant differences demonstrated within this parameter.

Free Fatty Acids. The values for free fatty acids are shown in Table 7 and graphed in Figure 3. Immediately upon recovery the water values (W-W, W-R) are significantly elevated over the polydose values. This trend is also repeated during the final minutes of recovery where the

water-walk values are much higher than the polycose-walk values and the water-rest values are also significantly raised over the polycose-rest measurements.

Blood Glucose. The blood glucose data are shown in Table 8 and charted on Figure 4. The ingestion of the polycose solution produced a profound increase in blood glucose levels both at rest and during exercise. The significant elevation of the glucose values from the polycose is evident throughout the entire recovery period and indicates the type of carbohydrate influx that can be produced through the use of this fluid. The polycose-rest condition allows the glucose values to increase dramatically and double the water-rest values.

Blood Insulin. Values for insulin are shown in Table 9 and displayed in Figure 5. As the time of recovery increases, so do the insulin values. The rise in insulin follows the increase in blood glucose, and rises to significant levels above the water ingested condition levels. There is very little insulin change during recovery for the water conditions in spite of the dramatic and significant polycose-walk and polycose-rest increases.

Blood Lactate. Blood lactate data are presented in Table 10 and displayed in Figure 6. All values were similar during the early collection period of recovery. As time progressed, however, the values in the polycose group were significantly elevated for the final three collections of

TABLE 5
BLOOD HEMATOCRIT DATA

TIME OF COLLECTION	CONDITIONS			
	P-R	P-W	W-R	W-W
Pre-Exercise	43.92	44.73	43.23	43.10
Recovery				
0	46.27	46.58	A42.57	44.78
5	45.52	45.46	43.60	43.45
10	44.68	45.53	42.75	43.05
15	44.00	45.52	A41.33	43.35
30	42.82	44.17	42.28	42.88
40	42.65	44.72	42.52	52.55
50	42.60	43.63	41.90	43.37
60	43.15	43.18	42.33	43.25
75	41.65	42.58	42.62	42.63

Legend P-R: Polycose-Rest W-R: Water-Rest
P-W: Polycose-Walk W-W: Water-Walk

A = Sig Diff ($p < .05$) between compared treatments (fluids)
(P-W vs W-W) (P-R vs W-R)
B = Sig Diff ($p < .05$) between compared conditions (recoveries)
(P-W vs R-R) (W-W vs W-R)
C = Sig Diff ($p < .05$) over time within that condition
(P-R minute 50 vs minute 60)

FIGURE 1: HEMATOCRIT

TABLE 6
BLOOD TRIGLYCERIDE DATA

TIME OF COLLECTION	CONDITIONS			
	P-R	P-W	W-R	W-W
Pre-Exercise	82.00	86.40	84.17	80.67
Recovery				
0	72.00	77.00	77.67	73.17
5	66.67	68.00	65.84	68.50
10	64.17	66.00	63.00	67.17
15	70.50	67.83	62.00	69.83
30	68.83	69.83	66.17	70.67
40	80.67	81.17	63.00	69.83
50	86.17	88.00	65.33	70.00
60	87.17	87.00	67.67	76.17
75	84.00	86.20	63.67	79.33

Legend P-R: Polycose-Rest W-R: Water-Rest
 P-W: Polycose-Walk W-W: Water-Walk

- A = Sig Diff ($p < .05$) between compared treatments (fluids)
 (P-W vs W-W) (P-R vs W-R)
 B = Sig Diff ($p < .05$) between compared conditions (recoveries)
 (P-W vs R-R) (W-W vs W-R)
 C = Sig Diff ($p < .05$) over time within that condition
 (P-R minute 50 vs minute 60)

A = significant difference between compared treatments
 B = significant difference between compared conditions
 C = significant difference over time within that condition

