California State University, Northridge

THE EFFECTS OF AN ORAL ELECTROLYTE SOLUTION
ON SERUM ELECTROLYTES FOLLOWING A SUBMAXIMUM
EXERCISE STRESS

A thesis submitted in partial satisfaction of the requirements for the degree of Master of Arts in Physical Education

by

Charles Frederick Wolcott

January, 1973
The thesis of Charles Frederick Wolcott is approved:

Committee Chairman

California State University, Northridge

January, 1973
ACKNOWLEDGMENTS

The author would like to take this opportunity to acknowledge with gratitude and thanks, the individuals who provided the most significant assistance in this study.

Dr. George Holland, my committee chairman, for the time and effort he has spent with me in formulating the design of the study and completion of the manuscript.

Dr. George Q. Rich III for laboratory instrumentation and research consultation in the Human Performance Laboratory, California State University, Northridge.

Dr. William Vincent, committee member, for his constructive suggestions throughout the study.

Dr. Delmar Mitchelson for technical advice, blood sampling, and medical monitoring.

Mr. Vigen K. Babayan, vice president of Stokely-Van Camp, Inc. in charge of research, development, and quality control for supplying all of the solutions ingested in this study.

Mr. Bob Clark, co-owner of Clark-Sarver Laboratories for the analysis of blood samples. Normal industrial costs for this service would have made the investigation impossible.
Mr. Chris Johnson for scholarly assistance in statistical design and computer analysis.
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>viii</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>The Problem</td>
<td></td>
</tr>
<tr>
<td>Statement of the Problem</td>
<td></td>
</tr>
<tr>
<td>Statement of the Purpose</td>
<td></td>
</tr>
<tr>
<td>The Hypothesis</td>
<td></td>
</tr>
<tr>
<td>Importance of the Study</td>
<td></td>
</tr>
<tr>
<td>Scope and Limitations</td>
<td></td>
</tr>
<tr>
<td>Organization of the Remaining Chapters</td>
<td></td>
</tr>
<tr>
<td>II. REVIEW OF RELATED LITERATURE</td>
<td>6</td>
</tr>
<tr>
<td>Physiological Loss of Water</td>
<td></td>
</tr>
<tr>
<td>Physiologic Absorption</td>
<td></td>
</tr>
<tr>
<td>Hormonal Influences</td>
<td></td>
</tr>
<tr>
<td>Findings from Electrolyte Research</td>
<td></td>
</tr>
<tr>
<td>Summary</td>
<td></td>
</tr>
<tr>
<td>III. RESEARCH METHOD AND DESIGN</td>
<td>20</td>
</tr>
<tr>
<td>Overview of Experimental Design</td>
<td></td>
</tr>
<tr>
<td>Selection of Subjects</td>
<td></td>
</tr>
<tr>
<td>Chemical Concentration of Electrolyte Solution</td>
<td></td>
</tr>
<tr>
<td>Measurement Techniques</td>
<td></td>
</tr>
<tr>
<td>Laboratory Protocol</td>
<td></td>
</tr>
<tr>
<td>IV. ANALYSIS OF THE DATA</td>
<td>29</td>
</tr>
<tr>
<td>Summary of the Major Findings</td>
<td></td>
</tr>
</tbody>
</table>
V. SUMMARY AND DISCUSSION .......................... 38

Summary
Major Findings
Discussion of the Findings
Conclusion
Recommendations

BIBLIOGRAPHY ............................................. 46

APPENDICES ............................................... 53
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Weight, Height, and Age</td>
<td>31</td>
</tr>
<tr>
<td>2.</td>
<td>Individual Serum Electrolytes</td>
<td>32</td>
</tr>
<tr>
<td>3.</td>
<td>Mean Change of Serum Electrolyte Levels</td>
<td>33</td>
</tr>
<tr>
<td>4.</td>
<td>True Oxygen Consumption</td>
<td>34</td>
</tr>
<tr>
<td>5.</td>
<td>Metabolic Efficiency</td>
<td>34</td>
</tr>
<tr>
<td>6.</td>
<td>Trend Analysis for Heart Rate and Pulmonary Ventilation</td>
<td>36</td>
</tr>
</tbody>
</table>
ABSTRACT

THE EFFECTS OF AN ORAL ELECTROLYTE SOLUTION ON SERUM ELECTROLYTES FOLLOWING A SUBMAXIMUM EXERCISE STRESS

by

Charles Frederick Wolcott

Master of Arts in Physical Education

The purpose of this study was to investigate the possible effects of ingestion of an oral electrolyte solution containing sodium, potassium, chloride, and phosphate, on cardiovascular, pulmonary, and metabolic efficiency of adult male subjects in the performance of a submaximum work capacity 170 test on a bicycle ergometer.

Twenty-six male students randomly selected from general activity classes at California State University, Northridge, served as subjects for this study. The experimental group was allowed the ingestion of a commercial oral electrolyte solution. Control group subjects were given a placebo solution containing only a flavoring agent and water with no electrolytes. The investigation utilized a double blind design. Neither subjects nor investigator
knew if the solution the subjects were drinking contained the electrolytes or a placebo. A submaximum work performance followed on a bicycle ergometer. Upon completion of the work bout a blood sample was taken for analysis of serum sodium, potassium, magnesium and chloride.

The data were statistically analyzed using independent group t-test of mean change, standard t-test for independent groups, and trend analyses. The null hypothesis stated that any changes brought about in serum sodium, potassium, magnesium, or chloride concentrations in blood plasma through ingestion of an oral electrolyte solution would have no significant effect upon cardiovascular, pulmonary, or metabolic efficiency. The null hypothesis was supported by the findings of this study.

The following general conclusion appears justified. The ingestion of an oral electrolyte solution prior to and after specific warm-up does not significantly alter serum sodium, potassium, magnesium, or chloride levels or cause a significant change in cardiovascular, pulmonary, or metabolic efficiency following a submaximum work capacity performance on a bicycle ergometer.
CHAPTER I

INTRODUCTION

Coaches, trainers, and athletes have long been faced with problems related to fluid replacement during and after strenuous physical activity. For a long time it was generally accepted to deny water to individuals working and perspiring heavily. This belief apparently began approximately one hundred years ago when British miners drank large amounts of water after excessive sweating and shortly thereafter developed cramps in their legs. The cramps, as we are aware today, were caused by dilution of already lowered blood sodium levels. As studies in this area increased, salt was found to be helpful if it was accompanied with adequate amounts of water (14).

