THE EFFECTS OF GLYCEROL-INDUCED HYPERHYDRATION ON A COLLEGIATE WOMEN'S SOCCER TEAM

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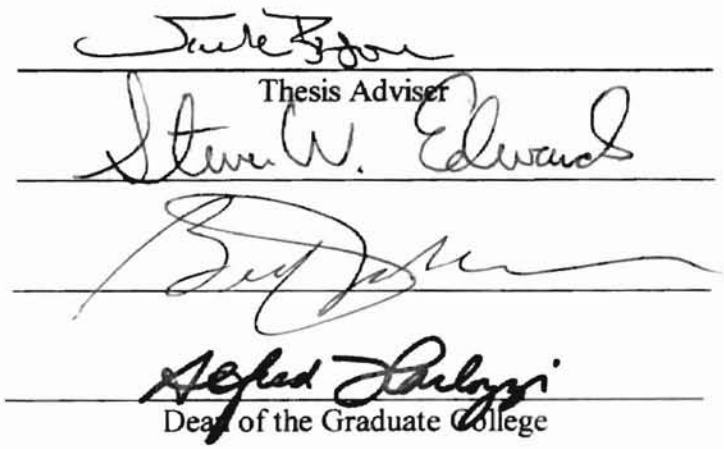

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CHAPTER I

Introduction

Exercise in a hot environment may result in dehydration. This condition develops when an individual loses fluid through sweating and does not consume adequate fluids to replace those lost during the exercise. Dehydration may lead to more serious health problems such as an increased core body temperature; increased heart rate, decreased sweat rate, and cutaneus blood flow leading to heat illness (3, 12, 15, 23, 28, 32, 40, 41). Individuals experience a decline in endurance performance following a dehydration of only 1% of total body weight (2). Athletes attempt to combat the effects of dehydration by drinking water before, during, and after exercise. Unfortunately, consuming such a large amount of water in such a short time period may result in gastric discomfort or possibly "water intoxication" (10, 14, 30, 45). The supplement glycerol may assist an athlete in maintaining a hyperhydrated state during exercise prolonging exercise duration and delaying the ill effects of heat illness.

The Food and Drug Administration's Office of Food Labeling classified glycerol as a carbohydrate as well as a sugar alcohol, a hydrogenated derivative of a sugar. Glycerol is the hydrogenated derivative of glyceraldehydes and dihydroxyacetone, therefore placing it in the category of a sugar alcohol (16). Glycerol has been proposed as a hyperhydrating agent due to its osmotic properties, which enable increased fluid retention as compared to ingesting water alone (45). This very sweet and syrupy, natural metabolite

is rapidly absorbed by the body. Following absorption, glycerol is nearly excluded from the central nervous system by the blood brain barrier but is evenly distributed into intravascular and extravascular water (44). Glycerol has also been identified as a substance that moves rapidly from one fluid compartment to another as evidenced by serum glycerol values reaching a peak level within 15 to 90 minutes following a single oral ingestion (37).

Riedesel and Lyons (23) found that glycerol created greater retention of water in the experimental subjects compared to the control group. The hyperhydration effects of glycerol lasted four hours. Those subjects that ingested the glycerol solution retained 80% of fluid intake compared with 50% fluid retention in subjects that drank water alone (23). Koenigsberg and associates (18) found that glycerol induced a hyperhydrated state over a period of 49 hours. Other investigations (23, 31) have also found beneficial effects with glycerol-induced hyperhydration. Results have demonstrated subjects that ingested a glycerol solution reported a lower mean heart rate compared to subjects that ingested a placebo solution (31). Glycerol research studying the effects of supplementation on sweat rates differs. Subjects that received the glycerol treatment have experienced varied sweat rates (18, 31). The benefits of glycerol-induced hyperhydration and hyperhydration in general have been confounded by subjects starting exercise in a hypohydrated state or becoming dehydrated during exercise (22).

The mechanism of glycerol on the body's fluid regulation was the focus of research by Freund et al (13). These researchers studied the effects of glycerol supplementation on total body water, hormonal, renal, vascular blood (erythrocyte) and plasma measurements. The results of their study lead to the hypothesis that several factors may be involved with

the effectiveness of glycerol in improving fluid retention. One of the possible hypotheses that evolved from these studies proposes that glycerol increases plasma osmolality, which in turn attenuates the decrease in plasma antidiuretic hormone concentration that typically occur with hyperhydration. Following the glycerol-induced hyperhydration, the higher concentration of antidiuretic hormone (ADH) compared to the level of ADH with ingestion of water alone could enable greater fluid retention. A second hypothesis from the Freund et al (13) research suggested that the reabsorption of glycerol by the renal tubules, separate from hormonal responses, might be a more likely mechanism for the effectiveness of glycerol in an individual increasing their fluid retention. The result of glycerol reabsorption by the renal tubles increases the concentration gradient in the medullary-collecting duct of the kidney, therefore leading to increased fluid retention.

Glycerol ingestion has also been shown to increase intracellular water resulting in total body-water expansion. The "sponge-like" action triggered in cells may allow for greater water retention (37). An individual that retains an excess reservoir of body water will be better equipped to battle the effects of dehydration (24).

To date, all projects investigating the benefits of glycerol have been conducted primarily in a laboratory setting. The laboratory allows for maximum control but does not simulate exercise in an extreme weather environment. Often athletes are required to train and compete in severe weather conditions, such as the extreme heat of the south or the frigid temperatures of the north. These athletes must learn how to adjust and become acclimatized to these climates. Glycerol has been found to assist in the prevention of dehydration in the laboratory; the present study utilized collegiate women's soccer players to examine its effects in the field setting.

Statement of Purpose

This study was designed as an attempt to assess the effects of glycerol on an individual's fluid retention among female soccer players during subsequent exercise bouts.

Delimitations

While designing this study, certain delimitations were accepted which possibly could compromise the outcome.

1. The sample group was delimited to a women's soccer team. This sample population was readily available and willing to participate, therefore this population was not selected from the general population by random sampling.
2. The subjects were delimited to healthy individuals as defined by an Oklahoma State University physician. The use of human subjects mandated that informed consent was secured from all subjects that agreed to undergo the treatment and testing.
3. The tests were performed and monitored immediately before and after the practice sessions to ensure accurate measurements. The availability of technical resources to the researcher and testing equipment allowed sophisticated data collection.
4. The testing procedures were delimited to a practice schedule determined by the coaching staff; therefore the practice schedule could have been altered daily.
5. Environmental conditions varied slightly during the investigation and might have greatly affected the selected variables of study in this research.
6. This study lasted seven days due to the soccer schedule and the beginning of the Oklahoma State University academic school year.

Limitations

The limitations of this study reflect the effects of the delimitations on collection, interpretation of the data, and the availability to expand the scope of inference beyond the sample population. Generalizations made from the results were compromised by the following limitations.

1. Healthy college age women's soccer players were utilized as subjects based on their availability and willingness to participate.
2. Results could not be generalized beyond post pubescent female subjects. Subject selection criteria were limited to honesty on their health history form and the clearance by a physician via a general physical.
3. Testing procedures warranted a limitation to body weight and fluid intake measurement. The subject's blood pressure and resting heart rate were taken prior to the exercise session for physiologic data.
4. Testing protocol was limited according to the Oklahoma State University Women's Soccer Team coaching staff
5. Fluid loss may have varied between subjects. The investigator attempted to maintain consistency in all tests throughout the evaluation period considering changes in the environmental conditions.
6. The testing protocol was limited to the environmental conditions. The environmental conditions varied daily.

Assumptions

The following assumptions were made for the study:

1. The difference in total body weight between pre- and posttest measurement represented fluid loss during the practice session.
2. The placebo solution and glycerol solution were similar in taste and color making it impossible for the subjects to know whether they were assigned to the control or experimental group.
3. The practice sessions created equal intensity for all subjects involved. The level of work by each subject was dependent on degree of motivation, competitive spirit and willingness to give maximal effort.
4. Subjects drank at their own rate, no more or less than the usual amount consumed during a normal practice session.
5. Subjects were honest on the health history forms concerning all medications took throughout the evaluation period.

