THE USE OF PERCENTAGE BODY WEIGHT LOSS AS A PREDICTOR FOR HEAT RELATED ILLNESS

By

JOHN PHILLIP VARDIMAN

Bachelor of Arts

Park College

Parkville, Missouri

1996

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July 1998

OKLAHOMA STATE UNIVERSITY

THE USE OF PERCENTAGE BODY WEIGHT LOSS

AS A PREDICTOR FOR HEAT

RELATED ILLNESS

Thesis Approved:

Thesis Advisor

Dean of the Graduate College

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to Dr. Bert Jacobson, my mentor and chairman of my research committee, for his patience and motivation throughout my many projects and coursework. I am also extremely grateful to the other committee members, Dr. Steve Edwards and Dr. Frank Kulling, for their guidance and support during the course of this study and my career at Oklahoma State University. I would like to thank all the members of the 1996 and 1997 Oklahoma State University Cowboy Football teams and Sports Medicine staff for the opportunity to work with them and use them in my study. This study would not have been possible without their help and support.

I wish to extend a special thank you to my parents, Bill and Billie Vardiman and grandmother Luetta Vardiman, for their belief in me and all that I can still accomplish. It was their faith and prayers that held the candle in the dark days of my studies and allowed me to accomplish another goal in my life. I also wish to give a special thank you to Brian and Jodi McWilliams for their friendship, support and Wisconsin hospitality that has allowed me to remain focused. The support that I have received from all my friends and family has been tremendous and can not be measured with a thank you. These few people have given me the energy and direction to complete this study and the graduate program.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

CHAPTER I

Introduction

Heat Related Illness (HRI), in different forms, has affected athletes health and performance for many years and continues to be a problem today. There are approximately 175 deaths per year in the United States that are attributed to heat illness (1). This fact in addition to the numerous non-fatal HRI's, creates a need for expanded research in the prevention of HRI in the athletic community. The athletic community as a whole is aware of the dangers of HRI and the simple measures of prevention. As long as athletes perform high levels of physical activity in a heat-stress environments there will be the increased risk of HRI.

HRI is seen in three severity's, each not having to be preceded by the other: heat cramps, heat exhaustion, and heat stroke (2,3,4,5). Heat cramps are involuntary clonic muscle contractions that usually occur in the beginning stages, in the lower leg muscles, gastrocnemius and soleus, and the abdominal muscles. The typical cause of heat cramps is dehydration and/or an electrolyte imbalance and if the condition is not resolved, the limbs will continue to cramp and the athlete will become susceptible to full body cramps where all muscles are prone for the full clonic contractions (2,3,6,7). Heat exhaustion is the second level of HRI. It is characterized by the increase of the core body temperature to at least 102 degrees Fahrenheit (F). This temperature increase will present the body with many various symptoms including syncope, dizziness, warm moist skin, vomiting, fatigue, headache and heat cramps (2,3,4).

Heat stroke is the final level of HRI and is considered to be a life-threatening emergency. This extreme condition is diagnosed by an increase in the bodies core

temperature to at least 106 degrees F. With this drastic rise in core temperature the athlete will exhibit hot dry skin, and an altered level of consciousness that can lead to unconsciousness, convulsions and death (2,3).

The symptoms that are present during heat emergencies at not always apparent and often go undetected during and after a sporting activity. Therefore, it would be in the best interest of the athlete to prevent this condition before it affects his/her health or performance. Voluntary and regulated fluid consumption is the most useful form of prevention of HRI for the athletes. Athletes performing physical activity in high temperature environments naturally sweat to cool their bodies. If sweating causes greater loss of fluid than the amount of fluid consumed before, during and after the physical activity, the athlete has put himself or herself at risk of HRI (8). Regardless of the control measures used (e.g. water breaks and weight charts before and after each practice) athletes are continuously plagued by the wrath of HRI.

The need exists for research to determine the effectiveness and predictability of percent body weight loss measures and prevention standards in athletic activity in order to reduce the incidence of HRI. The athletic community continues to demand performance in hot environments depending on the seasonal activity. If the activity yields a high sweat rate in the athlete it is vital to know the reliability of the body weight measures as a preventative factor of HRI.

Statement of the Problem

The problem of this study was to determine a specific percentage of body weight that may serve as a field measure for holding an athlete from athletic activity in order to prevent Heat Related Illness and its related affects.

Delimitations

1. 89 total subjects were involved in this study.
2. All subjects were healthy male varsity football athletes age's (17-25 years of age) from a rural Midwestern university team.
3. Samples were selected by treatment of heat related illness during the two year study.

Limitations

1. The episode subjects were not randomly selected, but were those treated for HRI.
2. The non-episode subjects were randomly selected from the remaining participating athletes.
3. All subjects were exposed to two and three practices per day in varying environmental conditions during the months of August of 1996, 1997.
4. There may be varying individual sensitivity to physical exertion in hot environments.

Assumptions

1. Good health was determined by preparticipation physical examination performed by the University Athletic Department team physician.
2. Subjects correctly followed all instructions.
3. Subjects were honest in the recording of their nude body weights.
4. Subjects were honest with non-apparent heat illness symptoms.

Hypothesis

HO1: There will be no difference in absolute body weight loss between the episode group and the non-episode group.

HO2: There will be no difference in relative body weight loss between the episode group and the non-episode group.

Definitions

Heat Related Illness (HRI)- Umbrella term; pertaining to signs and symptoms or diagnosis of heat cramps, heat exhaustion or heat stroke.