Since the time of these early investigations several commercial oral electrolyte solutions have been developed. These include Stokely-Van Camp's Gatorade, Becton-Dickinson's Sportade, Cramer's Side-line-sider, Bike's Half-time Punch, and Quickick by Quickick International. Generally these solutions contain salts, (sodium chloride, calcium carbonate, potassium chloride, and
magnesium carbonate) plus glucose, sugar, artificial flavoring and coloring. All of these commercial solutions have claimed their product will allow an athlete a sustained period of athletic participation by replacing the electrolytes and water lost through the process of sweating. Since the introduction of these products their effectiveness has been subjectively judged by hundreds of coaches and trainers. Several studies have been completed dealing with plasma electrolyte levels during variable exercise stress (18,19,23,24,37,38,40,43,45,46,47). Electrolyte levels currently used in commercial solutions only replace a small fraction of what is lost through sweating. There is agreement in the literature that water would have to be ingested in much greater quantities than usual and these quantities would probably exceed comfortable limits during participation.

A basic unanswered question is whether the concentration of electrolytes are actually replaced in various physiologic systems; and do these commercial products actually promote increased work output? This study was designed to investigate the effects of a selected oral electrolyte solution on specific serum electrolyte concentrations following a submaximum stress test.
The Problem

Statement of the Problem

The problem of this investigation was to determine the influence of an oral electrolyte solution on blood serum concentrations and physiological work efficiency.

Statement of the Purpose

The purpose of this study was to investigate the possible effects of ingestion of an oral electrolyte solution containing sodium, potassium, chloride, and phosphate, on cardiovascular, pulmonary, and metabolic efficiency of adult male subjects in the performance of a submaximum work capacity 170 test on a bicycle ergometer.

The Hypothesis

The null hypothesis was postulated for the purposes of this study. Any changes brought about in serum sodium, potassium, magnesium, or chloride concentrations in blood plasma through ingestion of an oral electrolyte solution would have no significant effect upon cardiovascular, pulmonary, or metabolic efficiency.
Importance of the Study

It is generally accepted that isotonic solutions are beneficial during athletic performance. If absorption of these electrolytes is as effective as the manufacturers claim, its usefulness in prevention of heat disorders cannot be underestimated. Every coach and trainer wants his athletes to have the maximum opportunity for safe and successful participation. If replacement of these electrolytes is effective along with normal fluid intake, efficiency of the physiological systems involved would also be increased. This is of extreme importance in performance of endurance tasks. If these isotonic solutions are not effective in replacing these solvents to the blood plasma, then possibly needless wastes of money are being incurred.

Scope and Limitations

The subjects for this study were twenty-six male college students enrolled in the general activity classes in the spring semester of 1972 at California State University, Northridge. Enrollment in general physical education activity classes is elective at this institution. For this reason it is possible that these subjects were not a representative cross sectional sampling of the male
population at this University. Subjects were randomly chosen from the male students enrolled in physical activity classes for that semester.

The study lasted six weeks. Each subject was given an orientation on a bicycle ergometer during the first laboratory visit. A second laboratory visit consisted of a pre and post exercise blood sample. A submaximum work stress was imposed upon subjects by performance on a bicycle ergometer until heart rate reached 170 beats per minute. Blood samples were fractionated in a centrifuge and the serum drawn off and sent to local laboratories for analyses.

Organisation of the Remaining Chapters

Chapter II contains a review of the literature pertaining to electrolyte absorption from oral solutions; fluid balance; electrolyte distribution during basal and post exercise conditions as well as the effect of ingested electrolytes on various physiologic responses. Chapter III includes a description of research design and procedural details of the investigation. Chapter IV contains the statistical analyses of the findings. Chapter V includes a presentation and discussion of major findings, recommendations for future study and a statement of conclusion.
CHAPTER II
REVIEW OF RELATED LITERATURE

Fluid and natural salt replacement are essential for people who are engaged in heavy physical activity, and become increasingly important when temperature and relative humidity are high. Dehydration causes a decrease in physical working capacity and makes one more susceptible to fatigue (3,5,48). If fluids and solvents are not available, then the possibility of heat disorders are increased. This review is divided into four main sections: physiological loss of water, physiologic absorption, hormonal influences, and findings from electrolyte research.

**Physiological Loss of Water**

Murphy, et al. (39) state that it is essential to have water and salt available on the practice field. If steps are taken to replace lost elements in sweat, heat cramps or heat exhaustion can be avoided. In most sports and work activities, thirst can be relied upon to be an accurate indicator for the amount of water needed for metabolic purposes (15,58).
Man's rate of sweating cannot exceed one liter per hour without his suffering some type of heat illness. This rate is often seen in athletics. The amount of sodium in sweat ranges from approximately twenty to seventy milliequivalents per liter, depending upon the degree of acclimatization of the individual. If an oral electrolyte solution contained twenty milliequivalents of sodium per liter of water, as some do, ingestion of a whole liter of liquid every hour would only be replacing part of the sodium losses from sweating (58). Whatever the loss, unless the athlete enjoys drinking large amounts of water or solution, he will seldom be able to replace all the fluid he has lost through sweating during heavy exercise.

Stevenson (2) indicates man must wait until he takes food to replace the last part of a salt and water deficit.

Greenleaf, et al. (30) report that in relation to other animals, man rehydrates slowly when he is deprived of water or in losses incurred by sweating. Men replace less water than they lose during a single period of dehydration. A second period of dehydration is marked by an even lower level of replacement. It would be easier to maintain adequate water consumption if factors controlling water intake were clearer. Work done in this area is insufficient to
draw distinct conclusions.

**Physiologic Absorption**

Absorption of electrolytes as a physiologic process has been referred to in several articles (9,10,20,27,28, 34,42,59). Absorption of water and its solvents is much greater in the upper small intestine than in the distal portions because of a greater surface area as well as an increased permeability to ions (10). Brooke, et al. (10,20) state that monovalent ions are easily absorbed. Divalent or poly-valent ions are absorbed poorly, but are not needed in such great quantities as monovalent ions.

Hunt found that the stomach empties itself at the rate of about three percent of the residual volume every minute. This produces a gastric emptying half time of about twenty minutes. Intestinal absorption of the solution in this study should be almost instantaneous in a non exercise state (59). Fordtran and Saltin (28,59) produced excellent findings in their study revealing gastric emptying is only slightly inhibited by heavy exercise. They state:

> It is the normal inhibitory mechanism of gastric emptying that limit replacement of sugars, water and sodium during exercise, and not any alteration of the gastric
emptying or intestinal absorption by the exercise itself (28:335).