Hypotheses

The hypothesis tested in this study pertained to post-exercise body weight in competitive, soccer players under treatment as compared to placebo conditions. Hypothesis: There will be no significant difference between the two groups, placebo and experimental, in post exercise body weight following intensive exercise over a seven day period. Glycerol supplementation will elicit no significant difference between the experimental and control groups water intake.

Significance of Study

Athletes that train in hot, humid weather may experience the ill effect of dehydration. During the course of practice or competition, an athlete may not consume adequate liquid to replace the fluids being lost due to intensive exercise (23). During uncompensable heat stress, the body's evaporative cooling requirement exceeds the climates cooling capacity (22). A supplement that assists an individual in battling the effects of dehydration would be extremely useful in the prevention of heat illnesses.

Currently, the ingestion of a large amount of water before, during, and after practice is the most common way to battle the ill affects of dehydration. Individuals who attempt to utilize highly advertised electrolyte drinks might develop the same uncomfortable gastro-intestinal discomfort or vomiting. Glycerol, because of its osmotic properties, potentially enables greater fluid retention than the ingestion of water alone (45). However, the research investigating the use of glycerol has led to different conclusions. The investigation intended to demonstrate that the supplementation of glycerol would decrease the heat stress on an athlete exercising in extreme heat and as a result help prevent dehydration and heat illness.

Definition of Terms

Aerobic Exercise – Exercise during which oxygen is metabolized to produce Energy. Aerobic exercise is required for sustained periods Of hard work and vigorous athletic activity. (43)

Aerobic Training – Exercise training for the purpose of attaining aerobic conditioning. No formula can be universally applied, but a general guideline is that aerobic conditioning will be obtained by normal healthy persons who exercise three to five time a week for 20 to 30 minutes each time at an intensity that produces a heart rate of 220 minus the age of of the individual. (43)

Dehydration – A condition, resulting from excessive loss of body fluid, that when fluid output exceed fluid intake. It may result from deprivation or excessive loss of fluid, reduction in total quantity of electrolytes, or injection of hypertonic solutions. (43)

Hyperhydration – A state at which an individual consumes adequate or more than adequate amount of fluid to maintain euhydration.

Hypohydration – A state at which an individual does not consume an adequate amount of fluid to maintain euhydration. This condition may also be associated with the term dehydration.

Interstitial – Placed or lying between. Pertaining to spaces within an organ or tissue (43)

CHAPTER II

REVIEW OF LITERATURE

Introduction

Exercise in a hot environment can result in a condition called dehydration. Athletes are in danger of injury or illness when wet bulb temperatures climb higher than 75 degrees Fahrenheit or relative humidity is above 90 percent (3). Dehydration develops when an individual does not consume adequate fluids during exercise (20, 21, 26, 42). It can elicit an increased core body temperature; increased heart rate, decreased sweat rate, and cutaneus blood flow, as well as a reduced aerobic exercise performance (3, 12, 15, 23, 28, 32, 40, 41). Athletes may try to combat the effects of dehydration by drinking excessive water, but consuming such a large amount of water in a short time period can lead to gastric distress (10, 14, 30, 45). A supplement of glycerol may assist the athlete in maintaining a hyperhydrated state during exercise without the requirement of drinking an excessive amount of water. Although glycerol has been found in some research studies to elicit gastric distress in isolated cases when the dosage was greater than 1.0g/kg glycerol solution a vast majority of subjects did not experience problems (18, 22, 33). The research thus far has been equivocal when investigating its benefits associated with dehydration (23). This investigation intended to utilize glycerol with a collegiate women's soccer team measuring its affects on fluid loss and water intake. The review of literature was divided into: a) glycerol and its benefits, b) the affect of glycerol on sweat

rate, c) the affect of glycerol on blood pressure, d) the affect of glycerol on mean heart rate, and e) the summary.

Glycerol and Its Benefits

According to the Food and Drug Administration's Office of Food Labeling, glycerol is labeled as a carbohydrate as well as a sugar alcohol, a hydrogenated derivative of a sugar. Glycerol is the hydrogenated derivative of glyceraldehydes and dihydroxyacetone, therefore placing it in the category of a sugar alcohol (16). Glycerol has been proposed as a hyperhydrating agent due to its osmotic properties, which enable increased fluid retention than ingesting water alone (45). This very sweet and syrupy, natural metabolite is rapidly absorbed by the body. Glycerol is evenly distributed into intravascular and extravascular water after being absorbed by the body. It is nearly excluded from the central nervous system by the blood brain barrier (44). Lyons and colleagues (23) found the rate of the body's ability to uptake and retain glycerol varies among the tissues. Glycerol has also been identified as a substance that moves rapidly from one fluid compartment to another as evidenced by serum glycerol values reaching a peak level within 15 to 90 minutes following a single oral ingestion. The catabolism and renal excretion of glycerol vary in levels of serum concentration (26).

Freund and associates (13) investigated the mechanism of glycerol on the body's fluid regulation. These researchers studied total body water, hormonal, renal, and vascular blood (erythrocyte) and plasma measurements simultaneously after subject's ingested glycerol. The results of their study lead to the hypothesis that the effectiveness of glycerol in improving fluid retention is a result of multiple factors. One possible hypothesis that evolved from these studies proposes that glycerol increases plasma

osmolality, which in turn attenuates the typical decrease in plasma antidiuretic hormone concentration that occurs with hyperhydration. Glycerol-induced hyperhydration results in a higher concentration of antidiuretic hormone (ADH) in the body. The higher level of ADH could enable greater fluid retention as compared to the ingestion of water alone. Preventing a negative water balance can assist an athlete in preventing dehydration (18). A second hypothesis evolving from the Freund et al, (13) research suggested that the reabsorption of glycerol by the renal tubules, separate from hormonal responses, might be a more likely mechanism for the effectiveness of glycerol in an individual increasing their fluid retention. The result of glycerol reabsorption by the renal tubles increases the concentration gradient in the medullary collecting duct of the kidney, therefore leading to increased fluid retention. These researchers also state that other fluid-regulating mechanisms including; blood pressure, glomerular filtration rate, and other diuretic hormones, do not appear to be factors in glycerol's ability to increase an individuals ability to increase water retention.

The Effect of Glycerol on Sweat Rate

The literature and research on the affect of glycerol supplementation on sweat rate has been equivocal. A study completed by Lyons et al, (23) proposed that glycerol could initially expand total body water by primarily increasing the volume of the interstitial fluid (ISF) and intracellular fluid (ICF), with very little effect on the individuals plasma volume (PV). The excess water in the extravascular space following the glycerol ingestion is available to maintain plasma volume, increase sweating, and reduce elevation of core temperature during exercise and thermal stress (23). An increase in sweating and

corresponding reduction in the body's core temperature lessens an athlete's risk of heat injury or illness. Previous studies support the contention that actual water lost from plasma during hypohydration is small in comparison to that lost from the ISF and ICF; however, the small size of PV available results in the PV sacrificing a disproportionally large percentage of its total volume (7, 19, 34).

There are other less likely explanations for the effectiveness of glycerol-induced hyperhydration to increase an individuals sweating. Glycerol is lipid soluble therefore making it difficult to predict how glycerol may affect cells involved in osmotic regulation. There is also evidence that changes in osmotic pressure has an effect of temperature regulation. It is also possible that glycerol has a pharmacological effect on the temperature regulation center and/or sweating rate (13).

