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The Effect of Two States of Hydration on Muscular Endurance in Men

Melissa L. Petrucci

Eastern Illinois University

This research is a product of the graduate program in Physical Education at Eastern Illinois University. Find out more about the program.

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The Effect of Two States of Hydration on Muscular Endurance in Men

TITLE

BY

Melissa L. Petrucci

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Science

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

2000 YEAR

I HEREBY RECOMMEND THAT THIS THESIS BE ACCEPTED AS FULFILLING THIS PART OF THE GRADUATE DEGREE CITED ABOVE

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ABSTRACT

The Effect of Two States of Hydration on Muscular Endurance in Men  

Melissa L. Petrucci

The purpose of this study was to investigate the effects of two states of hydration has an effect on muscular endurance in men. Two groups of four men randomly assigned to each group participated in both states of hydration. Both groups were tested at baseline for height, weight, intra- and extra-cellular water, total body water, and a one-repetition maximum strength test. Subjects were then tested after a 24 hour period of water deprivation, and after a 24 hour period of normal water intake (8 ten oz glasses of water). A urine specific gravity test, intra- and extra-cellular water, total body water, and weight were used to determine hydration. A maximum repetition test at 50 percent of the subjects' IRM was used to determine muscle endurance. Results showed that there was no statistical significance (p<.05) between hydration and muscular endurance at a decrease of one percent total body weight. It was concluded that while in the literature it may appear that there may be a relationship between hydration and performance, there was no statistical difference between the two states of hydration in this experiment.
Dr. Pritschet,

To say thank you for your good spirit, guidance, help and time would simply not begin to express my gratitude. You’ve been available to me day and night throughout this experience, and without you, it would likely have been a failure. You’re an amazing role model for me and all who follow hereafter. A special thank you once again.

Melissa L. Petrucci  M.S.
DEDICATION

I would like to dedicate my master's thesis to my parents, Judy and Al Fosco, who have supported and encouraged me throughout my academic career.
ACKNOWLEDGEMENTS

The author would like to give a special thank you to Dr. Brian Pritschet for all the time, effort, support and guidance he has put forth throughout her master's thesis. The author would also like to thank Dr. Thomas Woodall, Dr. Jill Owen, and Dr. John Emmett, for their valuable contributions, as they were greatly appreciated.

A special thanks also to Herbert Aaron Pelz and the eight subjects who have given their time and effort for this research project.
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INTRODUCTION

Many people are unaware of how important proper hydration is to their performance as an athlete, or even as a recreational exerciser. The physiology of the body requires that we replace lost fluids during physical activity, because the body's natural cooling system is the evaporation of sweat from the skin. Therefore, humans lose the water their bodies need to keep cool, and it must be replaced in order for the body to perform optimally. The body's natural balance is delicate, and perhaps even the slightest variation may affect the performance of those in training.

Depending on physical activities, ambient temperature, wind, and other factors related to exercise, the body may exist in three states of hydration. These are: dehydration, normal hydration, and super-hydration. It is likely that the body performs best at levels of normal hydration, but it may be able to perform adequately at slightly different levels of dehydration or super-hydration. When an athlete or exerciser is in training, it is best to try to maintain a level of normal hydration, not only for performance reasons, but for the health status as well. Such things as diet, exercise intensity, weather conditions and fluid intake are variables that may affect the body's hydration.

It is especially important in sports such as wrestling and bodybuilding to stress the importance of hydration, as these are sports where water restriction is a common practice due to attempts to meet weight requirements. The necessity for education
about hydration, however, is clear; people die if they are not properly hydrated. A well known example of this are the deaths of three NCAA wrestlers between November 7 and December 9, 1997 (The NCAA News: News and Features, 1997, 1998). The deaths of these wrestlers has since forced changes in the NCAA weight loss policies to try to prevent another such tragedy. The new guidelines are yet another version of the previously clarified revision of the weight loss policy that went into effect in April, 1996 (The NCAA News: News and Features, 1996).

In the last several years authorities have taken a much stricter stance with the wrestling community for the frequent use of dehydration by the athletes to make weight. However, in bodybuilding, athletes are still plagued with an overabundance of dehydrated participants, so that they will be “ripped up” for their show.

Education about proper hydration is important for all athletes. Their performance as well as their health may depend on it.