Water is absorbed principally by diffusion. The effects of adding water to a biological system is a uniform distribution between extracellular and intracellular compartments. Volume is increased and concentrations of solvents are decreased.

Glucose and electrolytes are actively absorbed by the intestines. Active absorption is sometimes called active transport of ions and is accomplished by specific enzyme systems. When ions are taken through a membrane it increases concentration on the inside and decreases concentration outside. Water now moves across the membrane to maintain isotonicity between the two fluids.

Fordtran, et al. (27) reported a sodium solution without glucose was absorbed at the rate of 3.1 mequiv./hour. A pure glucose solution was absorbed at 3.3 mmoles/hour. When both sodium and glucose were contained in the same solution, absorption rate increased to 9.2 - 12.3 mequiv./hour.

The major cation of blood plasma is sodium and major anions are chloride, bicarbonate, and proteins. Plasma and interstitial fluid make up extracellular fluid. The primary cation of intracellular fluid is potassium.
Little is known about intracellular concentrations of these electrolytes and there is reasonable doubt concerning the validity of present knowledge about intracellular fluid (9,42).

Kozlowski and Saltin (34) indicate it is questionable to what extent various fluid compartments in the body contribute to water and electrolyte losses. Sweat losses incurred by heavy physical exercise reduce physical working capacity more than when sweat is caused by thermal load alone. The intracellular fluid compartment is significantly reduced during a metabolic heat load. Fatigue can be attributed to metabolic impact at the cellular level. Concentrations of cations differ in various compartments. There is a tendency for sodium ions to diffuse out of extracellular fluid where the concentration is high, into intracellular fluid where concentration is low, but this does not always happen. This is explained by active extrusion of sodium from cells. Potassium ions also tend to diffuse out from intracellular to extracellular fluid. This is also opposed by active accumulation within cells. The mechanism which extrudes sodium from the cell and accumulates potassium within the cell is called the sodium ion pump (12).
Hormonal Influences

It was previously mentioned that an athlete cannot drink as much water as he loses during participation. To help control fluid balance of the body some of the water content of blood plasma is utilized (this accounts in part for concentration of electrolytes increasing as activity is performed) and causes a decrease in circulating blood volume. This or some other unknown phenomena causes secretion of an antidiuretic hormone (ADH) from the pituitary gland. This vasopressin hormone increases reabsorption of water in the kidneys. Urine output is slowed considerably (3).

Another hormone, aldosterone from the adrenal gland, is stimulated by a change in salt balance. It increases reabsorption of sodium from both the kidney and sweat glands at the expense of potassium. This hormone's effect is to conserve sodium by increasing the secretion of potassium to the extent that a potentially serious potassium deficit occurs. A sodium deficit is rare due to all the sodium conserving mechanisms. The only time sodium is lost in excess is heavy sweating and dilution of extracellular fluid by drinking plain water. Potassium deficits occur frequently as Snively (52) reports man cannot store potassium as he should. The body wants to keep a high
concentration of potassium but fails to do so even when the patient is dying of the deficit.

Toor, et al. (54) postulate that potassium losses over prolonged periods of time are cumulative. That is, if losses are not replaced daily, the deficit increases with time.

Coburn and Reba (21) suggest a cause and effect relationship might exist between potassium depletion and susceptibility to heat stroke. This feeling is widely supported (15,21,54), and is due to the fact that muscular weakness in heat illness results from excessive losses of intracellular potassium which is taken out of intracellular fluid to compensate for sodium losses in extracellular fluid. The reason for this shift is that no potential difference or electrochemical charge difference can exist to any great extent between cell membranes. Balakian (15) indicates that a majority of cases of heat stroke show potassium depletion in blood serum.

If there is such a problem with concentrations of sodium and potassium, should not athletes take large doses before competition? Too much sodium or potassium could cause just as severe a problem as too little. Proper balance of these electrolytes is desirable. It is possible to increase sodium and potassium before endurance activities
for the purpose of preserving electrolyte balance. The body's maintenance of homeostasis will often eliminate excesses before they are needed. If some sodium solvents are still present in the kidneys when the sodium conserving hormone aldosterone is secreted, some benefit might be derived.

Even though considerable clinical biological research has been done, relatively little is known about electrolytes and their interrelationships. In 1968, Wacker and Parisi (58) expected that breakthroughs in techniques of simultaneous measurement of the major biologic cations would be only a few years off. Presently the literature does not contain information of innovations in this field. Measurement of these concentrations will provide important knowledge of the complex interrelationships between electrolytes.

Findings from Electrolyte Research

Pitts, et al. (42) found best performances are achieved by replacing, hour by hour, water lost in sweating. Any amount of water less than this leads to serious inefficiency and eventually to exhaustion in a matter of hours. They also found that replacement of salt and glucose had no significant advantages. The findings relative
to salt and glucose replacement found in Pitt's study were not substantiated in other studies.

Earlier reports in the 1930's documented that serum calcium concentration rose in response to muscular exercise. Recent findings are reported indicating that calcium concentration showed no consistent changes. Rose, et al. (46) in 1968 clearly determined that calcium concentration, along with potassium ion concentration, rose in response to muscular exercise.

Little, et al. (35) reported as early as 1949 that ingestion of 1.0 - 1.5 liters of water five minutes prior to exercise had no adverse effects on heart rate or minute volume of ventilation. They concluded no physiological justification for restrictions of water in athletic contests.

Londeree, et al. (36) reported that water given any time immediately before or during the workout will help to combat the ill effects of heat stress. Their study also indicated getting water before workout had no advantage over ingestion during activity. Subjects were reportedly more comfortable getting water prior to their performance.

Schrier, et al. (50) in a study published in
August 1970 found serum sodium, potassium, or chloride concentrations did not change significantly after moderate or severe exercise in early or late periods of military training.

Studies completed in this area have not been consistent in their findings. The generally accepted findings of these studies are summarized by Lind (11) in a short review. Sweating for prolonged periods without adequate replacement of salt and water will eventually lead to salt depletion, fatigue, and heat exhaustion. This is found most frequently in men who are unacclimatized and drink freely without regard to salt replacement. Once salt depletion is started a chain of events is begun. Extracellular sodium begins to move out with water in sweating. Water moves into intracellular spaces due to osmosis. Intracellular fluid is now more concentrated, water moves in to equalize the gradient. Extracellular fluid shrinks and intracellular fluid increases in volume. Concentrations in intracellular fluid must decrease so ions must move out. In this way electrolyte and fluid balance are disturbed.