● P-R ○ OW-R
 ■ P-W □ W-W
 ▲ Fluid Ingestion

FIGURE 2: TRIGLYCERIDES

TABLE 7
BLOOD FREE FATTY ACIDS

TIME OF COLLECTION	CONDITONS			
	P-R	P-W	W-R	W-W
Pre-Exercise	0.13	0.15	0.20	0.22
Recovery				
0	^C 0.38	^C 0.34	^C 0.53	^C 0.41
5	N.C.	N.C.	N.C.	N.C.
10	N.C.	N.C.	N.C.	N.C.
15	N.C.	N.C.	N.C.	N.C.
30	^C 0.31	^A 0.16	0.33	0.34
40	N.C.	N.C.	N.C.	N.C.
50	N.C.	N.C.	N.C.	N.C.
60	0.08	0.15	^{AB} 0.28	^{ABC} 0.69
75	0.06	0.14	^{AB} 0.27	^{ABC} 0.75

Legend N.C. = No collection specified for this time

P-R: Polycose-Rest W-R: Water-Rest

P-W: Polycose-Walk W-W: Water-Walk

A = Sig Diff ($p < .05$) between compared treatments (fluids)
(P-W vs W-W) (P-R vs W-R)

B = Sig Diff ($p < .05$) between compared conditions (recoveries)
(P-W vs R-R) (W-W vs W-R)

C = Sig Diff ($P < .05$) over time within that condition
(P-R minute 50 vs minute 60)

FIGURE 3: FREE FATTY ACIDS

TABLE 8
BLOOD GLUCOSE DATA

TIME OF COLLECTION	CONDITIONS			
	P-R	P-W	W-R	W-W
Pre-Exercise	103.50	101.83	101.67	100.17
Recovery				
0	AC ₁ 28.50	112.50	109.33	111.33
5	AC ₁ 35.83	C ₁ 24.00	113.83	117.33
10	AC ₁ 36.67	AC ₁ 26.17	107.33	107.50
15	ABC ₁ 50.33	ABC ₁ 25.33	104.33	101.00
30	ABC ₁ 89.83	AB ₁ 21.17	95.00	83.00
40	ABC ₁ 89.67	AB ₁ 13.67	92.50	84.00
50	ABC ₁ 65.17	AB ₁ 05.50	91.50	86.83
60	ABC ₁ 41.50	107.67	91.67	95.50
75	105.83	ABC ₁ 26.33	90.83	94.00

Legend P-R: Polycose-Rest W-R: Water-Rest
 P-W: Polycose-Walk W-W: Water-Walk

A = Sig Diff ($p < .05$) between compared treatments (fluids)
 (P-W vs W-W) (P-R vs W-R)
 B = Sig Diff ($p < .05$) between compared conditions (recoveries)
 (P-W vs R-R) (W-W vs W-R)
 C = Sig Diff ($p < .05$) over time within that condition
 (P-R minute 50 vs minute 60)

A = significant difference between compared treatments
 B = significant difference between compared conditions
 C = significant difference over time within that condition

● P-R ○ OW-R
 ■ P-W □ W-W
 ↗ Fluid Ingestion

FIGURE 4: GLUCOSE

TABLE 9
BLOOD INSULIN DATA

TIME OF COLLECTION	CONDITIONS			
	P-R	P-W	W-R	W-W
Pre-Exercise	4.83	8.03	8.17	6.82
Recovery				
0	3.85	4.48	3.73	3.95
5	N.C.	N.C.	N.C.	N.C.
10	N.C.	N.C.	N.C.	N.C.
15	N.C.	N.C.	N.C.	N.C.
30	ABC ₃ 0.93	ABC ₁ 8.15	5.72	3.43
40	N.C.	N.C.	N.C.	N.C.
50	N.C.	N.C.	N.C.	N.C.
60	ABC ₄ 4.05	9.17	5.22	3.43
75	ABC ₃ 4.20	ABC ₂ 20.65	5.27	4.47