Identification of the Problem

Hydration and muscular endurance seem to have been neglected as an area of research investigation. There appears to be little research found in this area, even though it is quite important to sport and exercise. Especially in sports such as wrestling where the event is timed and sustained muscle contraction is not uncommon, the performance of the athlete depends on his ability to maximally maintain a muscle contraction. In bodybuilding also, where competitors have to maintain sustained muscle contractions for a period of time, hydration seems to play a
major role in the overall performance of the muscle, and consequently the outcome of the competition. Muscle cramping due to dehydration may cause an athlete to perform sub-optimally and therefore cost him the match.

The purpose of this investigation was to examine the relationship between two states of hydration, water restriction and normal hydration, and its effect on muscular endurance performance. This study looked at whether or not there was in fact a relationship, and if so, to what degree did the state of hydration and its severity have on the performance of the subject.

**Hypothesis**

It was hypothesized that muscular endurance would be significantly better under the condition of normal hydration. Muscular endurance performance was expected to be significantly lower in fluid restriction trials versus normal hydration trials. Therefore, performance would decline as a result of water restriction.

**Limitations and Delimitations**

Due to the risk of injury to the subject, several limitations and delimitations were considered in this study. The fact that the subjects could not be severely dehydrated due to health concerns delimited the conclusions that could be drawn about the effects of extreme dehydration. Diet was also difficult to regulate perhaps adding small amounts of body water for some subjects. Caffeine intake and smoking could not be regulated (although there were no reported smokers in this particular...
investigation), and we had to assume that the subjects were honest in regard to the intake of caffeine and cigarette smoking along with alcohol use cessation 24 hours prior to testing.

Another limitation was the fact that the subjects may have had expectations of their own, prior to and during testing. The study was not blinded to the subjects as they were administering their own fluid intake, or lack thereof. The test protocol itself also has delimitations. In the university setting, using college students, it was difficult to regulate the subjects’ diet and liquid intake. It was assumed that the subject followed the protocol as asked. In the water restriction trial, students may have taken in foods with a high water content to supplement the lack of water intake. In the normal hydration trial, subjects may have added another beverage in with their water consumption, although it was stated specifically water was to be the only beverage taken during those 24 hours prior to testing. Subjects may also be involved in other activities that caused muscle fatigue prior to testing such as manual labor jobs or recreational sports, which also were supposed to be avoided prior to testing.

Finally, one last limitation was the time constraint and scheduling conflicts. Testing began near the end of spring semester, while students were entering final exams, and time was short. This made selection of subjects difficult, as it was important they be able to complete testing before they left after the semester. Results may be affected by this due to lack of sleep, poor eating habits, canceled testing times, early or late testing times, and disruption of exercise habits. Testing continued into the summer, and scheduling was once again difficult due to summer jobs and
summer classes, heat, and readjustment to the new semester. Once again there were several canceled meetings, and some subjects withdrew.

**Assumptions**

It was assumed that the subjects did their best on every trial, regardless of what their preconceived notion of what the outcome would be. Another assumption was that motivation levels were high when the test was administered. Because there was no outside encouragement from the tester, we had to assume intrinsic motivation from the volunteer subjects, and that they put forth 100 percent effort on their one rep maximum test, as well as the muscular endurance tests under two different states of hydration.

**Definition of Terms**

For the purpose of this study, the following definitions have been used:

- **Dehydration**: an abnormal depletion of body fluids (Merriam Webster, 2000)
- **Hydration**: the condition of having adequate fluid in the body tissues (Merriam Webster's Medical Desk Dictionary, 1996) (http://hg.healthgate.com/merriam/index.asp.)
- **Muscle Fatigue**: a state arrived at through prolonged and strong contraction of a muscle. Studies in athletes during prolonged submaximal exercise have shown that muscle fatigue is almost in direct proportion to the rate of muscle glycogen depletion. Muscle fatigue in short-
term maximal exercise is associated with oxygen lack and an increased level of blood and muscle lactic acid, and an accompanying increase in hydrogen-ion concentration in the exercised muscle (On-line Medical Dictionary, 1998)

**Muscle Endurance**

the ability of a muscle or muscle group to exert submaximal force for extended periods (Heyword, 1998)

**One-Rep Max Test**

weight lifting test designed to find the maximum weight a subject can lift a maximum of one time

**“Ripped-Up”**

having each individual muscle highly defined, usually through extensive weight lifting exercise and dehydration, to prevent water weight from visually impairing muscle definition and striations (usually done for body building competitions)