Most studies are in support of the above findings. Bergstrom, et al. (18) found plasma volume to decrease as
one would expect due to loss of water in sweating (i.e., concentration of solvents increase). They also found that sodium and potassium concentrations increased. This was due to the sodium conserving mechanism and passage of potassium from intracellular fluid to extracellular fluid. Chloride concentrations remained constant. They measured intracellular potassium concentration and reported concentrations fell in all subjects due to dilution from water taken up by the cells during exercise.

DeLanne, et al. (24) report sodium and potassium concentrations increased significantly during exercise. Both cations returned very rapidly to resting level concentrations at the conclusion of the exercise period. They also indicated potassium ion concentration increased to a much greater extent than calcium or sodium ions in plasma.

In studies of sweat content, Berenson, et al. (17) showed potassium concentration starts high and decreases as sweating progresses while sodium and chloride begins low and increases. Robinson and Robinson (44) identify this as an inverse relationship of sodium and potassium in sweat. As the concentration of potassium goes down the concentration of sodium goes up. It is also generally accepted in the literature as acclimatization occurs, concentrations of sodium ions in sweat decreases (13, 44).
Ahlborg, et al. (13) found only small changes in muscle cells. Sodium and chloride content increased and potassium content within muscle cells decreased four percent. Bergstrom and Hultman (19) detected a minor loss in potassium concentration from muscle cells and an increase in plasma potassium ions.

Beilin, et al. (16) analyzed the time of day factor by taking two blood samples per day. The second sample was taken twelve hours after the first. No experimental conditions were imposed. There was no difference attributable to time of sampling.

Flynn, et al. (26) reported effects of blood donation on plasma chemistry. After a 420 ml donation only potassium concentration was significantly altered and this amounted to only .2 mequiv./liter in thirty-eight percent of the donors and .5 mequiv./liter in fifteen percent of the donors.

In a study published in October of 1970, Costill, et al. (23) studied fluid ingestion during distance running and found that men lost body fluids at the rate of 1,668 ml/hour, but could only replace 822 ml/hour via oral ingestion. Any greater quantity would have made the subjects uncomfortable. They conclude it is highly unlikely that fluid replacement could keep up with fluid loss under these circumstances.
Rose, et al. (47) studied serum electrolyte changes after marathon running. They found supporting evidence for sodium and potassium increases and a significant decrease in serum magnesium. They conclude greater losses of magnesium through sweating than potassium. This may very well be the case in endurance activity of three hour duration. It appears that magnesium is depleted faster than other electrolytes and that replacement solutions should contain magnesium to replace this deficit.

**Summary**

Water and salt losses through sweating is one of the major factors limiting man's ability to perform for prolonged periods of time. If he were able to replace water and electrolytes lost in sweating, his performance might be improved.

There is agreement in the literature that water would have to be ingested in much greater quantities than is now considered normal and that these quantities would probably exceed comfortable limits for participation.

Electrolyte levels currently used in commercial solutions replace only a small fraction of what is lost through sweating. The complex interrelationships of these...
electrolytes are still a mystery and may continue to be for some time to come.

The Medical Letter on Drugs and Therapeutics (58) published in 1969, concludes that oral electrolyte solutions can only compensate for a part of electrolyte losses. These solutions are probably not any more helpful than salt tablets. They further state that no controlled studies have been done to support improved athletic performances from the use of electrolyte solutions.
CHAPTER III
RESEARCH METHOD AND DESIGN

The purpose of this study was to investigate the effects of an oral electrolyte solution on efficiency of a human submaximum work performance. This chapter is divided as follows: overview of experimental design, selection of subjects, chemical concentration of electrolyte solution, measurement techniques, and laboratory protocol.

Overview of Experimental Design

Data in this study were collected in the Human Performance Laboratory of the Physical Education Department at California State University, Northridge. The experimental group was allowed the ingestion of a commercial oral electrolyte solution. Control group subjects were given a placebo solution containing only a flavoring agent and water with no electrolytes. This investigation utilized the double blind technique. Neither subjects nor investigator knew whether the solution they were drinking contained electrolytes or was a placebo. A submaximum work
performance followed on a bicycle ergometer. Upon completion of the work bout a blood sample was taken for analysis of serum sodium, potassium, magnesium, and chloride. Statistical methods employed in this study were: independent group t-test of mean change, standard t-test for independent groups, and a trend analysis. The .05 level of significance was established at the beginning of this study.

Selection of Subjects

Subjects were randomly selected from male students enrolled in physical education general activity classes during the spring semester, 1972. For selection purposes, class computer numbers for 167 general activity classes offered that semester were placed on index cards. These cards were shuffled and twenty cards were drawn at random. These were the twenty classes from which subjects were drawn. Following class selection, an additional deck was numbered from one to twenty-four. For each class selected, two student numbers were drawn at random. The IBM student record sheets were used to determine the identification number of each student in each class.

Upon selection, each subject was given information explaining the purposes of the investigation and the
important need for the subject's participation to insure a random sample. A brief discussion of laboratory protocol and the subjects time involvement was also included. The orientation forms used for this purpose are contained in Appendix A, B, and C.

Chemical Concentration of Electrolyte Solution

The two solutions utilized in this study were donated by Stokely-Van Camp, Inc., makers of Gatorade. They were standardized and sealed in glass bottles coded for identification. The solutions were coded JD-02650 A and B respectively. Following collection of data, the investigator and his chairman opened the sealed envelope containing the information needed to identify the placebo and experimental solution. A copy of this letter can be found in Appendix G. It was found that JD-02650 A, the solution ingested by group A, was the placebo solution. This contained lemon-lime flavor, clouding agent, citric acid, and calcium saccharin. Acidity of the product was 0.12 and osmolarity was 20. Solution JD 02650 B was the solution ingested by group B. This was the experimental (Gatorade) solution. Solution B contained all of the ingredients solution A contained plus a five percent glucose solution with electrolytes to supply the following ionic
concentrations: sodium, 21.0 milequiv./liter, potassium, 2.5 milequiv./liter, chloride, 17.0 milequiv./liter, and phosphate, 6.8 milequiv./liter.