Investigations on sweat rate and rectal temperature has suggested that the thermoregulatory set point may be altered with glycerol ingestion. Glycerol ingestion has been found to not only augment the sweat response, but also initiate a lower rectal temperature (23). A study at the University of New Mexico found that glycerol supplementation increased the subjects sweat rate by 33% (45). Moroff and Bass (24) discovered that core temperature decreased and sweating increased following hyperhydration. The increased sweat rate and decreased rectal temperature as a result of glycerol supplementation would better equip an athlete's body to combat the stress inflicted by exercise in extreme heat. Lyons and colleagues (23) utilized water and orange juice as well as glycerol to investigate hyperhydration. They found the ingestion of glycerol reduced urine output and elicited a lower mean rectal temperature when compared to the other two fluid regiments.

Investigations conducted by Latzka et al (22) found that the glycerol and water experimental group maintained a higher level of total body water, but also found that whole body sweating rates was not different among trials. Research conduced by Fortney et al (12) also observed no change in sweat rate.

The Effect of Glycerol on Blood Pressure

Research investigating the benefits of glycerol-induced hyperhydration has thus far been equivocal and has primarily been conducted in the laboratory settings. The cardiovascular, temperature regulatory, and renal systems individually or in combination can be compromised by dehydration due to exercise in a hot environment (37). Many different systems work together to maintain a physiological state of euhydration including the renal, endocrine, gastro-intestinal, central nervous and cardiovascular systems (18).

Investigators at University of New Mexico reported lower heart rates following glycerol ingestion. A lower heart rate may suggest the possibility of reduced cardiac output due to glycerol supplementation (22). Utilizing glycerol-induced hyperhydration may increase an individuals sweating rate, decrease the extent of dehydration, as well as reduce the elevation of heart rate and body temperature of subjects exercising in a hot environment (18).

Not all research boasts that glycerol-induced hyperhydration may assist in cardiac workload. Latzka et al (22) hypothesized that the increase in total body water elicited by glycerol-induced hyperhydration would help better maintain blood volume during uncompensable heat stress, therefore leading to improved cardiac filling, cardiac output,

and blood pressure preservation as compared to a control group. Latzka et al, (22) concluded that glycerol-induced hyperhydration did not alter cardiac output or blood pressure.

The Effect of Glycerol on Mean Heart Rates

The investigations examining the affects of glycerol-induced hyperhydration on mean heart rates has been equivocal thus far. Latzka and colleagues (22) found that heart rates were not different at rest among trials but increased over time during exercise. Following 10 minutes of exercise, heart rates were greater in the control trial than the glycerol and water trials, however this difference diminished as the exercise continued. Latzka et al, (22) reported that heart rates at exhaustion from heat strain were not different. Murray et al, (33) conducted a study involving five female and four male subjects. This glycerol supplementation study found no significant differences in heart rate during exercise. Research by Wendtland et al, (46) also reported no cardiovascular benefits with glycerol-induced hyperhydration.

Rowell et al, (38) found that cardiac output was reduced by about one liter/minute when individuals were exercising in uncompensable heat stress, as compared with control values measured in a temperate climate. In the Latzka et al, (22) study, cardiac output also decreased by one liter/minute and stroke volume decreased despite a heart rate increase of 14 beats/minute. Latzka and colleagues, (22) investigation was unclear why hyperhydration led to slightly lower heart rates with no other cardiovascular or heat-tolerance advantages. The lower heart rate may imply that the hyperhydration trials demonstrated a larger blood volume than the control trial, except for the fact that in the

study the control group completed the exercise hypohydrated therefore the response may represent the effect of dehydration rather than hyperhydration. Latzka et al, (22) concluded that glycerol-induced hyperhydration produced no significant benefits for an athlete exercising in extreme heat.

To the contrary, Montner et al, (31) reported that glycerol- induced hyperhydration elicited a lower mean heart rate and an increase in exercise time to exhaustion. Lyons and co-investigators, (23) reported great variability in the heart rates among subjects. The large range was attributed to the subject's different physical fitness levels. This large variance produced no significant changes in mean heart rate from the different fluid regimens. Although not significant, the glycerol-induced subjects demonstrated a consistently lower mean heart rate and may represent a reduced cardiac workload. Koenigsberg and associates (18) reported that glycerol supplementation can assist an athlete in battling the complications of exercising in extreme heat by increasing sweating, decreasing the extent of dehydration, reducing the elevated heart rate and body temperature.

The Summary

The athletic arena often places its participants in the dangerous position of dehydration. This condition can easily develop if the athlete does not consume adequate fluids during even one hard practice in extreme heat (20, 21, 26, 42). Unfortunately, the athlete must try to perform when dehydration elicits an increased core body temperature, increased heart rate, decreased sweat rate, and cutaneus blood flow, as well as reduced aerobic exercise performance (3, 12, 15, 23, 28, 32, 40, 41). The athlete may attempt to

maintain an adequate fluid balance by drinking excessive water or electrolyte drinks but often experiences vomiting or gastro-intestinal discomfort from the excess fluids (44).

Prior research has been equivocal regarding the benefits of glycerol-induced hyperhydration. This experiment was designed to determine if glycerol-induced hyperhydration can significantly increase water retention during intense exercise in hot weather via decreased fluid loss. The fact that a mere 2% decrease in total body fluid can have an adverse effect on performance and place the athlete in a state of dehydration encourages further research on the effects of glycerol-induced hyperhydration (41, 45). Providing the best method to maintain euhydration while performing in extreme heat would allow the athlete to participate to the best of their ability without the worry of dehydration or heat related illness.

CHAPTER III

PROCEDURES

Introduction

The objective of this study was to determine the effects of glycerol supplementation on female intercollegiate soccer player's fluid retention during subsequent exercise bouts. This chapter contains a detailed description of the procedures of this study. The procedures are divided into: a) the setting, b) source of data, c) instrumentation, d) permission and consent, e) the testing procedure, f) and the treatment of data.

Setting

The testing was performed over a seven-day period at the women's soccer facility at Oklahoma State University in Stillwater, Oklahoma. All subjects were measured daily, before and after each practice session. Each day the subjects participated in at least two practice sessions. The environmental factors were uncontrolled due to field-testing and varied daily.

Source of the Data

Volunteers from the Oklahoma State University Women's Soccer Team were recruited for the research study. The volunteers were readily available and willing to

participate in the project therefore they were not randomly selected from the general population. Eighteen female subjects between the ages of 18 and 22 volunteered for this investigation. One subject was dropped on the second day of testing due to heat illness. The subjects received a copy of the experimental procedures and all methods and protocols were explained thoroughly (Appendix A). The volunteers were required to read and sign an informed written consent (Appendix B) and completed a health questionnaire (Appendix C) designed to evaluate the subject's health status and medical history. A physician approved each participant with a general physical examination. Any history of cardiac abnormalities, renal abnormalities, or heat related illness disqualified the subject from participation in the study (Appendix D). Only healthy subjects were used to maintain the internal validity of the study. Volunteers with allergies to glycerol, orange juice, Gatorade, acesulfam K (Sunette), or asparytame (NutraSweet) were excluded from the study for their own safety.

Instrumentation

The instrumentation utilized for this study included a Diebolt electronic digital scale and Lumiscope blood pressure cuff. The Diebolt electronic digital scale (Dallas, TX) was recently calibrated and measured the subjects weight to the nearest 10^{th} decimal place. The Lumiscope Professional Aneroid Sphygmomanometer made by Lumiscope CC. Inc. Edison, N.J, monitored a subject's blood pressure. An investigator utilizing the subject's right radial pulse monitored mean heart rate manually.

Permission and Consent

Permission to conduct the study was granted by the Institutional Review Board at Oklahoma State University (Appendix E). Once the volunteers completed their health questionnaire, the physician determined if the subjects were cleared for participation in the study. Exclusions from the study included individuals who reported allergies to Gatorade, orange juice, glycerol, Sunette, or NutraSweet, and any volunteers who reported previous heat illness or injury, cardiac abnormalities or renal abnormalities (Appendix D). Side effects such as nausea, gastro-intestinal distress, vomiting, light-headedness, and a bloated feeling have been noted in some studies. Other studies report no negative side effects following glycerol ingestion (45).