Absolute body weight loss- Weight loss that occurs during practice sessions measured in pounds of body weight.

Relative body weight loss- Weight loss that occurs during practice sessions measured in percentage of body weight.

Dehydration- Condition resulting from excessive loss of body fluid.

Clonic- Pertaining to clonus; alternate contraction and relaxation of muscles.

Rhabdomyoloysis- Destruction of skeletal muscle tissue. Rarely this condition may follow strenuous exercise and may be a result of HRI.

CHAPTER II

REVIEW OF LITERATURE

Introduction

Through the recent years much attention has been directed toward HRI and its effect on athlete's performance at all levels of activity (7). The majority of all HRI's occur at the extreme hot environments as measured by the Wet Bulb Globe Temperature (WBGT) (8,9,10). Arnheim and Prentice (2) and Booher and Thibodeau (3) have both identified HRI prevention in six different categories: 1. Fluid and electrolyte replenishment, 2. Gradual acclimatization, 3. Identifying susceptible people, 4. Clothing, 5. WBGT records, 6. Weight records. These preventative measures are well established in athletics as well as in the military, yet HRI continues to be a problem when athletes or soldiers are exposed to extreme physical activities in hot environments (1).

The existing data has continued to prompt studies on HRI in the athletic community. These studies have prompted the American College of Sports Medicine to update its position stand on HRI (11, 12). Recommendations have been made for the amateur athlete and physically active people in the United States. The recommendations include pre-event nutrition and hydration, activity hydration, fluid temperatures, carbohydrate content and type of container for optimal fluid delivery and absorption.

Effects of Dehydration on the Body

Studies have shown that exercise in hot environments induces a higher sweat rate in athletes to allow for regulation of the core body temperature (1,6,13). It is not uncommon for an athlete to lose 1-2 liters of fluid per hour of activity and if this sweat loss exceeds that of the amount of fluid intake, dehydration will occur (6). Adolf and associates (16) reported an average sweat rate of 4.1 liters every 24 hours with a range of 1-11 liters every 24 hours in military men. Broad et al. (17) concluded that there was a range of from 0.85-5 liters of fluid loss in a 90 minute soccer game. To measure the amount of fluid loss in the field, body weights are commonly used. Each pound of actual body weight lost is equal to 450 ml of fluid, therefore one liter of fluid is equal to 2.2 pounds of actual body weight. During an average practice an athlete can lose up to 2-4 lbs. of body weight (18).

With the loss of water and electrolytic constituents from the body many physiological problems can arise (19). Each consecutive liter of fluid loss will increase the heart rate 8 beats per minute, cardiac output will decline 1 liter per minute and the core body temperature will rise 0.3 degrees Celsius (18). Bross (1) and Coyle and Montain (20) showed that a 3 % decrease in body weight increased the core temperature. Murray (28) found that the core temperature will increase 0.18-0.72 degrees F with 1% relative body weight loss. At any level of dehydration there is going to be some level of cardiovascular functional impairment. Many studies have correlated the core body temperature and relative body weight loss (21,22,23). Gisolfi and Lamb (23) studied runners in 32-kilometer foot races. They found that athletes with a 3%

decrease in relative body weight also had an increased rectal temperature (core body temperature) (21). Noakes (21) studied different types of races both running races and canoeing and discovered very similar sweating rates and weight loss in the athletes performing the activity. The recorded sweat rates were 50% percent higher than the recorded fluid intake for the athletes in the study. Noakes (21) stated that for competitive athletic community the ACSM's fluid intake guidelines were unrealistic.

With dehydration, physical signs and symptoms begin to occur. These characteristics start to occur as early as 1-2% dehydration. Greenleaf (24) and Gisolfi and Lamb (23) presented similar scales of relative body weight loss versus physical signs and symptoms that shows thirst beginning as early as 1 % and decreased work capacity at 4% and resulted in possible collapse if combined with exercise and heat. Adolf and associates (16) concluded that at approximately 2% dehydration thirst begins. Arnheim and Prentice (2) and Booher and Thibodeau (3) expressed an increased risk of heat illness and decreased physiological function at 3% of body weight loss. Broad et. al (17) used a similar scale for an athletes performance versus percent body weight loss. This scale shows a decrease in performance at 1.8% and a great performance deficit at 5-6% body weight loss. Armstrong et.al (25) stated that urine color is a good indicator of hypohydration and other HRI in athletes when a urine analysis (UA) is not feasible and other signs and symptoms do not provide a prediction.

Urine color will darken in cases of dehydration however does not detect signs of other HRI. These problems can be detected by a UA. Rhabdomyolysis can be detected in the urine but will not effect the color. This condition is when muscle tissue is broken

down from intense exercise sessions in hot environments without proper acclimatization (26).

Broad et. al (17) examined actual body weight changes and voluntary fluid intake comparing soccer, basketball and netball athletes. The athletes were weighed before and after each practice to attain a sweat rate and relative body weight loss to determine percent dehydration. All fluid intake was monitored for efficiency. It was found that competition sessions had a higher sweat rate than training sessions, and outdoor sports and indoor sports had comparable sweat rates. In some situations the indoor sports reported higher sweat rates due to lower levels of air circulation.

Summary

Broad et. al (17) suggested a primary example for the need for further study of heat illness. There has been research to determine the effects of dehydration on the body's cardiovascular system, mental functioning, and athletic performance. These studies have used actual body weight loss as the measurement tool for determining relative body weight loss and dehydration. These studies have also given scales with relative dehydration versus core body temperature and physiological effects but there is not a scale to determine when signs of heat illness will begin. There is a need for determining a predictive percent body weight loss that will produce objective signs and symptoms of heat illness. This predictor could be used to ensure that heat illness is prevented and the athletes health is not compromised in a training or competitive session.