**Measurement Techniques**

A modified Sjostrand submaximum work capacity criterion (51) was used as a measuring device for a near maximum work performance of the subjects in this study. The subjects performed the test on a bicycle ergometer manufactured by Monark of Sweden (1). The resistance work factor for each subject was one kilopond for the first ten minutes. Resistance was increased the second ten minutes to two kiloponds, the next six minutes three kiloponds, and the final six minutes four kiloponds. The number of pedal revolutions was kept constant at fifty per minute. This rate and having a wheel circumference of six meters yielded meters per minute, or the total distance traveled per minute. The described rate and coefficient of friction yielded work loads of 300kpm/min., 600kpm/min., 900kpm/min., and 1200kpm/min. Transition to increased load was made without interruption.

Heart rate was monitored during the last five seconds of each minute with a Sanborn 500 Viso-Cardiette, manufactured by Howlett-Packard. Silver-silver chloride
floating electrodes were utilized with a conduction electrode jell developed for the NASA program provided by Bio-Com Medical Instruments of Culver City, California. Primary electrode placement was at a V6 position off the manubrium, with ground electrode at left wrist.

Pulmonary ventilation was monitored through the Parkinson C.D. IV Gasometer in liters per minute. A Collins triple "J" high velocity one way breathing valve with a rubber mouthpiece and standard nose clip were used for air direction control. This meter is distributed by Instrumentation Associates, Inc. of Lexington, Massachusetts. An expired air sample from an inline air mixing chamber was taken with a 50cc oiled syringe during the last minute of performance. From this sample respiratory oxygen and carbon dioxide were analyzed by the Instrumentation Laboratory Ultra pH and Blood Gas Analyzing System, Model 113-51. Ventilatory and respiratory gas data were used to compute the volume of oxygen during the last minute of work stress to determine the possible influence of serum electrolyte changes upon metabolic work efficiency.

Blood samples were taken using the Becton-Dickinson Vacutainer system. All samples were fractionated within a half hour of being drawn and refrigerated. The
samples were analyzed for sodium, potassium, and chloride concentrations by Clark-Sarver Clinical Laboratories of Burbank. The magnesium data were analyzed by Central Diagnostic Laboratories of North Hollywood. Serum sodium and potassium were analyzed using the popular flame photometry technique. Chloride was analyzed using the Schales and Schales method. Magnesium levels were found using EDTA titration with a calmagite indicator developed by Diehl and Ellingboe.

Laboratory Protocol

After subjects had been selected, appointments for laboratory orientation visits were made. At the orientation each subject was treated separately. Subjects were asked to fill out a pre-study questionnaire and read through the experimental procedure instructions prepared by the investigator. This was discussed by the investigator and the subject with special attention to the conditions each subject had to comply with on or before his final experimental session. Copies of the questionnaire, experimental procedure and pre-experimental conditions are contained in Appendix B and C.

Each subject was then given a demonstration trial of the equipment that would be used during the performance
of his stress test at the next laboratory visit. None of the subjects refused to participate in the study after this point. Each subject then performed a practice trial for six minutes on the bicycle ergometer at two kiloponds at a rate of fifty revolutions per minute.

Heart rates during the sixth minute of work were used to equate and divide subjects into two groups. The heart rates were listed in ascending order and divided into pairs. A coin was flipped to determine which group the first of each pair would enter, the second subject was entered in the other group.

Following the orientation visit an appointment was made for each subject to return to the laboratory to receive his experimental treatment and perform time he must comply with all the conditions given him at the orientation session. The major conditions for each subject three hours prior to experimental performance included no smoking or consumption of any food or beverage, including water. They were also reminded not to exercise in the moderate to heavy range during the previous twenty-four hours. Each subject was tested approximately four weeks after orientation.

Upon arrival in the laboratory for the final session, a physician drew 5 to 8cc of blood from the cubital vein of the left arm of each subject. Following this
sample each subject was given a 250ml cup of electrolyte or placebo solution. The solution was administered at room temperature (25°C) and subjects were told to drink the solution at a comfortable rate but to finish it as rapidly as possible. The next ten minutes were spent connecting experimental apparatus to the subject. An environmental chamber was utilized which enabled the investigator to control ambient temperature within the 27 to 28°C range and relative humidity within the thirty-five to forty-five percent range.

The submaximum work capacity stress test was promptly begun ten minutes after ingestion of the solution was completed. After completion of the first nine minutes of pedaling at one kilopond and fifty revolutions/min, subjects were all given a second 250ml cup of the same solution originally ingested, for a total amount of 500ml of solution. Following ingestion of this second cup, monitoring of pulmonary ventilation was initiated. Subjects were instructed to continue pedaling until the investigator directed them to stop.

Immediately upon completion of the stress test the subjects remained seated on the bicycle and the final blood sample was removed from the subject's dorsal metocarpal vein at the back of the wrist. No tourniquet was used that
might have occluded the flow of blood prior to venipuncture. Westerman (60) believed that variability in serum potassium levels found in previous research was partly due to different techniques of blood collection. His suggestion of using an unexercised extremity and no tourniquet was followed. Care was exercised in collection of samples so there was no hemolysis of red blood cells which could have altered serum potassium concentration levels. Necessity of an immediate post exercise venipuncture was stressed in previous work by DeLanne, et al. (24).

The amount of oxygen was computed in the following manner. An air sample was taken during the last minute of exercise and analyzed for oxygen and carbon dioxide content. Data from the Instrumentation Laboratory instrument are interpreted for standard readings on a nomogram. True percent O$_2$ utilized is then multiplied times the volume of inspired air during the last minute as it was recorded on the Varian Recorder as part of the Parkinson C.D. IV Gasometer.
CHAPTER IV

ANALYSIS OF THE DATA

The purpose of this study was to investigate the effects of ingesting an oral electrolyte solution on cardiovascular, pulmonary, and metabolic efficiency of adult male subjects while performing a submaximum work capacity 170 test on a bicycle ergometer.

Data were analyzed to determine if any significant differences existed between groups in: weight, height, and age; pretest and post test electrolyte levels; mean change of electrolyte levels; metabolic efficiency; and trend analysis of cardiac rate and pulmonary ventilation. The double blind technique was utilized in the study.

Following the collection of data, group A was identified as the placebo group, group B the experimental (Gatorade) group.

Originally forty subjects were randomly selected to participate in this study. Twelve subjects were dropped from the study prior to the orientation session for the following reasons: Five dropped out of school, five
could not be reached by telephone or mail, and two refused to participate. Two subjects attended their orientation session and did not participate in the experimental session. The first felt very faint due to lack of sleep and food and was disqualified prior to his demonstration trial on the bicycle ergometer. The second subject completed the orientation session without complication. He underwent surgery to his right foot for a papilloma and was advised against participation during experimental testing sessions by his doctor.