Testing Procedure

All subjects reported to the testing site prior to treatment and signed an informed consent form in accordance with the Oklahoma State University Institutional Review Board (Appendix B). This form included a thorough description of the experimental procedures before beginning the treatment. The subjects were randomly assigned to the experimental or placebo group. Identical protocols and instrumentation for all subjects were used in an attempt to control any confounding variables. The subject's nude body weight was taken and recorded (Appendix F) utilizing a digital scale. The nude method of weighing was necessary because a subjects clothing potentially would retain perspired fluid creating unnecessary extraneous variables. The subject's stepped behind a curtain leaving only their lower legs and feet exposed. Subjects then discarded their clothing and stepped onto the scale that was visible on the floor below the curtain and body weight was determined (3, 22, 23, 29).

The subjects' blood pressure and resting heart rate were measured to provide physiologic data. Blood pressure was measured utilizing the right arm of each subject and the mean heart rate was manually monitored using the right radial artery (23) (Appendix G). Prior to practice, a water bottle (1000 ml) was prepared and individually marked for each athlete. The subjects drank ad-libitum during the exercise session (Appendix H).

Following the pre-practice testing procedures and prior to the practice session the experimental group was given a glycerol dose of 1.0g/kg body weight mixed with orange juice concentrate (Appendix I). The control group was given a placebo dose of orange juice concentrate (37). The exercise session was approximately two hours of soccer drills and field play. Any feelings of gastrointestinal discomfort and/or vomiting were immediately reported to the examiner. At the beginning of the practice session, environmental temperature and relative humidity were taken and recorded using a wet bulb sling psychrometer (Appendix J). Each subject was given an adequate amount of water to drink ad libitum during the intense practice. The remaining fluid in each subject's bottle was measured and total fluid consumed was calculated following each practice session.

At the conclusion of the practice, the athletes immediately reported to the testing area for post-practice body weight measurement (Appendix F). The subjects stepped behind the curtain, discard their clothing, and then stepped onto the scale visible on the floor below the curtain. Following all post-practice testing the remaining water in the subjects designated water bottles was measured (Appendix H).

This procedure was adhered to before and after each practice session during the seven-day examination period. The results were recorded immediately for comparison. Following a complete day of testing all equipment was disinfected and cleaned thoroughly to prevent the spreading of bacteria or disease.

Treatment of Data

The pre-test data generated in this investigation originated from health history questionnaires (Appendix C) and initial screening session. The data was used to describe the tested sample in the terms of health and physical fitness status. The independent variables in this study included the placebo or glycerol supplementation. The dependent variables in this study were the fluid loss during exercise measured by weight and subject water intake. Comparisons between the placebo and glycerol treatments were analyzed using the Statistical Package for Social Sciences (SPSS v. 5.01). The comparisons between water intakes, taking into account body weight were made analyzing to the $p<.05$ level of significance.

CHAPTER IV

Manuscript

THE EFFECTS OF GLYCEROL-INDUCED HYPERHYDRATION ON A COLLEGIATE WOMEN'S SOCCER TEAM

The ability to exercise for prolonged periods in a warm environment is reduced when dehydration and hyperthermia occurs (1, 8, 36). Fluid ingestion during exercise can replace a portion of the body fluid lost in sweat, and to some extent minimizes hyperthermia and circulatory stress. The rate at which an ingested fluid enters the body is controlled by the rate at which it empties from the stomach (11), which typically cannot keep pace with the fluid losses incurring during moderate to heavy sweating (9). These athletes must learn how to adjust and become acclimatized to these climates. Additionally, exercising in a hot environment leading to dehydration typically occurs when an individual does not consume adequate fluids during exercise to compensate for the fluid loss (18, 20, 27).

Since sweat is hypotonic to plasma, excessive sweating results in greater losses of water than salt and leads to a condition termed "hypohydration" rather than dehydration. The consequence of hypohydration leads to serious health problems such as heat illness resulting from an increased core body temperature, increased heart rate and decreased sweat rate (3, 12, 15, 21, 28, 32, 39, 40, 41). Maximal oxygen uptake may decrease or remain unchanged, but the duration over which VO2 max can be maintained is significantly

reduced. Dehydration during exercise has been shown to decrease an individuals aerobic exercise performance following a fluid loss of only 1% to 3% of their total body weight (14, 26, 45). Athletes attempt to combat the effects of dehydration by drinking water before, during, and after exercise. The American College of Sports Medicine recommends drinking 500 mL of water 2 hours before the start of competition (2). Unfortunately, the extra water obtained through traditional hyperhydrating techniques is transitory, as the kidneys are extremely efficient at rapidly excreting any excess fluid. Additionally, an athlete risks gastric discomfort or the inconvenience of voiding urine.

Athletes constantly are searching for means of improving performance. A commonly used means of enhancing athletic performance involve the manipulation of metabolic processes. Glycerol has been shown in some cases to enable greater fluid retention than the ingestion of water alone; therefore, allowing the athlete to maintain a hyperhydrated state (13, 18, 21, 37). Riedesel and Lyons (22) found the use of glycerol resulted in greater retention of water in experimental subjects when compared to the placebo group. Interestingly, the hyperhydration effects of glycerol were found to last over a four-hour period (18, 21). Other investigations have also found beneficial effects with glycerol-induced hyperhydration. Results have shown that subjects ingesting a glycerol solution demonstrated a lower mean heart rate compared to the control group receiving a placebo (21, 31, 37). The difference in heart rate may be due potentially to different sweat rates (27). If glycerol supplementation can help maintain plasma volume, it would in turn support circulatory, metabolic and thermoregulatory function (20).

The purpose of this study was to examine the effects of glycerol supplementation on hyperhydration among healthy women's intercollegiate soccer athletes in a field

(athletic) setting. Previous research investigating the benefits of glycerol has primarily been conducted in the laboratory setting (13, 18, 20, 21, 31, 33, 37, 46). We hypothesized that a glycerol supplementation in solution would expend total body fluids during environmentally stressed exercise over an extended period of time.

METHODS

The testing period lasted seven days in August during pre-season practice regimen at a Midwestern University. The subjects participated in vigorous exercise during at least two intensive practices daily in extreme temperatures. Practice sessions were held in an environment averaging 78° ranging from 70 to 106°F (21 to 41°C) and relative humidity averaged 64%. Pre-practice procedures began when the subjects reported to testing areas at an assigned time for demographic data collection. Daily pre-practice testing included nude body weight measurement utilizing the Diebolt electronic digital scale (Dallas, TX), heart rate (BPM) and blood pressure measurement (mmHg). Environmental conditions were monitored utilizing a sling psychrometer prior to each practice. The subjects were encouraged and allowed to drink ad libitum. Following the practice, each subject reported immediately to the testing center. Post-practice procedures consisted of nude body weight measurement.

Subjects reported to the testing site prior to practice for body weight measurements and lined up outside the shower area in the locker room facility. Each subject stepped behind a curtain, removed all clothing and stepped onto the Diebolt electronic digital scale (Dallas, TX) visible below the curtain. Each subject that reported to the blood pressure/heart rate station was seated comfortably in a quiet room as to

ensure accurate measurement. The examiner utilized a Luminoscope professional aneroid to measure blood pressure. Resting heart rate was measured utilizing the subject's right radial pulse.

During each soccer practice, the subjects were allowed and encouraged to drink ad libitum. Each subject was given a water bottle containing 1000 ml of water, the investigators monitored intake and refilled the bottles when necessary. The total fluid consumed for each subject was recorded following each practice. Following the pre-test measurements; the subject randomly received a Styrofoam cup with either glycerol or placebo solution. Each day, half of the subjects received a dose of glycerol (HUMCO, Texarkana TX) and the other half received placebo solution. The glycerol dose was based on 1.0 g/kg body weight combined with enough orange juice to result in a 33% solution (1/3 glycerol and 2/3 orange juice). The placebo solution consisted of a 3:1 water/orange juice concentrate. The volume of a placebo dose was equal to the amount of fluid the subject received in the glycerol group, identical in taste and texture. Fluid loss was calculated using total body weight and water intake as detailed in the following table.