CHAPTER III

METHODOLOGY

Subjects

Eighty nine healthy male varsity football athletes ranging in age from 17-26 and residing in a rural Midwestern college town were used in this study. The 39 episode subjects, 25 from 1996 and 14 from 1997, were identified from the population after being treated for signs and symptoms of HRI during two-a-day and three-a-day football practices in the month of August. The 50 non-episode subjects, 25 from 1996 and 25 from 1997, were randomly selected from the population. The mean weight for the episode group was 234.8 pounds and comparatively the mean weight for the non-episode group was 228.5 pounds. All subjects were briefed of the medical importance of recording weights before and after each practice. A two-group pretest/posttest design was used. This study was approved by the Institutional Review Board at Oklahoma State University (Appendix D). All data collected over the two separate years of two-a-day and three-a-day practices was held in strict confidence and maintained by the principal investigator.

All athletes received a required pre-participation physical examination given by the team physician. The pre-participation physical is comprised of a general health screening, orthopedic examination and mandatory departmental drug test. Proper medical history documentation was required before participation.

Preliminary Procedures

Prior to all practice sessions the athletes were instructed in how to weigh themselves. The athletes were directed to be nude or wearing dry shorts. The athletes were reminded before and after each practice to weigh immediately before and after the training sessions, before fluid consumption and or excretion to assure the accuracy of the weighing. Only the subjects treated for signs or symptoms of HRI were selected for the episode group.

Equipment and Testing Procedures

The study used a single blind controlled design. The subject was not informed of the study. The principal investigator was the only individual with the knowledge regarding the weight fluctuation. The subjects were informed and reminded to weigh before and after each practice session. Any subject that had any questions on the use of the scale was instructed on the proper procedure at that time. The scale used to weigh the subjects was a Toledo Scale (Toledo Scale Corporation, Toledo, Ohio). The first weighing before the first practice session was determined to be the athlete's baseline weight (BLW)(Appendix A) in both the episode and non-episode groups. When the subject displayed any signs or symptoms of heat illness the athlete was taken to the medical area for treatment. Prior to ingestion of fluids the athlete was weighed to determine the athletes episode weight (EW)(Appendix B). If the medical circumstances did not permit the athlete to weigh before treatment was administered, all fluids administered orally and or intravenously were recorded in liters and converted to pounds of fluid weight (FW). The athlete was immediately weighed after necessary

treatment was administered and prior to urinary or fecal excretion to determine the athlete's post episode weight (PEW).

If a post episode weight (PEW) was recorded the fluid weight supplement (FW) was subtracted from the post episode weight (PEW) to get the episode weight (EW). The episode weight (EW) was then subtracted from the base line weight (BLW) to determine the absolute body weight loss (AWL) for each episode [BLW – (PEW-FW) =AWL] (Appendix C). Eleven subjects in the 1996 data had dual episodes and two subjects had triple episodes. The 1997 data presented three subjects with dual episodes.

The control subjects were randomly selected from the remaining non-affected athletes and were weighed in the same manor. The subjects initial weighing was the subject's base line weight (BLW). The subject did not display any signs or symptoms of HRI, so a post practice session weight (PPW) was recorded to replace the episode weight (EW). The practice session in 1996 and 1997 pre-season practices that had the highest incidence of heat illness for each year was used to determine the PPW. The practice session for 1996 was recorded as having a 90% relative humidity reading with a wet bulb temperature reading of 71 degrees F and a dry bulb temperature reading of 79 degrees F. The practice session for 1997 was recorded as having 92% relative humidity reading with a wet bulb temperature reading of 73 degrees F and a dry bulb temperature reading of 78 degrees F. These two dates represent a good indicator of possible body weight loss in the non-episode subjects. The post practice session weight (PPW) was subtracted from the base line weight (BLW) to determine the absolute body weight loss (AWL) in the non-episode subjects.

Post Procedure

After the athlete was weighed and treated and was given directions to consume a normal amount of food and large quantities of fluids (e.g. water, juices and electrolyte drinks). The athletes that displayed HRI signs and symptoms were weighed before the next practice session and were monitored closely for any additional signs and symptoms. If the athlete's weight was not within 2-3 pounds of his BLW the athlete was held from activity until the desired weight was achieved (Appendix B).

Statistical Design

A single blind controlled design was used to test both hypotheses in this study. A t-test at a $p<0.05$ level of significance was used. A Gain score analysis was used to determine the difference in the means of the episode and non-episode groups and to determine a relative body weight loss to predict HRI in athletes active in a heat stress environment.

CHAPTER IV

RESULTS AND DISCUSSION

Results

This investigation involved the testing of both hypotheses at a $p<0.05$ level of significance. Both hypothesis tested stated that there would be no difference in absolute and relative body weight loss between the athletes showing signs of HRI (episode group) and those athletes who did not show signs of HRI (non-episode group). The problem of this study was to investigate if a difference existed between the weights of post practice and post episode and the base line weights of the control group and the episode group.