Groups A and B were selected using heart rate for the sixth minute of work at the orientation trial. Each heart rate score was matched to another similar score and a coin was flipped to determine which group the first of each pair would enter. The second subjects were entered in the other group.

To further assess the equivalence of the two groups data for weight, height, and age were analyzed. Weight was measured in kilograms, height in centimeters and age in months. Results of this analysis are reported in Table 1. Weight and height data appear to be well equated. The difference of the means for weight between groups is 1.51 kilograms. Group B was the heavier of the two. Height also favored group B as the taller group by 2.25
centimeters, seemingly a very small difference.

Age of group B was greater by 27.39 months or approximately two and one-quarter years.

TABLE 1
WEIGHT, HEIGHT, AND AGE

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Standard Error</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>74.27</td>
<td>11.02</td>
<td>3.06</td>
<td>-.370</td>
<td>.358</td>
</tr>
<tr>
<td>Group B</td>
<td>75.78</td>
<td>9.74</td>
<td>2.70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>177.80</td>
<td>6.95</td>
<td>1.93</td>
<td>-.886</td>
<td>.193</td>
</tr>
<tr>
<td>Group B</td>
<td>180.05</td>
<td>5.95</td>
<td>1.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>244.23</td>
<td>27.00</td>
<td>7.49</td>
<td>-2.462</td>
<td>.010</td>
</tr>
<tr>
<td>Group B</td>
<td>271.62</td>
<td>29.66</td>
<td>8.22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The second analysis was designed to determine if any differences existed between groups in the pretest or post test electrolyte levels. Results of this analysis are presented in Table 2. There were no differences in pretest scores on potassium, magnesium, or sodium. A significant difference was found at the .01 level in pretest chloride between the two groups. The physiological cause of this significant difference is unknown.

Post test scores showed no difference in sodium or
magnesium. Potassium approached the .10 level and chloride showed a significant difference at the .01 level.

TABLE 2
INDIVIDUAL SERUM ELECTROLYTES

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Mean</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>146.45</td>
<td>1.496</td>
<td>.145</td>
</tr>
<tr>
<td>Group B</td>
<td>144.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>4.27</td>
<td>0.761</td>
<td>.542</td>
</tr>
<tr>
<td>Group B</td>
<td>4.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>1.94</td>
<td>0.100</td>
<td>.912</td>
</tr>
<tr>
<td>Group B</td>
<td>1.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloride:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>102.82</td>
<td>2.742</td>
<td>.012</td>
</tr>
<tr>
<td>Group B</td>
<td>100.92</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post test-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>145.82</td>
<td>0.360</td>
<td>.724</td>
</tr>
<tr>
<td>Group B</td>
<td>146.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>4.80</td>
<td>1.640</td>
<td>.112</td>
</tr>
<tr>
<td>Group B</td>
<td>5.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>1.94</td>
<td>0.100</td>
<td>.906</td>
</tr>
<tr>
<td>Group B</td>
<td>1.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloride:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>104.18</td>
<td>3.122</td>
<td>.005</td>
</tr>
<tr>
<td>Group B</td>
<td>101.85</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Scores of electrolytes showed such variance that a separate analysis of mean change between pretest and post
test electrolytes was made. Table 3 shows that of the
four electrolytes analyzed in this study, no significant
levels existed. Levels reached by sodium and potassium:
.133 and .271 are reported so the reader may draw his own
conclusion for the level of confidence he chooses to
accept.

**TABLE 3**

**MEAN CHANGE OF SERUM ELECTROLYTE LEVELS**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Mean</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>0.636</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group B</td>
<td>-2.154</td>
<td>1.546</td>
<td>.133</td>
</tr>
<tr>
<td>Potassium:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>-0.527</td>
<td>1.126</td>
<td>.271</td>
</tr>
<tr>
<td>Group B</td>
<td>-0.769</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>0.000</td>
<td>0.000</td>
<td>.996</td>
</tr>
<tr>
<td>Group B</td>
<td>0.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloride:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>-1.364</td>
<td>0.871</td>
<td>.603</td>
</tr>
<tr>
<td>Group B</td>
<td>-0.923</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Results of true oxygen consumption in the last
minute of exercise are shown in Table 4. No differences
were found between groups in oxygen consumption from either
raw data or after correcting for body mass differences.
TABLE 4
TRUE OXYGEN CONSUMPTION

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Standard Error</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 O&lt;sub&gt;2&lt;/sub&gt;/min.:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>2.37</td>
<td>0.394</td>
<td>0.565</td>
<td>-0.800</td>
<td>.21</td>
</tr>
<tr>
<td>Group B</td>
<td>2.52</td>
<td>0.716</td>
<td>0.199</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ml O&lt;sub&gt;2&lt;/sub&gt;/kg/min.:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>-31.4</td>
<td>4.0</td>
<td>1.0</td>
<td>-1.011</td>
<td>.153</td>
</tr>
<tr>
<td>Group B</td>
<td>-33.7</td>
<td>7.0</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5 illustrates analysis of metabolic efficiency between groups. Metabolic efficiency was determined by analysis of efficiency of each subject in his last minute of work. It was a numerical score found by dividing the work performed in the last minute of exercise by the amount of oxygen consumed in that same period. No differences were found between groups.

TABLE 5
METABOLIC EFFICIENCY

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Mean</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>4.283</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group B</td>
<td>4.122</td>
<td>0.496</td>
<td>.629</td>
</tr>
</tbody>
</table>
The last analysis performed in this study was a trend analysis to determine if a trend existed in cardiac rate or pulmonary ventilation, and if so were these trends significantly different.

Scores for each minute or each trial were analyzed separately. Data showed no significant differences between groups for either heart rate or pulmonary ventilation.

Scores were then tested for differences between trials. These data were found to be highly significant. This demonstrates that the subject's heart rate and pulmonary ventilation changed significantly from the beginning of the test to the end. This is a normally predictable occurrence in a performance study of this type.