Change in Subject Body Weight Calculation

Pre-Exercise Body Weight (kg)	+	Water Intake (kg)	-	Post-Exercise Body Weight (kg)	=	Change in Body Weight (kg)

Table 1. Water Retention Calculation

Comparisons between the placebo and glycerol data were made utilizing the Statistical Package for Social Sciences (SPSS v. 5.01). The comparisons between water intakes, taking into account body weight, were made analyzing to the $p<.05$ level of significance.

RESULTS

All the subjects completed the testing sessions as described. Only one subject was dropped from the study because of heat illness. Additionally, none of the subjects experienced nausea or bloating as documented as a possible side effect (18). Physiological information was taken prior to the first practice (Table 2). Specific subject data is displayed in Tables 3-5 (See Appendix K-M). Before participating, all subjects read and signed an informed consent form, completed a physical examination and health history questionnaire in accordance with guidelines set forth by the University Institutional Review Board.

Age	Body weight (kg)	Systolic Blood Pressure (mmHg)	Diastolic Blood Pressure (mmHg)	Heart Rate (bpm)
M=19.55±4.7	M = 60.92±17.5	M = 119.12±30	M = 74.94±5	M = 82.59±48
Range = 18.2-22.9	Range = 52.95-70.45	Range = 115-130	Range = 60-90	Range = 60-108

Table 2. Mean, Standard Deviation, and Range for Physiological data. All values are at the first pre-practice measurement, day one.

The experimental group consumed 18.5±20.0 kg water per subject, while the control group consumed 15.44±16.5 kg water for the testing period. The difference in water intake was considered to be significantly different ($F=8.46$, $p<.01$) with the experimental group consuming an average 9.06 kg more than the experimental group. The increased amount of fluid intake for the glycerol group was covaried statistically to the placebo when fluid intake was factored into pre-exercise body weight.

Nude Bodyweight

Sweat rate was determined by changes in body weight and correcting for fluid intake. Subtracting post-exercise body weight from pre-exercise body weight and fluid intake derived the percentage of fluid intake retained. Over the sixteen preseason practices the experimental subjects body weight loss of 0.346±8.27 kg was significantly lower ($F= 7.17$, $p<.001$) when compared to the control group weight loss of 5.178±5.6 kg. Additionally, the experimental group lost a total 5.53kg compared to the control group loss of 46.60 kg over the seven-day testing period. The experimental group maintained hydration during the testing session. While the placebo group resulted in weight loss that potentially indicates a dehydrated state. The summary of body mass changes vs. temperature for individual practices is displayed in Appendix N.

DISCUSSION

The ability of an athlete to perform in a hot environment depends on many factors, such as air temperature, humidity, intensity and duration of activity. These factors will eventually compromise cardiovascular function. One of the primary responsibilities of the cardiovascular system is the transportation of heat from the working skeletal muscles to

the skin surface for cooling. Dehydration may elicit an increase in blood viscosity, thereby raising individual blood pressure; it may also bring about a decrease in venous return (3, 7). A decrease in venous return will lead to a decrease in cardiac output and stroke volume; this lowering of circulation will limit the amount of oxygen reaching the muscles resulting in a decrease in work potential.

Athletes that retain excess water are better equipped to deal with strenuous activity while maintaining a steady body weight. The control group in this investigation did not have adequate water stored to maintain a steady weight during the exercise and lost a significant amount of body weight during the practices. Body weight changes over the seven-day testing period potentially were due to fluid loss and minimal loss due to body fat as evident in the pre and post-exercise body weight fluctuations. The loss of body weight during the exercise sessions placed the control subjects at risk of dehydration. Increased sweat rate during exercise (24, 37) allowed the investigators of the present study to surmise that the excess water the experimental group drank was retained and utilized during the exercise in extreme heat. In the present investigation, the experimental subjects consumed a significantly greater amount of fluids due to an increased sweat rate. The glycerol hyperhydration theoretically allows the athlete to consume less water because their body has retained excess water (13).

The experimental group body weight loss was significantly lower (5.53 kg) over the 16 practice sessions compared to the control group (46.60 kg). Research on glycerol has found glycerol supplementation elicits an increased sweating rate (23, 31, 37). Previous investigation exploring the benefits of glycerol-induced hyperhydration research have confounding results due to subjects starting exercise in a hypohydrated state or

becoming dehydrated during exercise. The research conducted by Fortney et al (12) contradicts the increased sweating rate by recording no change in sweat rate. Lyons et al (24), showed no change in sweat rate in those subjects that received glycerol-induced hyperhydration.

SUMMARY

Fatigue during prolonged severe exercise is associated with marked hyperthermia (8, 25), depletion of muscle glycogen (17, 35), and hypoglycemia (2, 6). Attempts to attenuate the effects of these factors by supplementation during exercise have been met with mixed results. Although, fluid ingestion has been shown to reduce core temperature during exercise (8). Athletes are placed at risk for dehydration when required to exercise in extreme heat. Glycerol is a vehicle an individual can use to help their body retain the fluid necessary to perform in a hot environment. In this investigation, glycerol elicited a significant difference in water intake and body weight loss between placebo and control groups.

Future research involving glycerol-induced hyperhydration should include both male and female athletes exercising in extreme heat. This study was limited to the use of college age women's soccer player but was the first to investigate glycerol supplementation on athletes participating in NCAA athletics. Athletes participating at the collegiate level are optimal subjects because of the strict regimen of intense practices they must adhere to daily. Additionally, future investigations utilizing female subjects should also examine their menstrual cycle since a woman's body may retain excess water in certain stages of her cycle.

Future research needs to be conducted examining glycerol supplementation in a competitive setting and over a longer period of time. This type of research application yields less environmental control for the investigation, but elicits results during the rigorous exercise in the extreme heat collegiate athletes must participate in today. Future research on glycerol induced hyperhydration utilizing collegiate athletes would provide more information on these present findings and establish more of an understanding of glycerol and its effects.

Chapter V

CONCLUSIONS & RECOMMENDATIONS

Athletes that exercise in a hot environment may suffer the consequences of dehydration. Present research investigating the effect of glycerol on hyperhyration has been equivocal. The present study offers the first glycerol supplementation findings based on collegiate athletes exercising in the field setting. It has been hypothesized that glycerol allows an individual to retain fluids; potentially decreasing blood pressure and pulse rate, as well as decrease body temperature (18, 22, 23, 31, 37). This study was designed to investigate the effects of glycerol supplementation on fluid loss and water intake.

Compliance of supplement ingestion was remarkably high. All subjects reported on time daily for testing and only one subject was lost throughout the testing period. The subjects that volunteered for this investigation represent a unique subject pool. These individuals were collegiate athletes and possess physical qualities and experiences that may not be typical of the average individual. The null hypothesis in this investigation was rejected on the variables of water intake and body weight. This investigation found subjects ingesting the glycerol solution maintained a healthy body weight during intense exercise. The experimental group was better equipped to battle the intense heat due to the positive effects of the glycerol supplementation. Therefore, the results of this

investigation lead to the conclusion that glycerol supplementation elicits greater fluid retention therefore assisting in the prevention of heat illness.

The following recommendations are made based on the realization that this study could have been conducted differently in many ways. Further, research warranted in this area includes, but is not limited to, the use of male and female subjects, a longer supplementation period, untrained subjects, an endurance-training scheme, and a variety of sports utilized.