The episode group base line weights ranged from 164 pounds to 318 pounds with a mean of 234.8 pounds. The non-episode group base line weights ranged from 164 pounds to 324 pounds with a mean of 228.5 pounds. The range of total relative body weight loss in the episode group was between +1.79 % and –11.23% with a mean percent loss of -3.58%, SD=2.43%. The range for the total relative body weight loss in the non-episode group was between 0% and -5.39% with a mean of –1.82%, SD=1.10%. The range for the combined groups total percentage body weight loss was -11.23% and +1.76% with a mean of -2.75% (Table I).

A Gain score analysis of weight loss means yielded a difference of 4.05 pounds between means. A Gain score analysis of the percentage weight loss resulted in a difference of 1.76%, SD=2.10%. The t-test analysis for percentage body weight loss equaled 4.70 (Table II). Therefore both of the hypothesis were rejected as there was

statistical significance shown between the total body weight loss in the episode group when compared to the non-episode group.

TABLE I

Raw Data

Means and Standard Deviations

	Episode Group(N=39)	Non-Episode Group(N=50)
BLW (Pounds)	234.84 (SD=39.5)	228.48 (SD=39.86)
EW (Pounds)	226.56 (SD=39.5)	224.26 (SD=38.93)
Absolute WL (Pounds)	8.27 (SD=5.35)	4.22 (SD=2.69)
Relative WL (%)	3.58% (SD=2.43)	1.82 (SD=1.10)

TABLE II

T-Test Results

	t-value	df	2-tail Sig	SE of Diff
% Body Weight loss	4.70	103	.000	.375
Total Body Weight Loss	4.83	103	.000	.839

Discussion of Results

Based on the results of this investigation the mean body weight loss percentage was greater in those athletes that displayed signs and symptoms of heat illness (Episode Group=3.58%, Control Group=1.82 %). The Gain score analysis mean difference of 1.76% showed statistical significance. Therefore, the author suggests that the mean weight loss of the control group, 3.58%, be used as the predictor for the beginning of HRI.

Arnheim and Prentice (2) and Booher and Thibodeau's (3) suggested 3% relative body weight loss scale is the closest example to stating individuals are at risk of heat illness at a lower level of weight loss. The results of this study found that athletes could present with HRI signs and symptoms with 0% weight loss and having up to 11.23 % body weight loss. The range of this weight loss was great and the mean of the episode group, 3.58 %, is a reliable, small percentage of body weight loss to be used as a predictive measure for HRI.

The American College of Sports Medicine gives recommendations for amateur athlete's pre-event nutrition and hydration and activity hydration. As Noakes (21) suggested these recommendations from the ACSM may not be realistic or able to fulfill the need for the elite level athletes who participate at the competitive level. The competitive athlete has been recorded as losing 1-5 liters of liquid per hour during strenuous activity (6,17). With each liter being approximately 2.2 pounds an athlete can lose 2-11 pounds per hour during athletic activity in a heat stress environment (6,17,18).

With this extreme weight loss it is important to keep all weight fluctuation supervised by medical personnel as to prevent HRI from occurring.

It is common practice to keep weight fluctuation charts and to monitor athletes daily weight changes from practice to practice. Though these activities occur, weight charts are generally not used as a preventative measure for HRI. It is generally not until the athlete shows signs of HRI that the athlete is monitored with more scrutiny. After the athlete is treated for HRI with ice to cool the body and IV and oral fluids the athlete is generally held from activity for approximately 1-3 days. The number of days the athlete is held from activity depends upon the severity of the HRI and the speed of his/her recovery.

The author suggests that more scrutiny be placed on weight fluctuations prior to 3.58% relative body weight loss before signs and symptoms of HRI occur. The athletes that present with this amount of weight loss can be put on an alternate activity plan so that HRI is prevented and the athlete is kept active constantly without harm. By modifying one or two training sessions for an athlete who presents with weight loss below 3.58%, absence from practice sessions or competitions can be prevented. Alternate activity can be chosen by the supervising coaches or medical staff. This modification could limit the athlete to activity in a controlled climate or team activity with limited uniform requirements (e.g. shorts, shirt and helmet rather than full uniform). It is also recommended that fluids be constantly available for the athletes. Some teams practice with fluid rationing, giving only mandatory water breaks. This practice is not recommended but if it is being followed, water breaks should occur every

15-30 minutes depending on the weather conditions and Wet Bulb Globe Temperature to allow for proper hydration.

It is difficult to compare this study to previous studies as this study was concerned with prevention of HRI in contrast to core body temperature and performance levels in athletic activity in heat stress environments. The primary concern was with the athletes health and safety, therefore the athlete was treated medically prior to any data collection. Also, this study was considered to be a field study as it was conducted in an uncontrolled environment. The athletes were exposed to changing weather conditions and varying environmental elements in contrast to controlled climate conditions in an exercise testing laboratory.

This study contrasted other studies with the use of body weights paralleled with another variable such as Heat Related Illness instead of athletic performance and core body temperatures. It was different with its concern for the HRI associated with percentage weight loss that the athlete suffered. It replicated Brauds (19) protocol of weighing pre and post activity however a specific sport and subject gender was used in this investigation. It differed from Adolf and associates (16) as the percentage weight loss was found post episode and not daily. The present results are due to the ability to attain accurate weights before administration of IV and or oral fluids given during medical treatment. Medical care was the first priority and if weights were unattainable before treatment then the TWL was found from the weight of the fluids.

CHAPTER V

Summary, Conclusions and Recommendations For Further Study

Summary

89 male varsity athletes ranging in age from 17-26 were weighed before and after two-a-day and three-a-day practice sessions for two chronological years to determine percent body weight loss in athletes participating in activity in heat stress environments. Athletes who were treated for signs and symptoms of heat related illness were placed in the episode group (N=39). The control group was randomly selected from the athletes who did not display signs and symptoms of HRI (N=50). Weight loss was measured at the time of episode for the episode group and was measured on the day of the highest incidence of heat illness for the control group.