**Specific Gravity**

a measure of concentration. It is the weight of a substance, as compared (as a ratio) with that of an equal volume of water (On-line Medical Dictionary, 1997)

**Urine**

In man, the urine is a clear, transparent fluid of an amber colour and peculiar odour, with an average density of 1.02 gm/cm3. The average amount excreted in 24 hours is from 1.183 to 1.774 liters. Chemically, the urine is mainly an aqueous solution of urea, salt, and ureic acid, together with some hippuric acid and
peculiar pigments. It usually has an acid reaction of, owing to the presence of phosphates of soda or free ureic acid. Normally, it contains about 960 parts of water to 40 parts of solid matter, and the average daily excretion is 35 grams of urea. 75 grams of ureic acid and 16.5 grams of salt. Abnormally it may contain sugar as in diabetes, albumin as in Bright’s disease, bile pigments as in jaundice, or abnormal quantities of some one or more of the normal constituents (Webster’s Dictionary, 1998)
CHAPTER II

REVIEW OF RELATED LITERATURE

There have been many studies that have examined the effects of hydration on endurance. However, most of the research conducted in the past has been with running or cycling, not with resistance training or anaerobic activity. The review of literature is organized into two sections: research related to whole body hydration and research examining the effects of hydration on muscular endurance.

Whole Body Hydration

One important point that several of the authors agreed upon when looking at dehydration was the fact that when a person does not replace fluids lost during exercise or sweating, the body can no longer cool itself effectively (usually in cardiovascular endurance exercises), and therefore one's performance drops (Vibrant Life, 1996; Executive Health's Good Health Report, 1998; Palaestra, 1998).

According to Montain, et al. (1998), moderate hypohydration (a four percent body weight loss) reduces muscle endurance measured by performing single-leg, knee-extension exercises to exhaustion while lying supine inside a whole body 1.5TMR system. Similarly, Caterisano, Camaione, Murphy, and Gonino (1988) found that there was a significant decrease in muscle endurance when comparing dehydration (loss of three percent body weight) to euhydration among six anaerobically trained and six sedentary subjects, measured by using maximal leg extension repetitions performed at or above 50 percent of their peak torque output.
One study done by Greiwe et al. (1998), however, presents evidence to the contrary. The findings of this research study on seven healthy men who did not use dehydration as a part of their current regular training program, suggest that isometric strength and endurance of the knee extensors and the elbow flexors are unaffected three or more hours after rapid dehydration of approximately four percent loss of body mass. Isometric strength testing of the right knee extensor and right elbow flexor was determined first by finding peak torque using a Biodex Multi-Joint System. This system was also used for all subsequent testing. Peak torque was determined by maximal contraction against an immovable arm attachment, and thereafter 50 percent of peak torque was used measuring time to fatigue for a sustained contraction. Other studies in the literature that support the idea that dehydration showed no change in endurance after dehydration are Serfass, Stull, Alexander, and Ewing (1984) and Singer and Weiss (1968).

Bijlani and Sharma's research (1980) seemingly combine both outcomes. They found that dehydration amounting to two percent of the subjects body weight did not impair mechanical efficiency, however three percent dehydration reduced the endurance time for isometric contraction of the extensors of the forearm. This study used 14 healthy young male volunteers. They were dehydrated using a hot room and increasing sweat by stepping up and down on a stool 30 cm high at a frequency of 20/min for 10 minutes done in two consecutive bouts. Maximal contraction was measured with his pronated left forearm resting on a flat surface and the palm over a partially inflated rubber bag obtained from a sphygmomanometer cuff. The bag was connected to a mercury manometer, and the subject was told to press the bag with his
palm using only his forearm extensor muscles. The subject then pressed the bag, increasing the level of the mercury in the manometer. Two sub-maximal trials were made with a one minute rest in between, and then there was a five minute rest period. Endurance was measured then by holding the pressure at 80 percent (± two percent) of his maximal trial for as long as possible.

Another similarity in these articles was that drinks that include caffeine and alcohol promoted dehydration instead of helping to prevent it (Wilmore and Costill, 1994). In order to maintain normal hydration and subsequently obtain optimal performance, one should maintain a normal level of hydration and good physical health.