Legend N.C. = No collection specified for this time

P-R: Polycose-Rest W-R: Water-Rest

P-W: Polycose-Walk W-W: Water-Walk

A = Sig Diff ($p < .05$) between compared treatments (fluids)
(P-W vs W-W) (P-R vs W-R)

B = Sig Diff ($p < .05$) between compared conditions (recoveries)
(P-W vs R-R) (W-W vs W-R)

C = Sig Diff ($p < .05$) over time within that condition
(P-R minute 50 vs minute 60)

FIGURE 5: INSULIN

TABLE 10
BLOOD LACTATE DATA

TIME OF COLLECTION	CONDITIONS			
	P-R	P-W	W-R	W-W
Pre-Exercise	9.18	9.60	8.90	9.82
Recovery				
0	^C 14.58	12.10	10.52	12.60
5	10.15	9.32	8.17	9.07
10	N.C.	N.C.	N.C.	N.C.
15	N.C.	N.C.	N.C.	N.C.
30	^A 13.20	9.25	7.73	7.77
40	N.C.	N.C.	N.C.	N.C.
50	N.C.	N.C.	N.C.	N.C.
60	^{ABC} 20.95	11.72	6.72	8.67
75	^{ABC} 19.65	^{AB} 14.27	7.10	9.25

Legend N.C. = No collection specified for this time

P-R: Polycose-Rest W-R: Water-Rest

P-W: Polycose-Walk W-W: Water-Walk

A = Sig Diff ($p < .05$) between compared treatments (fluids)
(P-W vs W-W) (P-R vs W-R)

B = Sig Diff ($P < .05$) between compared conditions (recoveries)
(P-W vs R-R) (W-W vs W-R)

C = Sig Diff ($p < .05$) over time within that condition
(P-R minute 50 vs minute 60)

FIGURE 6: LACTATE

polycose-rest and for the final measurement of polycose-walk. No differences were indicated between a water-rest and a water-walk recovery.

Cardiorespiratory Determinations

The physiological parameters of expired gases and heart rate are presented in this section. The 60 minutes of treadmill work was not statistically different for any of the conditions and was physiologically consistent for all heart rate, $\bar{V}_E$, $\dot{V}O_2$ l/m, $\dot{V}CO_2$ l/m, $\dot{V}O_2$ ml/kg.m and $\bar{R}$ values.

$\bar{V}_E$. The values for expired air are shown in Table 11 and graphically presented in Figure 7. Determinations were consistent for walking recoveries in the water and polycose groups. While using a resting recovery, however, a significant increase in respiration is seen in the polycose group during the later portion of recovery when compared to the water-rest group.

$\bar{V}O_2$. The values for oxygen utilization are shown in Table 12 and displayed in Figure 8. There is a significant elevation of oxygen usage at minute 40 for polycose-rest above the value for water-rest. This value agrees with other physiological parameters for this time period. Oxygen consumption during the water-walk recovery is significantly elevated at minutes 50 and 60. This increase compares with a similar rise in free fatty acid levels in Figure 3.

$\bar{V}CO_2$. Carbon dioxide production for the four conditions is shown in Table 13 and displayed in Figure 9. Respiratory

adaptations are commensurate with mode of recovery. Production of carbon dioxide is increased during rest for polycose ingestion when compared to water ingestion.

$\dot{V}O_2$ Ml/Kg/Min. Values for all conditions are shown in Table 14 and graphed in Figure 10. Data for Table 13 indicates that mean values are at 67% $\dot{V}O_2$ max which was specified as the training intensity for the study. Values for comparable recoveries are similar.

$\bar{R}$ Values. Respiratory quotient measurements are recorded in Table 15 and charted in Figure 11. Due to the carbohydrate intake, the values for polycose-rest and polycose-walk are elevated above their respective water recoveries. Significant margins of this difference, however, are few in number as shown in Table 14.