Conclusions

The findings of the study suggest that heat related illness can start within the range of 0% body weight loss and 11.25% body weight loss, with a mean of 3.58% in comparison to 1.82% for those athletes not having Heat Related Illness. Using 3.58% body weight loss as the highest measure for predicting HRI and using lower, stricter standards can prevent HRI from occurring and can prevent unnecessary absences from training and competition. If the athletes presents with a percentage weight loss at 3.58% or below he/she can be held from activities or have alternate activities assigned

until his/her weight is at an acceptable level. Measures also can also be used to prevent HRI from occurring is to have liquids constantly available or have more frequent water breaks and to monitor the environmental conditions. These simple preventative measures can maintain the health of athletes who participate in activities in heat stress environments and prevent the possibility of severe Heat Related Illness from occurring.

Recommendations for Further Study

In attempt to further the study of percentage body weight loss the author suggests utilizing the same protocol of pre/post practice weights using a one trained examiner to weigh the athletes and record all weights before all practices. This examiner would also be responsible for checking for proper clothing. Also, it would possibly be more accurate to get a bed scale to weigh the episode group when they displayed signs and symptoms of HRI and are unable to use the stand up scale. This could alleviate any clerical errors in the recording of liters of fluid administered, along with the conversion to body weight in pounds.

References

1. Bross, M., Nash, B., Carlton, F. (1994). Heat emergencies. American Family Physician, 50(2), 389-396.

2. Arnheim, D. and Prentice, W. (1997). Priciples of Athletic Training (9th ed.). St. Louis: McGraw Hill.

3. Booher, J. & Thibodeau, G. (1994). Athletic Injury Assessment (3rd ed). St. Louis:Mosby and Yearbook.

4. Armstrong, L., Hubbard, R., Kraemer, W., Deluca, J. Christensen, E. (1987). Signs and symptoms of heat exhaustion during strenuous exercise. Annals of Sports Medicine, 3(3),182-189.

5. Sidebottom, J. (1992). When it's hot enough to kill. Registered Nursing, 55(8), 30-35.

6. Gisolfi, C., (1998). Preparing your athletes for competition in hot weather. Sports Science Exchange, Coaches Corner.

7. Hubbard, R. (1990). Heatstroke pathophysiology: the energy depletion model. Medicine and Science in Sport and Exercise, 22(1), 19-28.

8. Sawka, M., and Greenleaf, J. (1992). Current concepts concerning thirst, dehydration and fluid replacement. Medicine and Science in Sport and Exercise, 24(6), 643-644.

9. Ellis, D. (1998). Football coaches guide to heat illness and hydration. Sports Science Exchange, Coaches Corner.

10. Kark, J., Burr, P., Wegner, B., Gastaldo, E., Gardner, J. (1996). Exertional heat illness in Marine Corps recruit training. Aviation Space and Environmental Medicine, 67(4), 354-360.

11. Thein, L. (1995). Environmental conditions affecting the athlete. Journal of Orthopedics and Sports Physical Therapy, 21(3), 158-171.

12. American College of Sports Medicine (1985). Prevention of thermal injuries during distance running. The Medical Journal of Australia, 16(5), 876-879.

13. Convertino, V., Armstrong, L., Coyle, E., Mack, G., Sawka, M., Senay, L., Sherman, W. (1996). American college of sports medicine position stand. Exercise and fluid replacement. Medicine and Science in Sport and Exercise, 28(1), I-VII.

14. Murray, B. (1996). Fluid replacement: the American College of Sports Medicine position stand. Sports Science Exchange, 9(63).

15. Nielsen, B. (1996). Olympics in Atlanta: a fight against physics. Medicine and Science in Sport and Exercise, 28(6), 665-668.

16. Adolf and Associates (1947). Physiology of man in the desert. New York: Interscience.

17. Broad, E., Burke, L., Cox, G., Heeley, P., Riley, M. (1996). Body weight changes and voluntary fluid intakes during training and competition sessions in team sports. International Journal of Sports Nutrition, 6, 307-320.

18. Coyle, E. (1994). Fluid and carbohydrate replacement during exercise: How much and why? Sports Science Exchange, 9(3).

19. Maughan, R., Leiper, J., Shirreffs, S. (1996). Rehydration and recovery after exercise. Sports and Science Exchange, 9(3).

20. Coyle, E. and Montain, S. (1992). Benefits of fluid replacement with carbohydrates during exercise. Medicine and Science in Sports and Exercise, S324-S330.

21. Noakes, T., Adams, B., Myburgh, K., Greeff, C., Lotz, T., Nathan, M. (1988). The danger of an inadequate water intake during prolonged exercise. European Journal of Applied Physiology, 57(2), 210-219.

22. Sawka, M., Young, A., Latzka, W., Neufer, D., Quigley, M., Pandolf, K. (1992). Human tolerance to heat strain. Journal of Applied Physiology, 73, 368-375.

23. Gisolfi, C. and Lamb, D. (1990). Perspectives in exercise science and sports medicine: fluid homeostasis during exercise (vol. 3). Carmel:Benchmark Press.

24. Greenleaf, J. (1992). Problem: thirst, drinking, behavior and involuntary dehydration. Medicine and Science in Sports and Exercise, 24(6), 645-655.