Analysis between groups for each trial from the tenth to the thirty-second minute of exercise also found no significant differences in the two parameters tested. Data for these analyses can be found in Table 6.
TABLE 6
TREND ANALYSIS FOR HEART RATE AND PULMONARY VENTILATION

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Mean Square</th>
<th>( f )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>between groups</td>
<td>54.771</td>
<td>0.015</td>
<td>.898</td>
</tr>
<tr>
<td>between trials</td>
<td>7227.779</td>
<td>114.979</td>
<td>.000</td>
</tr>
<tr>
<td>each trial by groups</td>
<td>23.415</td>
<td>0.372</td>
<td>.995</td>
</tr>
<tr>
<td>Pulmonary ventilation:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>between groups</td>
<td>77.465</td>
<td>0.079</td>
<td>.778</td>
</tr>
<tr>
<td>between trials</td>
<td>4599.919</td>
<td>66.294</td>
<td>.000</td>
</tr>
<tr>
<td>each trial by groups</td>
<td>56.368</td>
<td>0.812</td>
<td>.706</td>
</tr>
</tbody>
</table>

Summary of the Major Findings

The findings of the analysis are summarized as follows:

1. Weight and height data seem to be comparable between groups.
2. Average age of group B subjects is older by approximately two and one-quarter years.
3. Serum chloride across groups was significantly different at both the pretest and post test scores.
4. Analysis of mean change of electrolyte levels showed no significant differences between sodium, potassium, magnesium, or chloride.
5. Metabolic efficiency between groups showed no significant difference.

6. Trend analysis of heart rate and pulmonary ventilation showed no significant differences between groups.
CHAPTER V

SUMMARY AND DISCUSSION

Summary

The purpose of this study was to investigate the effects of an oral electrolyte solution on metabolic efficiency of a human submaximum work performance. The experimental group was allowed the ingestion of a commercial oral electrolyte solution. The control group was given a placebo solution containing only a flavoring agent and water with no electrolytes. The investigation utilized the double blind technique. A submaximum work capacity performance followed on a bicycle ergometer. Prior to and following completion of the work bout a blood sample was taken for analysis of serum sodium, potassium, magnesium, and chloride. Statistical methods employed in this study were the independent group t-test of mean change, standard t-test for independent groups, and a trend analysis.

Major Findings

Major findings of this study can be summarized as follows:
1. No significant differences were found on analysis of mean change between the groups for any of the four electrolytes analyzed.

2. Metabolic efficiency between groups showed no significant differences.

3. Analysis of heart rate and pulmonary ventilation showed no significant differences between groups.

**Discussion of the Findings**

This study was undertaken to determine the effects of an oral electrolyte solution on serum electrolytes and their effects upon cardiovascular, pulmonary and metabolic work efficiency during a submaximum work capacity performance.

Serum chloride was found to be significantly different at the .01 level at the pretest score. The investigator can only attribute this difference to have occurred by chance alone. Post test scores on serum chloride were also significant at better than the .01 level. Serum chloride levels from pretest to post test increased in value in both groups. Significance at the pretest and post test made analysis of the mean change essential. No significant differences were found in any one of the four
electrolytes analyzed in this study. Sodium and potassium reached a significance of .133 and .271 respectively.

It is interesting to note that even though group B ingested the electrolyte solution they lost greater amounts of serum sodium and potassium and lost less serum chloride. On the other hand, group A receiving the placebo solution, lost less serum sodium and potassium and a greater amount of serum chloride.

Magnesium levels in the serum did not change for either group. The probability this could have happened by chance alone was .996.

Rose, et al. (46,47) found a significant increase in serum sodium and potassium ion concentrations in response to muscular exercise. A significant decrease in serum magnesium was also reported. Subjects in the study by Rose, et al. exercised for three to four hours. The subjects in this investigation exercised for a maximum of thirty-two minutes, with the average being 24.3 minutes. This investigation shows a general increase in serum sodium and potassium concentrations but not significantly so. This was in agreement with a number of similar studies (18,23,50). This investigation also shows no difference (pretest P = .912, post test P = .906) in serum magnesium levels. The differences in results obtained from this
study and the one done by Rose, et al. are most likely attributable to the exercise time of the subjects.

Metabolic efficiency was determined by analysis of metabolic efficiency of each subject in the last minute of work. Metabolic efficiency was a numerical score found by multiplying the number of revolutions per minute of the bicycle ergometer times six meters per revolution, times the kilopond rating for that minute. This number is divided by the amount of true oxygen consumed in the last minute. Analysis of the data for metabolic efficiency revealed no significant difference between groups.

Heart rate and pulmonary ventilation were analyzed between groups and each trial by each group. No significant differences were found upon analysis.

In a pilot study by the investigator of ingestion of 250ml of fluid ten minutes prior to exercise, it was found to have no apparent ill effects on the participants tolerance for exercise. Further, subjects participating in this study unanimously agreed that ingestion of solution did not bring about any uncomfortable feelings prior to or during the exercise bout.

Londeree, et al. (36) reported that ingesting water prior to a work bout had no advantage over ingestion during the activity. Little, et al. (35) reported
ingestion of 1.0 - 1.5 liters of water prior to exercise had no adverse effects on heart rate or minute volume of ventilation. That amount of water is greater than twice the amount ingested at two separate occasions in this study.

In his work with marathon runners, Costill, et al. (23) found on separate test days with water, no water and an electrolyte-glucose solution, no significant differences were found in heart rates, $V_O^2$, or minute ventilation. Subjects in that study were allowed ingestion of each solution in separate performances on the treadmill. It was found that gastric emptying was only slightly decreased, while intestinal absorption was not significantly altered.

**Conclusion**

The null hypothesis of this study stated that cardiovascular, pulmonary, or metabolic efficiency would not change significantly due to ingestion of an oral electrolyte solution containing sodium, potassium, magnesium, or chloride. The null hypothesis was found to be tenable. The following general conclusion appears to be justified. Ingestion of an oral electrolyte solution prior to and after specific warm-up does not significantly alter serum sodium, potassium, magnesium, or chloride levels or cause
a significant change in cardiovascular, pulmonary, or metabolic efficiency following a submaximum work capacity performance on a bicycle ergometer. The following implications are advisable in light of the findings of this study.

1. It appears that ingestion of an oral electrolyte solution prior to and following specific warm-up has no effect on efficiency of a human submaximum work performance.

2. Cardiovascular and pulmonary efficiency are apparently not affected by ingestion of an oral electrolyte solution prior to a submaximum work capacity performance.