Heart Rate. Measurement of heart rate is listed in Table 16 and graphically presented in Figure 12. Adaptations to a walking recovery are similar for the polycose and water groups when monitored for heart rate. During resting recovery the values for polycose are consistently and significantly elevated above those for water throughout the recovery period.

TABLE 11
 $\bar{V}_E$ RESPIRATORY DATA

TIME OF COLLECTION	CONDITIONS			
	P-R	P-W	W-R	W-W
Rest	7.41	6.78	6.78	6.12
Exercise 59-60	67.18	61.16	60.87	65.10
Recovery				
0-2	30.04	30.01	29.50	30.94
2-6	14.51	13.71	13.52	13.44
6-9	11.90	11.47	8.99	12.02
16-19	10.65	35.28	9.03	34.67
24-27	10.47	34.50	7.21	33.23
36-39	A ₁ 11.69	35.16	6.89	36.10
46-49	A ₁ 10.54	35.81	6.53	35.90
56-59	9.96	36.41	7.63	36.60
60-62	NC	19.51	NC	19.16
62-66	NC	10.80	NC	12.14
66-70	NC	9.77	NC	9.61
70-75	NC	8.71	NC	8.61

Legend P-R: Polycose-Rest W-R: Water-Rest
P-W: Polycose-Walk W-W: Water-Walk

A = Sig Diff ($p < .05$) between compared treatments (fluids)
(P-W vs W-W) (P-R vs W-R)
B = Sig Diff ($p < .05$) between compared conditions (recoveries)
(P-W vs R-R) (W-W vs W-R)
C = Sig Diff ($p < .05$) over time within that condition
(P-R minute 50 vs minute 60)

A = significant difference between compared treatments

● P-R ○ OW-R
■ P-W □ W-W
▲ Fluid Ingestion

FIGURE 7: $\bar{V}_E$

TABLE 12
 $\bar{V}O_2$ l/m RESPIRATORY DATA

TIME OF COLLECTION	CONDITIONS			
	P-R	P-W	W-R	W-W
Rest	0.31	0.25	0.25	0.25
Exercise 59-60	2.98	2.81	2.85	2.96
Recovery				
0-2	1.11	1.12	1.17	1.17
2-6	0.42	0.44	0.42	0.43
6-9	0.41	0.41	0.32	0.39
16-19	0.37	1.70	0.32	1.67
24-27	0.37	1.63	0.27	1.59
36-39	A0.38	1.62	0.26	1.72
46-49	0.35	1.59	0.27	A1.71
56-59	0.32	1.63	0.29	A1.76
60-62	NC	0.68	NC	0.77
62-66	NC	0.37	NC	0.43
66-70	NC	0.33	NC	0.34
70-75	NC	0.31	NC	0.31

Legend P-R: Polycose-Rest W-R: Water-Rest

P-W: Polycose-Walk W-W: Water-Walk

A = Sig Diff ($p < .05$) between compared treatments (fluids)
(P-W vs W-W) (P-R vs W-R)

FIGURE 8: $\bar{V}O_2$ l/min

TABLE 13
 $\bar{V}CO_2$ l/m RESPIRATORY DATA

TIME OF COLLECTION	CONDITIONS			
	P-R	P-W	W-R	W-W
Rest	0.24	0.19	0.19	0.19
Exercise 59-60	2.51	2.38	2.42	2.56
Recovery				
0-2	1.01	0.97	0.98	1.03
2-6	0.38	0.37	0.36	0.37
6-9	0.32	0.32	0.25	0.33
16-19	0.28	1.35	0.24	1.31
24-27	0.28	1.35	0.20	1.26
36-39	^A 0.31	1.36	0.19	1.34
46-49	0.28	1.35	0.19	1.34
56-59	0.27	1.37	0.20	1.29
60-62	NC	0.61	NC	0.60
62-66	NC	0.31	NC	0.33
66-70	NC	0.29	NC	0.26
70-75	NC	0.26	NC	0.26