25. Armstrong, L., Maresh, C., Castellani, J., Bergeron, M., Kenefick, R., Lacasse, K., Riebe, D. (1994). Urinary indices of hydration status. International Journal of Sports Nutrition, 4, 265-279.

26. Clarkson, P. (1993). Worst case scenerios: Exertional rhabdomyolysis and acute renal failure. Sports Science Exchange, 4(42).

27. Segal, K. (1996). Use of bioelectrical impedance analysis measurements as an evaluation for participating in sports. American Journal of Clinical Nutrition, 57, 469S-471S.

28. Murray, R. (1995). Fluid needs in hot and cold environments. International Journal of Nutrition 5, 562-573.

APPENDIXES

APPENDIX A

RAW DATA:

BASE LINE WEIGHTS FOR

EPISODE AND NON-EPISODE GROUPS

BASE LINE WEIGHTS

EPISODE GROUP

BLW (pounds)	Frequency	Percent	Valid Percent	Cum Percent
318	1	1.8	1.8	1.8
315	3	5.5	5.5	7.3
295	1	1.8	1.8	9.1
280	2	3.6	3.6	12.7
278	2	3.6	3.6	16.4
270	5	9.1	9.1	25.5
267	2	3.6	3.6	29.1
262	1	1.8	1.8	30.9
253	2	3.6	3.6	34.5
247	1	1.8	1.8	36.4
245	2	3.6	3.6	40.0
231	2	3.6	3.6	43.6
230	3	5.5	5.5	49.1
229	2	3.6	3.6	52.7
228	1	1.8	1.8	54.5
226	1	1.8	1.8	56.4
225	1	1.8	1.8	58.2
221	3	5.5	5.5	63.6
216	1	1.8	1.8	65.5

(Episode Group Continued)

BLW(Pounds)	Frequency	Percent	Valid Percent	Cum Percent
215	2	3.6	3.6	69.1
210	1	1.8	1.8	70.9
208	1	1.8	1.8	72.7
204	2	3.6	3.6	76.4
202	1	1.8	1.8	78.2
199	1	1.8	1.8	80.0
198	1	1.8	1.8	81.8
196	1	1.8	1.8	83.6
193	1	1.8	1.8	85.5
187	2	3.6	3.6	89.1
182	2	3.6	3.6	92.7
180	2	3.6	3.6	96.4
179	1	1.8	1.8	98.2
164	1	1.8	1.8	100.0
TOTAL	55	100.0	100.0	

BASE LINE WEIGHTS

NON-EPISODE GROUP

BLW(Pounds)	Frequency	Percent	Valid Percent	Cum Percent
324	1	2.0	2.0	2.0
312	1	2.0	2.0	4.0
300	1	2.0	2.0	6.0
295	1	2.0	2.0	8.0
290	1	2.0	2.0	10.0
284	1	2.0	2.0	12.0
280	1	2.0	2.0	14.0
275	1	2.0	2.0	16.0
272	1	2.0	2.0	18.0
270	1	2.0	2.0	20.0
263	1	2.0	2.0	22.0
254	1	2.0	2.0	24.0
245	1	2.0	2.0	26.0
242	2	4.0	4.0	30.0
241	2	4.0	4.0	34.0
240	1	2.0	2.0	36.0
238	1	2.0	2.0	38.0
237	1	2.0	2.0	40.0
234	2	4.0	4.0	44.0

(NON-EPISODE GROUP CONTINUED)

BLW(Pounds)	Frequency	Percent	Valid Percent	Cum Percent
233	1	2.0	2.0	46.0
229	1	2.0	2.0	48.0
226	1	2.0	2.0	50.0
225	1	2.0	2.0	52.0
221	1	2.0	2.0	54.0
218	3	6.0	6.0	60.0
217	1	2.0	2.0	62.0
215	1	2.0	2.0	64.0
214	1	2.0	2.0	66.0
212	1	2.0	2.0	68.0
211	1	2.0	2.0	70.0
210	1	2.0	2.0	72.0
196	2	4.0	4.0	76.0
189	1	2.0	2.0	78.0
188	1	2.0	2.0	80.0
187	1	2.0	2.0	82.0
186	1	2.0	2.0	84.0
185	1	2.0	2.0	86.0
184	1	2.0	2.0	88.0
179	1	2.0	2.0	90.0
176	1	2.0	2.0	92.0

(NON-EPISODE GROUP CONTINUED)

BLW(Pounds)	Frequency	Percent	Valid Percent	Cum Percent
175	1	2.0	2.0	94.0
173	1	2.0	2.0	96.0
166	1	2.0	2.0	98.0
164	1	2.0	2.0	100.0
TOTAL	50	100.0	100.0	

APPENDIX B

RAW DATA:

EPISODE WEIGHTS FOR

EPISODE GROUPS AND NON-EPISODE GROUPS

EPISODE WEIGHTS

EPISODE GROUP

EW(Pounds)	Frequency	Percent	Valid Percent	Cum Percent
314	1	1.8	1.8	1.8
309	1	1.8	1.8	3.6
305	1	1.8	1.8	5.5
304	1	1.8	1.8	7.3
285	1	1.8	1.8	9.1
284	1	1.8	1.8	10.9
271	1	1.8	1.8	12.7
268	1	1.8	1.8	14.5
267	1	1.8	1.8	16.4
265	1	1.8	1.8	18.2
263	1	1.8	1.8	20.0
261	1	1.8	1.8	21.8
260	1	1.8	1.8	23.6
259	3	5.5	5.5	29.1
258	1	1.8	1.8	30.9
241	1	1.8	1.8	32.7
240	1	1.8	1.8	34.5
235	1	1.8	1.8	36.4
233	1	1.8	1.8	38.2