Glycerol supplementation potentially will allow an athlete to combat the effects of dehydration. Although, the lack of research conducted in the field warrants caution. Coaching staffs should be careful utilizing this supplement because it has not been widely tested in the field setting. Glycerol supplementation should only be used with physician supervision due to the potential for gastrointestinal dysfunction. Glycerol proposes to be an exciting supplement to assist in the fight against dehydration. Future research is required to duplicate or refute the results of the present investigation.

Future research needs to be performed involving athletes exercising in extreme heat outside the laboratory. This type of investigation does not allow total environmental control but would yield results based on athletes exercising in a typical hot, summer environment. Athletes that may benefit from glycerol supplementation in the future will most likely be exercising in an environment similar to the one in the present study rather than a controlled laboratory setting. Future study should be made including males as well as females. The timing of the menstrual cycle is also of interest because of thermoregulation changes that occur and the excess water weight a female may retain. Additionally future double blind studies need to be performed to reduce chance of error.

Research using a longer period of supplementation may allow the glycerol to have an even greater affect. Future investigation collecting blood or 24 hour urine samples would require the combination of field testing and laboratory work but would yield the most extensive results.

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APPENDIXES

APPENDIX A

EXPERIMENTAL PROCEDURES

Experimental Procedures

1) Subject read and signed the Informed Consent Form.
2) Health questionnaire completed.
3) Physician review questionnaire: rejected or accepted the volunteer.
4) The subject reported to the training room facility for the women's soccer complex, Oklahoma State University.

Pre-practice Procedures

5) One half of the subjects were asked to report to the blood pressure/pulse station while the other half reported the station.
6) The subject's that reported to the blood pressure/pulse station were asked to sit in a relaxed position with her right arm extended, resting on a table.
7) The researcher placed the Lumiscope Professional Aneroid (Blood Pressure Cuff) around the subject's right arm and monitored the subject's blood pressure for approximately 30 seconds. The blood pressure cuff expanded to fit tightly around the arm while the measurement is being taken. The cuff then slowly released it's air to fit loosely around the arm.
8) The examiner then asked the subject to continue to relax her right arm while the radial pulse was measured. The examiner measured the radial pulse by placing a hand around the subject's right wrist, two fingers resting over the pulse. The subject's radial pulse was monitored for 15 seconds.
9) The subjects that reported to the station lined up outside the shower room in the locker room facility.
10) The subject at the front of the line were asked "Please step into the shower room".

11) Once the subject entered the shower area, she was advised, "At no time will you be visible to either examiner, you will be totally covered behind the shower curtain. The examiners only see your lower legs and feet".

12) A digital scale was visible below one of the shower curtains once the subject entered the room.

13) The subject was told, "Please step behind the shower curtain and remove all of your clothing including sports bra and underwear."

14) The subject was told "Please notify the examiner when all clothing has been removed."

15) The examiner then instructed as follows "Please step onto the digital scale". The scale read your nude weight to the nearest 10^{th}.

16) Following the measurement the subject was told, "Please step off the scale and get dressed, then step from behind the curtain".

17) The subject will be told, "Thank you, you may step out of the shower area".

18) Designated practices required the subjects, following the completion of all pre-practice testing to report to a supplement table where an examiner handed her the designated glycerol solution or placebo solution.

19) The examiner asked the subject, "Please drink all of the solution."

20) Following the consumption of the solution the subject was told, "You are free to report to the practice field and remember you are only to drink from your designated water bottles."

Post –Practice Procedure

1) All subjects were asked to report to the station.
2) The subjects that reported to the weight station lined up outside the shower room in the locker room.
3) The subject at the front of the line was asked "Please step into the shower room".
4) Once the subject had entered the shower area, she was advised, "At no time will you be visible to either examiner, you will be totally covered behind the shower curtain. The examiner will only see your lower legs and feet".
5) A digital scale was visible below one of the shower curtains once the subject entered the room.
6) The subject was told, "Please step behind the shower curtain and remove all of your clothing including sports bra and underwear."
7) The subject was told "Please notify the examiner when all clothing have been removed."
8) The subject then was instructed as follows "Please step onto the digital scale". The scale read the subject's nude to the nearest 10^{th}.
9) Following the measurement the subject was told, "Please step off the scale and get dressed, then step from behind the curtain".
10) The subject was told, "Thank you, you may step out of the shower area".
11) The subjects that had completed all post-practice testing were told, "You are free to leave, thank you."

12) Following subject testing all water consumed was measured utilizing the Digital Scale. The water remaining in the subjects designated water bottles was weighed. The weight minus the mass of the water bottle was then recorded.

APPENDIX B

INFORMED CONSENT

Informed Consent Form

I. _____, hereby authorize or direct Kim Cornelisse, or associates or assistants of her choosing, to perform the following treatment or procedure.

You are invited to participate in a study designed to investigate the effects of glycerol on an athletes sweat rate, blood pressure, and mean heart rate while exercising in extreme heat. The study will investigate the timing of glycerol ingestion on the athletes sweat rate, blood pressure and mean heart rate, as well as the effect of glycerol ingestion on an athlete's perceived rate of recovery. The purpose of this study is to determine if glycerol assists an athlete in preventing dehydration as well as heat illness. The results obtained from this research may contribute to the type and frequency of fluids consumed by an athlete before, during, and after exercising in extreme heat.

Prior to testing you will be given an explicit description of the test procedures. The measurements will include blood pressure, pulse rate, nude body mass as described in the written and oral protocol, and perceived state of physical readiness. The testing will be completed before and after each practice session for the pre-season period of time. Prior to one practice in the day you will receive a 1.0g/kg body weight glycerol solution with Gatorade or a placebo solution consisting of Gatorade, NutraSweet, and Sunett.

In some cases glycerol may cause dizziness, gastric discomfort or vomiting. You will be given water bottles with your name on them to drink from during practice. You will be allowed to drink as much as you want but you must drink from your own water bottle. Following practice all water will be weighed to measure the amount of fluid you have consumed. Your participation in this study should take approximately 30 minutes

*Subject's Initials*_____

before and after practice. This is done as part of an investigation entitled "Glycerol-induced hyperhydration on a collegiate women's soccer team." The purpose of the procedure is to determine the effectiveness of glycerol in preventing dehydration and heat illness.

I understand that participation is voluntary; that there is no penalty for refusal to participate, and that I am free to withdraw my consent and participation in this project at any time without penalty after notifying the project director.

I may contact Kim Cornelisse at (405) 743-8387, Dr. Bert Jacobson at (405) 744-5500, or Dr. Jack Ransone at (405) 744-9439. I may also contact Sharon Bacher, IRB Executive Secretary, 203 Whitehurst, Oklahoma State University, Stillwater, OK 74078; telephone number: (405) 744-5700.

I have read this form and I understand the test procedures that I will perform. I sign it freely and voluntarily. I understand that I can withdraw at any time. I have received a copy of this consent form for my files.

Date: _____ Time: _____(a.m./p.m.)

Signature _____

Print Name: _____

I certify that I have personally explained all elements of this form to the subject or his/her representative before requesting the subject or his/her representative to sign it.

Investigator Signature: _____

APPENDIX C

HEALTH HISTORY QUESTIONNAIRE

Health History Questionnaire

Please complete the following questionnaire to the best of your ability. This information will be used in determining your eligibility to participate in this research study. All information will be kept confidential.

Age_____ Date_____ Birth date_____

Height_____ Weight_____ M____ F___

How many days a week do you do at least thirty minutes of continuous Exercise? _____

What type of exercise do you do on a regular basis (run, walk, lift weights, swim, stairmaster)? _____

Do you exercise inside___outside___?

Mark X if you have suffered from any of the following.