Legend P-R: Polycose-Rest W-R: Water-Rest

P-W: Polycose-Walk W-W: Water-Walk

A = Sig Diff ($p < .05$) between compared treatments (fluids)
(P-W vs W-W) (P-R vs W-R)

FIGURE 9: $\bar{\text{VCO}}_2$ l/min

TABLE 14
 $\bar{V}O_2$ ml/kg-min RESPIRATORY DATA

TIME OF COLLECTION	CONDITIONS			
	P-R	P-W	W-R	W-W
Rest	4.41	3.53	3.52	3.46
Exercise 59-60	42.50	39.76	40.57	41.74
Recovery				
0-2	15.87	15.89	16.58	16.46
2-6	6.73	6.25	5.93	6.09
6-9	5.88	5.79	4.57	5.52
16-19	5.36	24.13	4.58	23.54
24-27	5.29	23.10	3.80	22.46
36-39	^A 5.46	22.95	3.68	24.24
46-49	5.03	22.52	3.79	24.26
56-59	4.51	23.14	4.13	^A 24.99
60-62	NC	9.51	NC	10.85
62-66	NC	5.19	NC	6.08
66-70	NC	4.54	NC	4.82
70-75	NC	4.33	NC	4.40

Legend P-R: Polycose-Rest W-R: Water-Rest
P-W: Polycose-Walk W-W: Water-Walk

A = Sig Diff ($p < .05$) between compared treatments (fluids)
(P-W vs W-W) (P-R vs W-R)

A = significant difference between compared treatments
 B = significant difference between compared conditions
 C = significant difference over time within that condition

FIGURE 10: $\dot{V}O_2$ ml/kg-min

TABLE 15
 $\bar{R}$ VALUES, RESPIRATORY DATA

TIME OF COLLECTION	CONDITIONS			
	P-R	P-W	W-R	W-W
Rest	0.77	0.76	0.76	0.77
Exercise 59-60	0.84	0.85	0.85	0.87
Recovery				
0-2	0.91	0.87	0.84	0.89
2-6	0.81	0.84	0.86	0.85
6-9	0.77	0.80	0.77	0.84
16-19	0.74	0.79	0.76	0.79
24-27	0.75	0.82	0.73	0.79
36-39	0.82	0.84	0.72	0.78
46-49	0.80	0.85	0.69	0.78
56-59	A0.85	0.84	0.70	0.74
60-62	NC	0.89	NC	0.78
62-66	NC	0.88	NC	0.78
66-70	NC	A0.91	NC	0.75
70-75	NC	0.83	NC	0.85

Legend P-R: Polycose-Rest W-R: Water-Rest

P-W: Polycose-Walk W-W: Water-Walk

A = Sig Diff ($p < .05$) between compared treatments (fluids)
(P-W vs W-W) (P-R vs W-R)

FIGURE 11: $\bar{R}$ Values

TABLE 16
HEART RATE ($\bar{H}R$) DATA

TIME OF COLLECTION	CONDITIONS			
	P-R	P-W	W-R	W-W
Rest	59.67	56.33	56.17	57.00
Exercise 59-60	173.83	160.50	158.17	165.00
Recovery				
0-2	NC	NC	NC	NC
2-6	102.83	101.33	94.17	101.33
6-9	94.33	100.67	86.17	102.67
16-19	A90.33	124.67	79.17	120.50
24-27	A83.17	121.00	70.50	118.50
36-39	A91.33	122.33	63.67	123.17
46-49	A85.00	123.33	64.17	125.50
56-59	A86.00	122.17	65.33	124.67
60-62	NC	NC	NC	NC
62-66	NC	NC	NC	NC
66-70	NC	NC	NC	NC
70-75	NC	NC	NC	NC

Legend P-R: Polycose-Rest W-R: Water-Rest
P-W: Polycose-Walk W-W: Water-Walk

A = Sig Diff ($p < .05$) between compared treatments (fluids)
(P-W vs W-W) (P-R vs W-R)

A = significant difference between compared treatments
 B = significant difference between compared conditions
 C = significant difference over time within that condition

● P-R ○ OW-R
 ■ P-W □ W-W
 ▲ Fluid Ingestion

FIGURE 12: HEART RATE

CHAPTER V

DISCUSSION

The effect of prolonged heavy exercise is one that can be evaluated through several physiological parameters. The parameters selected for this study are not only appropriate for monitoring the specific hematological and cardiorespiratory responses observed in this study, but also compare favorably with parameters of related studies.