3. This study seems to indicate the electrolyte group, group B, suffered greater losses in serum electrolyte levels in all cases except chloride. This might suggest that ingestion of these solutions is actually creating a stress on natural buffer systems present in the body to counteract physiological changes that occur during exercise. However, further studies would be needed to substantiate this claim.
Recommendations

Electrolyte research involving human performance is extremely limited. There is a tremendous need for additional research in this area. The investigator offers the following recommendations for future study:

1. Different amounts of solutions should be studied to develop some general guidelines concerning the amount of fluid that should be ingested in various environmental conditions.

2. An attempt should be made to investigate the various possibilities of times of ingestion of electrolyte solutions prior to, during, and especially following exercise in an effort to more effectively study replacement times.

3. An attempt should be made to control humidity and/or temperature at higher levels for shorter periods of time. Studies of this nature would be extremely useful for more data on severe heat stress connected with heavily exercising individuals.

4. Monitoring of subjects in actual participation and competitive situations under heat stress conditions utilizing oral electrolyte solutions
is another very practical study needed to be undertaken. Ingestion time and amounts should be studied to a greater extent before further studies dealing with physiologic effects during performance are undertaken.
BIBLIOGRAPHY

Books


Periodicals


47. Rose, L. I.; Carroll, D. R.; Lowe, S. L.; Peterson, E. W.; and Cooper, K. H. "Serum electrolyte changes after marathon running." Journal of


Others


APPENDIX A

February 1972

Dear Mr.

You have been randomly selected to participate in a human performance research study to be conducted in the Physical Education building this spring. Forty subjects were randomly selected from all of the male students enrolled in general education classes in the Department of Physical Education. The research involves a study of the immediate effects of an oral food beverage upon the physical performance of stationary bicycling.

The entire study will not require more than two hours of your time. I will be able to schedule each participant at a time that is most convenient to you.

It is very important that every subject participate in this study. Enclosed with this letter is a self addressed stamped post card. Please indicate the best time for me to contact you by telephone for an appointment for orientation in this project. If a telephone conversation is not convenient, indicate the best mailing address for correspondence.

Please fill out the necessary information card and mail it at your earliest possible convenience.

Very truly yours,

Charles F. Wolcott
Department of Physical Education
San Fernando Valley State College
Northridge, California 91324

Phone: home 886-6655
work 885-3205
APPENDIX B

NAME: _____________________________

PRE-STUDY QUESTIONNAIRE

Please circle the appropriate response:

1. Do you participate in any form of regular physical exercise? YES  NO

2. Are you now under a doctors care and/or taking medication prescribed by a physician. YES  NO

3. Are you a diabetic, or do you have a history of diabetes in your family? YES  NO

4. Have you had nephritis or any other kidney disease as a child? YES  NO

5. Do you have congenital or rheumatic heart disease? YES  NO

6. Are you known to have sickle cell anemia? YES  NO

7. Can you think of any reason why your heart rate should not approach 170 beats per minute? (this is only a moderate to heavy work load) YES  NO

8. Can you think of any physical limitations you might have that might disqualify you from this study? YES  NO
APPENDIX C

EXPERIMENTAL PROCEDURE

This research project is designed to test the effects of an oral electrolyte solution on serum electrolytes following a sub-maximum work capacity performance. In other words, this project will investigate the changes in the efficiency of human performance brought about by drinking a nationally recognized food beverage.

At our first visit you will be asked to perform on the bicycle ergometer for 6 minutes, as an orientation session. At our second meeting you will again perform on the bicycle ergometer for a period of time that will vary for each individual. At this second meeting, two small 10cc. blood samples will be taken by a Physician.

Following your second performance, the investigator will upon completion of the project, inform you by mail as to the results of your efforts.

I would like to thank you in advance for the time and effort you will devote in this project.

Very truly yours,

Charles F. Wolcott
Physical Education
APPENDIX C (Continued)

It will be necessary for a study of this nature that you comply with all of the following conditions on or before the day of your scheduled experimental session.

Three days prior to your session:
1. No alcohol, drugs, or medication.

Twenty-four hours prior to your session:
1. Attempt to eat your normal diet.
2. Limit exercise of any form that might be classified in the moderate to heavy range.

Three hours prior to your session:
1. No smoking.
2. DO NOT CONSUME ANY FOOD OR BEVERAGE, WATER INCLUDED!!!
January 4, 1972

Mr. Charles F. Wolcott
Physical Education Department
San Fernando Valley State College
Northridge, California 91324

Dear Mr. Wolcott:

Thank you for your letter of December 22nd advising us of your intention to begin your research project.

For several other double blind experimental projects, we prepared the Gatorade and the placebo solution under code numbers so that even the investigators do not know which is which. The information was sent to a third party in a sealed envelope and opened only after the experiments were completed. The products were prepared and shipped in cases of quart jars just as the Gatorade is sold.

Under separate cover we are sending to your attention 2 cases each of these products coded JD-02650 A and B. The only point you should keep in mind is that the placebo in this case does not have any of the electrolytes and the glucose. The milliequivalents for each ion are given in the booklet we sent you. Another copy is enclosed for your use in case you have lost the one we sent.

The code number identification and the analysis for each solution will be placed in a sealed envelope and sent to your Thesis Chairman, Dr. George Holland.

Please let us know if you will require any additional amounts of the products. We look forward to learning of your findings.

Best wishes for the New Year.

Sincerely yours,

Vigen K. Babayan

VKB/mm
Enc.
January 4, 1972

Dr. George Holland
c/o SFVSC
Physical Education Department
San Fernando Valley State College
Northridge, California 91324

Dear Dr. Holland:

At the request of Mr. Charles F. Wolcott of your department, we are sending to your attention a sealed envelope containing the coding of Gatorade and a placebo solution. The envelope is to be turned over to Mr. Wolcott after the double blind experiments he is conducting are completed.

Thank you for your kind cooperation.

Sincerely yours,

V. K. Babayan

VKB/mm
Enc.
cc: Mr. Charles F. Wolcott
January 4, 1972

Mr. Charles F. Wolcott
Physical Education Department
San Fernando Valley State College
Northridge, California 91324

Dear Mr. Wolcott:

The coded products JD-02650 A and B represent the placebo and Gatorade respectively.

The placebo (JD-02650 A) has the lemon-lime flavor, clouding agent, citric acid and calcium saccharin. The acidity of the product is 0.12 and the osmolarity is 20.

The Gatorade (JD-02650 B) has the above ingredients plus the dextrose and the electrolytes to meet our specifications for the product.

If we can be of further assistance, please advise us.

Sincerely yours,

V. K. Babayan

VKB/mm