Diabetes	( )	Allergy to Glycerol	( )
Heart Disease	( )	Allergy to Aspartame (NutraSweet)	( )
Blood Disease	( )	Allergy to Gatorade	( )
Renal Abnormalities	( )	Allergy to Orange Juice	( )
Cardiac Abnormalities	( )	Heat Related Illness	( )
High Blood Pressure	( )	Trouble with Dehydration	( )
Pericarditis	( )		
Tumor, Growth, Cyst, Cancer	( )	If you marked yes please explain in	
Any ruptured organs	( )	more detail. _____	
Seizure Disorder	( )	_____	
Abnormal Bleeding	( )	_____	
Kidney Disease	( )	_____	
Kidney Stones	( )	_____	
Blood in Urine	( )	_____	
Kidney Abnormalities	( )	_____	
Gastrointestinal Bleeding	( )		

Mark X in the space provided if Yes.

Have you ever felt dizzy, light-headed or passed out during or after exercise? ( )

Have you ever had chest pain while exercising? ( )

Have you ever had irregular heart beats or heart palpitations? ( )

Have you ever been told you have a heart murmur? ( )

Have you ever been seen by a heart specialist? ( )
If yes? When_____

Have you ever had an echo-cardiogram? ( )

Have you ever had a stress (heart) exam? ( )

Please list ALL medication that you are currently taking:_____
_____
_____

Subject Signature: _____

Examiner Signature: _____

Physician Signature: _____

APPENDIX D

LIST OF PHYSICAL DISQUALIFICATIONS

Reasons for Subject Disqualification

Diabetes
Heart Disease
Blood Disease
Cardiac Abnormalities
Renal Abnormalities
High Blood Pressure
Pericarditis
Tumor, Growth, Cyst, Cancer
Ruptured organs of any kind
Seizure Disorder
Abnormal Bleeding
Kidney Disease
Kidney Stones
Blood in Urine
Kidney Abnormalities
Gastrointestinal Bleeding
Allergy to Glycerol
Allergy to Aspartame (Nutrasweet)
Allergy to Gatorade
Allergy to Orange Juice
Allergy to Acesulfam K (Sunette)
History of Heat Related Illness
Trouble with Dehydration

APPENDIX E

OKLAHOMA STATE UNIVERSITY INSTITUTIONAL REVIEW BOARD APPROVAL

OKLAHOMA STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD

Date:	August 5, 1999	IRB #:	ED-00-145
Proposal Title:	"EFFECTS OF GLYCEROL - INDUCED HYPER HYDRATION ON A COLLEGIATE WOMEN'S SOCCER TEAM"		
Principal Investigator(s):	Bert Jacobson Kim Cornelisse		
Reviewed and Processed as:	Expedited		

Approval Status Recommended by Reviewer(s): Approved

Signature:

Carol Olson

Carol Olson, Director of University Research Compliance

August 5, 1999
Date

Approvals are valid for one calendar year, after which time a request for continuation must be submitted. Any modification to the research project approved by the IRB must be submitted for approval. Approved projects are subject to monitoring by the IRB. Expedited and exempt projects may be reviewed by the full Institutional Review Board.

APPENDIX F

BODY MASS DATA SHEET

Body Mass Data Sheet

Date:
Practice:

Subject #	Nude Body Mass Before (kg.)	Nude Body Mass After (kg.)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		

APPENDIX G

BLOOD PRESSURE/PULSE RATE DATA SHEET

Blood Pressure/Pulse Rate Data Sheet

Date:

Practice:

Subject #	Blood Pressure Before (mm/Hg)	Pulse Rate Before (bpm)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		

APPENDIX H

MASTER H_2O DATA SHEET

Master H_2O Data Sheet

Date:
Practice:

Subject #	Weight H_2O Before (lbs.)	Volume H_2O Before (mL)	Weight H_2O After (lbs.)	Volume H_2O After (mL)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				

APPENDIX I

CALCULATION OF DOSAGE SIZES FOR SUBJECTS

Calculation of Dosage Sizes for Subjects

Input data:

Den. of glycerol = **1.249** g/mL

Dosage size = **1.0** g/kg nude body mass

% Solution = **40** %

Calculate volume of dosage size:

V(dosage size) = Dosage size (g/kg nude body mass) / Density (g/mL)

V(dosage size) = 0.801 mL/kg nude body mass

Calculate volume of solution for individual players:

Req'd vol. of glycerol = nude body mass (kg) x vol. of dosage size (mL/kg)

Req'd vol. of O.J. = [Req'd vol. of glycerol (mL) / (% sol'n/100)] - Req'd vol. of glycerol (mL)

Player I.D. #	Nude Body Mass (kg)	Req'd Volume of Glycerol (mL)	Req'd Volume of Orange Juice (mL)	Total Volume of Solution (mL)
1	53.00	42.43	63.65	106.08
2	62.10	49.72	74.58	124.30
3	62.35	49.92	74.88	124.80
4	61.15	48.96	73.44	122.40
5	72.85	58.33	87.49	145.82
6	56.65	45.36	68.03	113.39
7	61.55	49.28	73.92	123.20
8	55.20	44.20	66.29	110.49
9	68.70	55.00	82.51	137.51
10	54.20	43.39	65.09	108.49
11	56.75	45.44	68.15	113.59
12	53.95	43.19	64.79	107.99
13	66.40	53.16	79.74	132.91
14	59.95	48.00	72.00	120.00
15	55.40	44.36	66.53	110.89
16	70.25	56.24	84.37	140.61
17	60.40	48.36	72.54	120.90
18	68.65	54.96	82.45	137.41
19	53.35	42.71	64.07	106.79
Totals	1153	923.02	1384.53	2307.55

APPENDIX J

TEMPERATURE/RELATIVE HUMIDITY DATA SHEET

TEMPERATURE/RELATIVE HUMIDITY DATA SHEET

	Dry Bulb	**Wet Bulb**	**Relative Humidity**		**Dry Bulb**	**Wet Bulb**	**Relative Humidity**
Date:				Date:			
Time:				Time:			
Date:				Date:			
Time:				Time:			
Date:				Date:			
Time:				Time:			
Date:				Date:			
Time:				Time:			
Date:				Date:			
Time:				Time:			
Date:				Date:			
Time:				Time:			
Date:				Date:			
Time:				Time:			
Date:				Date:			
Time:				Time:			
Date:				Date:			
Time:				Time:			

	Systoltic Blood Pressure (mm/Hg)															
Experimental Subjects	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	122	112	112	110	108	108		108	108	104	116	114	118	112	114	116
2	118	116	110	122	106	112	122	120	128	118	112	124	116	120	124	112
3	122	108	114	108	108	112	112	108	112	104	112	112	118	112	112	120
4	120	122	112	118	124	122	130	124	118	116	118	120	118	108	132	114
5	115	106	108	116	102	110	108	114	108	108	104	108	132	106	112	108
6	115	117	110	114	128	122	120	122	112	120	116	108	118	108	122	116
7	116	106	108	112	116	112	102	108	104	104	106	104	106	108	112	106
8	115	116	114	108	110	122	118	118	106	118	110	112	124	112	112	112
Control Subjects																
9	130	116	120	112	108	118	112	122	118	104	12	116	122	120	118	116
10	118	116	122	110	110	122	118	130	112	118	114	118	124	112	118	112
11	120	108	108	112	120	116	122	112	126	108	120	120	114	122	122	120
12	118	112	112	108	112	108	112	118	122	106	108	110	112	110	108	126
13	130	130	132	120	122	122	118	128	122	122	122	122	122	122	130	130
14	115	106	116	108	108	116		116	118	116	116	112	114	108	114	114
15	118	116	112		114	118	118	110	106	108	110	108	108	116	108	112
16	115	116	114	112	112	110	112	120	110	112	118	108	112	114	112	112
17	118	106	116	118	110	112	112	108	116	108	112	114	112	116	118	118

Table 3. Systolic Blood Pressure data. All values are at the first pre practice measurement, day one