The 60 minutes of exercise at 65% $\dot{V}O_2$ max was not significantly different for any of the conditions and allowed the emphasis of the study to be directed by the independent variables. The solution of 5% polycose plus 2% fructose proved to be quite palatable as indicated by the subjects and was readily ingested.

Blood hematocrit values showed very little change during the evaluation (53). The gradual decrease of values for all conditions demonstrated a response to the typical reduction of plasma volume (20). The water-rest recovery is significantly lower than polycose-rest indicating the initial effect of glucose to raise the polycose-rest values as the water-rest values decreased. Figure 2 shows the decline of serum triglyceride values immediately following exercise. These values remain depressed with water intake but show a

more rapid elevation with ingestion of glucose and exercise (13).

The role of free fatty acids in exercise is well documented (2, 9, 13, 14, 35, 37, 44, 53). The graphic display in Figure 3 presents three typical responses observed in free fatty acids. A significant rise in FFA levels is seen during exercise. Work of minimal intensity (40% $\dot{V}O_2$ max) will create the highest levels of FFA mobilization (2, 9, 53). Glucose and insulin increases will limit FFA elevation through their enhancement of the body's carbohydrate supply. The enhancement of the body's carbohydrate supply is verified by the augmented R values following glucose ingestion in Figure 11, which indicates a carbohydrate fuel source is being used. The water-walk values reflect the augmented FFA levels that increased significantly during the exercise recovery in order to provide an energy source.

The continued ingestion of glucose has a dramatic effect on the blood glucose levels (3, 8, 11, 12, 13, 33, 38, 45, 53) as indicated in Figure 4. The significant increases shown for polycose-rest and polycose-walk are reflective of the 84 grams of carbohydrate ingested. The values for both polycose recoveries are significantly different than their respective water recoveries from minute 15 to minute 50. Upon completion of the polycose walking recovery that value also showed a significant increase. The blood glucose values during recovery showed

a slight decrease following their exercise bout and remained depressed for the remaining recovery period for both the water-walk and water-rest recoveries. The highest values for blood glucose were recorded approximately 10 minutes after the ingestion period indicating the rapid ingestion of glucose (13). The polycose-walk values remained much lower during the walking recovery than those for polycose-rest. The exercise played a definite role in regulating the elevation of glucose levels for both the polycose-walk and water-walk recoveries. In comparing the polycose-rest values to values from other studies these values appear to be quite high. The exercise recovery was able to significantly modify blood glucose levels to the point that the values were significantly different from their compared treatment (water-walk) and from their compared condition (polycose-rest). The reason for the amount of variance for this blood parameter is not quite clear at this time.

Insulin values showed a dramatic increase following polycose ingestion and lagged behind the glucose values by approximately 20 minutes. The typical "following" of glucose is demonstrated in Figure 5 and can be observed not only following glucose ingestion, but insulin also parallels its action during non-glucose recovery (2, 8, 14, 24, 33, 36, 38, 46). This low level of insulin response is evident during the water ingestions in Figure 5. The polycose-walk recovery demonstrated significantly lower values from the

rest recovery and followed an identical pattern to the blood glucose values noted in Figure 5.