(EPISODE GROUP CONTINUED)

EW(Pounds)	Frequency	Percent	Valid Percent	Cum Percent
230	1	1.8	1.8	40.0
229	1	1.8	1.8	41.8
226	1	1.8	1.8	43.6
223	1	1.8	1.8	45.5
220	2	3.6	3.6	49.1
219	1	1.8	1.8	50.9
218	1	1.8	1.8	52.7
216	1	1.8	1.8	56.4
215	1	1.8	1.8	58.2
212	1	1.8	1.8	60.0
211	2	3.6	3.6	63.6
210	1	1.8	1.8	65.5
207	2	3.6	3.6	69.1
206	1	1.8	1.8	70.9
200	2	3.6	3.6	74.5
199	1	1.8	1.8	76.4
196	1	1.8	1.8	78.2
194	1	1.8	1.8	80.0
192	1	1.8	1.8	81.8
190	1	1.8	1.8	83.6

(EPISODE GROUP CONTINUED)

EW(Pounds)	Frequency	Percent	Valid Percent	Cum Percent
179	2	3.6	3.6	87.3
178	1	1.8	1.8	89.1
175	1	1.8	1.8	90.9
173	1	1.8	1.8	92.7
171	2	3.6	3.6	96.4
166	1	1.8	1.8	98.2
162	1	1.8	1.8	100.0
TOTAL	55	100	100	

EPISODE WEIGHTS

NON-EPISODE GROUP

EW(Pounds)	Frequency	Percent	Valid Percent	Cum Percent
321	1	2.0	2.0	2.0
304	1	2.0	2.0	4.0
295	1	2.0	2.0	6.0
288	1	2.0	2.0	8.0
282	1	2.0	2.0	10.0
278	1	2.0	2.0	12.0
273	1	2.0	2.0	14.0
272	1	2.0	2.0	16.0
270	1	2.0	2.0	18.0
265	1	2.0	2.0	20.0
253	2	4.0	4.0	24.0
240	2	4.0	4.0	28.0
238	1	2.0	2.0	30.0
237	1	2.0	2.0	32.0
235	1	2.0	2.0	34.0
234	1	2.0	2.0	36.0
232	1	2.0	2.0	28.0
231	1	2.0	2.0	30.0
228	2	4.0	4.0	44.0

(NON-EPISODE GROUP CONTINUED)

EW (Pounds)	Frequency	Percent	Valid Percent	Cum Percent
228	2	4.0	4.0	44.0
225	2	4.0	4.0	48.0
222	1	2.0	2.0	50.0
221	1	2.0	2.0	52.0
220	1	2.0	2.0	54.0
216	1	2.0	2.0	56.0
215	1	2.0	2.0	58.0
214	1	2.0	2.0	60.0
213	2	4.0	4.0	64.0
212	1	2.0	2.0	66.0
210	1	2.0	2.0	68.0
206	1	2.0	2.0	70.0
204	1	2.0	2.0	72.0
191	2	4.0	4.0	76.0
187	1	2.0	2.0	78.0
186	1	2.0	2.0	80.0
185	1	2.0	2.0	82.0
184	1	2.0	2.0	84.0
181	1	2.0	2.0	86.0
179	1	2.0	2.0	88.0

(NON-EPISODE GROUP CONTINUED)

EW(Pounds)	Frequency	Percent	Valid Percent	Cum Percent
175	1	2.0	2.0	90.0
172	1	2.0	2.0	94.0
170	1	2.0	2.0	96.0
165	1	2.0	2.0	98.0
162	1	2.0	2.0	100.0
TOTAL	50	100.0	100.0	

APPENDIX C

RAW DATA

RELATIVE BODY WEIGHT LOSS

FOR

EPISODE AND NON-EPISODE GROUPS

PERCENTAGE BODY WEIGHT LOSS

EPISODE GROUP

%WL	Frequency	Percent	Valid Percent	Cum Percent
11.23	1	1.0	1.0	1.8
9.49	1	1.0	1.0	3.6
9.33	1	1.0	1.0	5.5
8.56	1	1.8	1.8	7.3
6.88	1	1.8	1.8	9.1
5.68	1	1.8	1.8	10.9
5.26	1	1.8	1.8	12.7
5.19	1	1.8	1.8	14.5
5.00	1	1.8	1.8	16.4
4.87	1	1.8	1.8	18.2
4.74	1	1.8	1.8	20.0
4.68	1	1.8	1.8	21.8
4.63	1	1.8	1.8	23.6
4.52	2	3.6	3.6	27.3
4.35	2	3.6	3.6	30.9
4.08	1	1.8	1.8	32.7
4.07	3	5.4	5.4	38.2
3.96	2	3.6	3.6	41.8
3.92	1	1.8	1.8	43.6

(EPISODE GROUP CONTINUED)