	Diastolic Blood Pressure (mmHg)															
	Practice															
Experimental Subjects	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	74	82	68	78	82	64		72	70	68	70	70	74	70	86	70
2	80	80	80	80	70	76	70	78	78	72	72	84	82	80	88	78
3	72	86	78	78	80	78	74	82	78	70	66	74	80	82	78	82
4	82	84	88	76	80	82	90	80	88	70	80	80	74	78	86	88
5	72	66	70	80	60	70	64	68	64	70	60	68	60	64	74	60
6	70	76	64	82	78	82	70	70	80	78	68	68	80	68	70	66
7	74	72	74	80	76	72	64	80	70	62	62	68	62	78	70	70
8	82	76	72	72	78	74	74	68	78	78	64	80	78	78	84	72
Control Subjects																
9	88	82	80	80	80	82	78	78	72	74	70	70	80	68	70	70
10	68	64	74	80	68	70	70	70	68	80	78	70	68	64	72	68
11	70	76	74	70	82	72	70	68	78	72	70	74	66	70	70	78
12	70	80	72	72	74	72	78	70	74	74	70	80	84	70	72	76
13	90	86	82	92	84	84	72	82	84	90	90	72	86	80	80	80
14	60	66	64	76	80	68		74	68	72	64	60	70	68	74	60
15	70	80	74		78	82	72	68	70	74	78	64	72	70	70	82
16	72	80	82	82	76	78	78	82	70	68	70	72	80	74	70	78
17	80	80	84	82	78	78	80	70	80	76	80	86	80	90	82	76

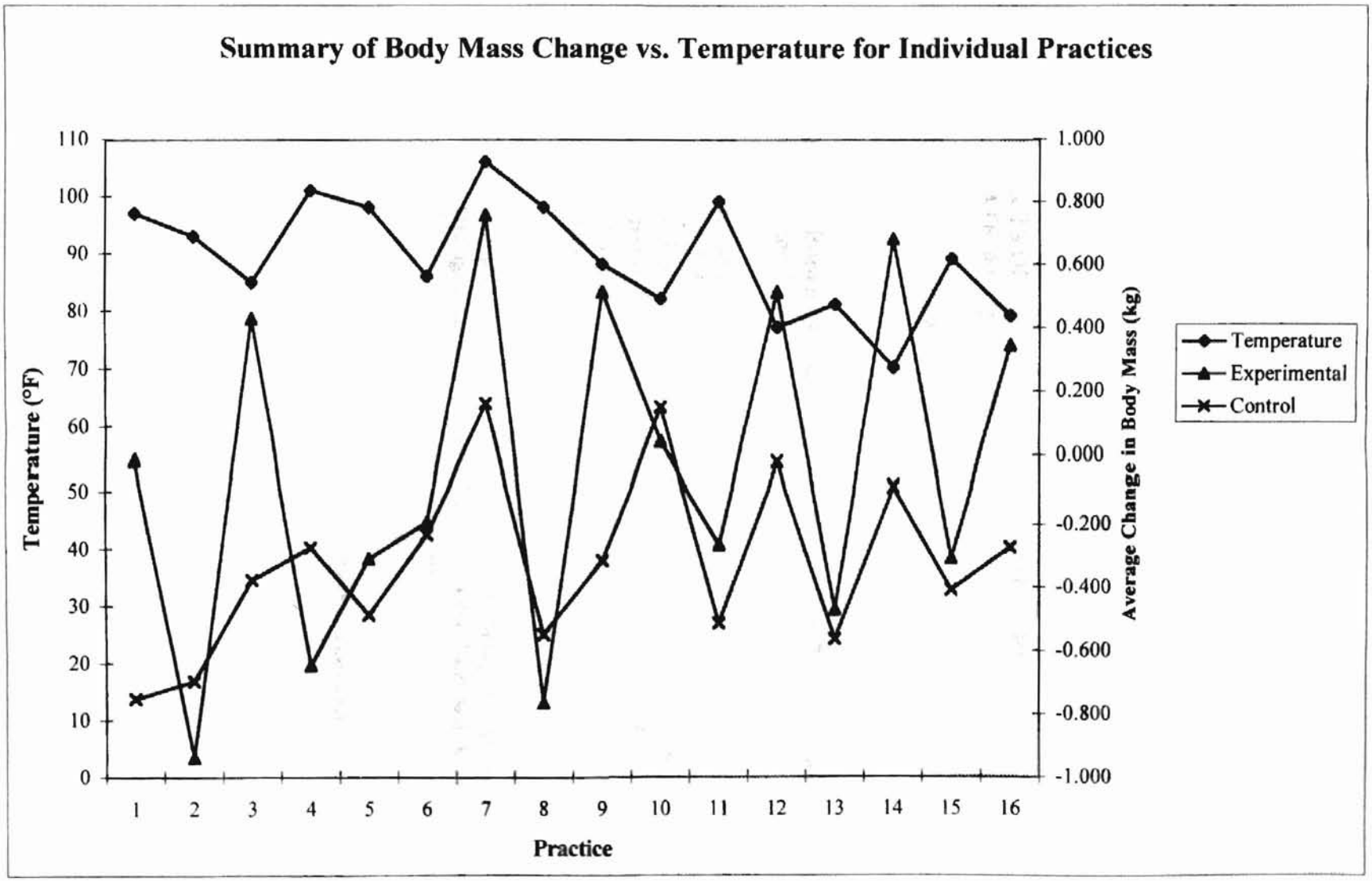
Table 4. Diastolic Blood Pressure data. All values are at the first pre practice measurement

APPENDIX M
PHYSIOLOGICAL DATA
HEART RATE

	Heart Rate (bpm)															
	Practice															
Experimental Subjects	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	84	114	90	84	90	108		72	84	84	96	90	78	72	84	96
2	72	84	90	90	84	78	102	84	72	72	78	84	78	66	78	78
3	84	96	96	108	102	84	84	114	90	102	96	90	96	66	96	84
4	108	90	114	114	102	108	96	84	96	108	90	90	84	78	90	108
5	90	108	90	138	108	96	108	90	96	102	90	84	60	84	78	90
6	96	108	108	114	96	90	84	96	102	90	96	96	78	108	90	96
7	72	84	66	84	66	72	72	96	72	78	84	96	78	72	66	72
8	84	114	78	90	72	90	108	84	96	72	90	78	72	72	72	96
Control Subjects																
9	102	114	90	90	84	66	84	108	90	90	90	84	78	96	96	90
10	78	84	84	90	90	90	78	84	78	78	72	84	78	66	72	78
11	72	96	72	60	72	78	84	78	90	84	78	78	84	78	78	84
12	90	102	96	96	90	96	102	84	84	90	78	90	78	78	66	132
13	66	102	102	90	84	90	72	90	84	84	84	90	72	84	78	90
14	60	78	78	84	102	84		66	78	66	84	66	66	66	66	78
15	90	108	84		96	96	96	84	96	102	96	102	78	90	78	108
16	84	102	90	96	96	78	78	96	102	90	72	84	72	66	72	84
17	72	96	84	84	84	78	84	78	78	84	72	90	78	72	72	84

Table 5. Heart Rate data. All values are at the first pre-practice measurement

APPENDIX N
SUMMARY OF BODY MASS CHANGE VS. TEMPERATURE FOR INDIVIDUAL PRACTICES


Summary of Body Mass Change vs. Temperature for Individual Practices
Temperature (°F)
Average Change in Body Mass (kg)
Practice
Temperature
Experimental
Control
110
100
90
80
70
60
50
40
30
20
10
0
1.000
0.800
0.600
0.400
0.200
0.000
-0.200
-0.400
-0.600
-0.800
-1.000
1
2
3
4
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16

VITA

Kimberly Joy Cornelisse

Master of Science

Thesis: THE EFFECTS OF GLYCEROL-INDUCED HYPERHYDRATION ON A COLLEGIATE WOMEN'S SOCCER TEAM

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Professional Memberships: National Athletic Trainers Association, Oklahoma Athletic Trainers Association.