The lactic acid values showed an increase following activity but due to the aerobic nature of the 60 minute exercise were able to return to their resting levels by minute 5 of recovery. The large ingestion of glucose produced a dramatic increase in blood lactate particularly when combined with no physical activity to help metabolize the glucose (12, 32). Significant increases are seen in the polycose-rest group and also in the polycose-walk values after a 15 minute rest. Exercise and glucose polymer/fructose ingestion played important roles in controlling lactic acid levels.

When comparing the cardiorespiratory data in Tables 11 through 16 and Figures 7 through 12, one can observe consistent responses from the conditions. There are no physiological differences between the water-walk and polycose-walk recoveries. The polycose-rest values, however, were significantly greater than those for water-rest during at least one collection period of all cardiorespiratory parameters measured. The continued ingestion of glucose was able to elevate blood glucose, triglycerides, insulin and lactate values. Elevated values of $\bar{R}$, $\dot{V}O_2$ l/m, $\dot{V}CO_2$ l/m, $\dot{V}O_2$ ml/kg-min, $\dot{V}E$ and heart rate are also observed at the same time of recovery as the augmented blood values. The metabolism of food sources requires energy and has been identified for increasing the body's metabolic rate. This

normal response combined with the clearance and reduction of glucose, lactate, insulin and triglyceride levels is reflected through increased metabolic parameters. The $\bar{R}$ values in Figure 11 demonstrate the variance between polycose ingestion and water ingestion during a rest recovery. The elevated values for the polycose-rest recovery are representative of physiological response to blood parameters.

The heart rate values for polycose-rest were significantly elevated over water-rest values during the final 45 minutes of recovery. This long lasting modification of resting heart rate did not allow a return to pre-exercise levels as are noted in the water-rest data. Whether this elevation of heart rate values would have any effect (positive or negative) on a future exercise performance is not clear. It is also interesting to note that exercise (as in the glucose and insulin values) decreased the values for the polycose-walk recovery. For heart rate comparisons there were no significant differences between the polycose-walk recovery and the water-walk recovery.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine the effects of rehydration in male athletes following prolonged heavy exercise by comparing water versus a glucose polymer/fructose electrolyte solution. Subjects ran on a treadmill at a speed and grade that would elicit a metabolic rate of approximately 67% $\dot{V}O_2$ max. Immediately upon completion of the exercise the subjects performed either a rest-recovery or a walking recovery (40% $\dot{V}O_2$ max). Venous blood samples were analyzed for lactic acid, insulin, hematocrit, glucose, free fatty acids and triglycerides. Oxygen consumption, carbon dioxide production, RQ and heart rate were also monitored.

CONCLUSIONS

Within the limitations of this study, the following conclusions were made:

1. The results indicate that a glucose polymer/fructose electrolyte solution elevates blood glucose levels and limits the use of free fatty acids.
2. The use of carbohydrate as a fuel source is enhanced as indicated by elevated R values.

3. Heart rate, $\bar{V}O_2$ l/min, $\bar{V}CO_2$ l/min, R, $\dot{V}O_2$ ml/kg-min parameters are significantly ($p < .05$) elevated at rest in response to increased glucose levels.

4. During exercise recovery ($40\% \dot{V}O_2$ max), there are no cardiorespiratory differences between polycose and water.

5. Free fatty acids contribute a significant energy source for walking and resting recoveries.

6. The subjects voluntarily reported the polycose solution to be quite palatable and preferred its use to water.

Recommendations for Further Study

In analysis of data from this study, several questions have been proposed. Blood glucose values are elevated during the polycose-walking recovery above those shown for water-walk. Whether these levels can prolong performance or allow the exercise to be at a lower metabolic cost has not been demonstrated. The polycose solution enhanced the carbohydrate fuel supply. A repeated exercise bout of a higher intensity (greater than $40\% \dot{V}O_2$ max) may provide a more accurate evaluation of the solute.

There are many values which were significantly elevated during rest following ingestion of 1.2 liters of polycose. To what extent these parameters would effect

a second performance following this ingestion is not clear, whether beneficial or detrimental.

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