%WL	Frequency	Percentage	Valid Percentage	Cum Percentage
3.89	1	1.8	1.8	45.5
3.85	1	1.8	1.8	47.3
3.73	1	1.8	1.8	49.1
3.72	2	3.6	3.6	52.7
3.70	1	1.8	1.8	54.5
3.49	1	1.8	1.8	56.4
3.46	1	1.8	1.8	58.2
3.21	1	1.8	1.8	60.0
3.17	1	1.8	1.8	61.8
3.11	1	1.8	1.8	63.6
3.06	1	1.8	1.8	65.5
3.03	1	1.8	1.8	67.3
3.00	1	1.8	1.8	69.1
2.59	1	1.8	1.8	70.9
2.25	1	1.8	1.8	72.7
2.04	1	1.8	1.8	74.5
1.96	1	1.8	1.8	76.4
1.90	1	1.8	1.8	78.2
1.65	2	3.6	3.6	81.8
1.53	1	1.8	1.8	83.6

(EPISODE GROUP CONTINUED)

%WL	Frequency	Percentage	Valid Percentage	Cum Percentage
1.31	1	1.8	1.8	85.5
1.26	1	1.8	1.8	87.3
1.22	1	1.8	1.8	89.1
.74	1	1.8	1.8	90.9
.56	1	1.8	1.8	92.7
.00	2	3.6	3.6	96.4
-1.30	1	1.8	1.8	98.2
-1.79	1	1.8	1.8	100.0
TOTAL	55	100.0	100.0	

PERCENTAGE BODY WEIGHT LOSS

NON-EPISODE GROUP

%WL	Frequency	Percentage	Percentage	Percentage
5.39	1	2.0	2.0	2.0
3.91	1	2.0	2.0	4.0
3.80	1	2.0	2.0	6.0
3.43	1	2.0	2.0	8.0
3.21	1	2.0	2.0	10.0
2.89	1	2.0	2.0	12.0
2.86	2	4.0	4.0	16.0
2.76	1	2.0	2.0	18.0
2.72	1	2.0	2.0	20.0
2.56	2	4.0	4.0	24.0
2.55	2	4.0	4.0	28.0
2.52	1	2.0	2.0	30.0
2.37	2	4.0	4.0	34.0
2.29	1	2.0	2.0	36.0
2.13	1	2.0	2.0	38.0
2.11	1	2.0	2.0	40.0
2.04	1	2.0	2.0	42.0
1.85	1	2.0	2.0	44.0
1.83	1	2.0	2.0	46.0

(NON-EPISODE GROUP)

%WL	Frequency	Treatment	Valid Treatment	Cum Treatment
1.78	1	2.0	2.0	48.0
1.77	1	2.0	2.0	50.0
1.75	1	2.0	2.0	52.0
1.73	1	2.0	2.0	54.0
1.71	1	2.0	2.0	56.0
1.67	1	2.0	2.0	58.0
1.65	1	2.0	2.0	60.0
1.38	1	2.0	2.0	62.0
1.28	1	2.0	2.0	64.0
1.27	1	2.0	2.0	66.0
1.25	1	2.0	2.0	68.0
1.22	1	2.0	2.0	70.0
1.06	1	2.0	2.0	72.0
.94	1	2.0	2.0	74.0
.93	3	6.0	6.0	80.0
.74	1	2.0	2.0	82.0
.73	1	2.0	2.0	84.0
.60	1	2.0	2.0	86.0
.57	1	2.0	2.0	88.0
.46	1	2.0	2.0	90.0

(NON-EPISODE GROUP CONTINUED)

%WL	Frequency	Percent	Valid Percent	Cum Percent
.45	1	2.0	2.0	92.0
.41	1	2.0	2.0	94.0
.39	1	2.0	2.0	96.0
.00	2	4.0	4.0	100.0
TOTAL	50	100.0	100.0	

APPENDIX D

INSTITUTIONAL REVIEW BOARD APPROVAL

OKLAHOMA STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD
HUMAN SUBJECTS REVIEW

Date: 08-27-97 **IRB#:** ED-98-006

Proposal Title: ESTIMATING BODY FLUID LOSS AS A PREDICTOR OF HEAT RELATED ILLNESS

Principal Investigator(s): Bert H. Jacobson, Phil Vardiman

Reviewed and Processed as: Exempt

Approval Status Recommended by Reviewer(s): Approved

ALL APPROVALS MAY BE SUBJECT TO REVIEW BY FULL INSTITUTIONAL REVIEW BOARD AT NEXT MEETING, AS WELL AS ARE SUBJECT TO MONITORING AT ANY TIME DURING THE APPROVAL PERIOD.
APPROVAL STATUS PERIOD VALID FOR DATA COLLECTION FOR A ONE CALENDAR YEAR PERIOD AFTER WHICH A CONTINUATION OR RENEWAL REQUEST IS REQUIRED TO BE SUBMITTED FOR BOARD APPROVAL.
ANY MODIFICATIONS TO APPROVED PROJECT MUST ALSO BE SUBMITTED FOR APPROVAL.

Comments, Modifications/Conditions for Approval or Disapproval are as follows:

Signature: John H. Wyckoff

Chair of Institutional Review Board

Date: August 28, 1997

cc: Phil Vardiman

VITA

John Phillip Vardiman

Candidate for the degree of

Master of Science

Thesis: THE USE OF PERCENTAGE BODY WEIGHT LOSS AS A PREDICTOR FOR HEAT RELATED ILLNESS

Major Field: Health, Physical Education and Leisure

Biographical:

Personal Data: Born in Marshall, Missouri, July 14, 1974, the son of Bill and Billie Vardiman, brother of Sarah and Johnene' Vardiman.

Education: Graduated from Marshall High School, Marshall, Missouri, in June of 1992; received a Bachelor of Arts degree from Park College in May, 1996; completed requirements for the Master of Science degree at Oklahoma State University in July, 1998.