According to Greiwe et al. (1998) to one of the testing done to date on muscle fatigue and dehydration is meaningful because of the fact that there are so many other outside influences such as diet, exercise and ambient temperatures. They claimed, “although numerous studies have influenced the effects of dehydration on muscular strength and endurance, the finding from most of these studies cannot be contributed to dehydration alone since they include confounding factors such as increased muscle temperature, caloric restriction, and exercise” (Greiwe et al., 1998). In their study they attempted to add to the existing literature more accurate results than previous studies had attained by controlling such things as percent body weight lost during hydration (approximately four percent), body (muscle) temperature which may play a role in decreasing isometric muscular strength, and pre-trial fatigue from prior exhaustive tests.
Another analysis (Barr, 1999) concludes that hypohydration reduces aerobic endurance, but its effects on muscle strength and endurance are not consistent and require further study. Furthermore, Barr’s research indicates that it is not dehydration that in fact causes a decrease in performance, but rather increased environmental temperature combined with decreased body water.

The research studies involving hydration and muscle endurance indicate that there is not enough convincing research for scientists to draw conclusions about hydration’s effects on muscle endurance. While there are some studies, most are not well controlled, or combine high environmental temperatures coupled with exercise to dehydrate subjects, which may impair their ability to perform optimally. The effects of fluid restriction during exercise appeared to cause a decrease in optimal performance, but the literature is yet inconclusive.

**Muscle Fatigue**

Muscle fatigue is caused by exhaustion in the central and/or peripheral systems, according to Fitts (1996). He focused on the peripheral system, which had the most relevance to his research and defined muscle fatigue as, “a decrease in the peak tension and power output resulting in a reduced work capacity.” Muscle fatigue involves first a drop in force, and then a drop in velocity, which then decreases power. Fatigue results mostly at the cellular level of the muscle and if a muscle is stimulated over time (either sustained contraction or repetitive contractions), the force will decline due to fatigue. Fatigue then is defined as a failure of the muscle to sustain force in a prolonged contraction or to reattain a force in repeated contractions (Encyclopedia Britannica, 2000). There is a relationship between the development of
fatigue and the depletion of energy stores in the exercising muscle. In prolonged or repetitive exercise, fatigue is associated with glycogen depletion due to oxidative glycolysis. In intense exercise that lasts only a few seconds to a few minutes in duration, and is associated with the accumulation of lactate and an intracellular acidosis due to anaerobic (nonoxidative) glycolysis (Encyclopedia Britannica, 2000).

Testing for muscle fatigue can be difficult, as several factors become important. Most of all, rest and recovery times are important to obtain valid test results. If adequate time for the rebuilding of muscle tissue is not allowed, the results of the second trial may be skewed; “…the design of the study was such that the subject performed exhaustive muscular endurance tests before and after dehydration” (Torranin, Smith and Byrd, 1979). Exercise testing within days of one another may invalidate one’s research as is also stated by Greiwe et al. (1998), “It is conceivable that a first exhaustive endurance test may affect the results of subsequent tests.” It is important to take this into consideration when looking at past research as well as research that is being planned for the future. Overall, such factors as recent exhaustive testing without rest may force a participant to perform at a lower ability than he normally would achieve. Because of the present limitations in hydration research, it is important to regulate all the factors that one can and the recovery period is one of them.

Along with the buildup of lactate in the muscle, such factors as blood plasma volume differences and neurological (central nervous system) fatigue may cause premature muscle exhaustion (Marino, 2000). Armstrong, Costill and Fink (1985) found that along with a change in body weight, the slight change in blood plasma
volume is a possible contributing cause of fatigue when studying competitive running performances. The decreased plasma volume resulted in increased cardiovascular endurance performance times when runners were dehydrated.

One final contributing factor to muscle fatigue is heat. The use of muscles requires energy and the byproduct of energy is heat. Excessive muscle temperature causes early exhaustion, “It is likely that the central nervous system is involved in the aetiology of fatigue from hyperthermia” (Coyle, 1999). He also states the combination of dehydration and hyperthermia causes a reduction in cardiac output and blood flow to the exercising musculature, and therefore has the potential to impair endurance performance.

Summary and Conclusions

Research appears to support the theory that dehydration will result in quicker muscle fatigue, than when exercising in a hydrated state. Although there was no mention of hydration in the muscle endurance article (Armstrong, Costill and Fink, 1985), it established the understanding that with less body water to cool down the body systems, and less water for the cells to use, muscles would tend to become fatigued more quickly than if they had more water (Coyle, 1999).

From another perspective however, it seems that there may be no correlation between hydration and muscle endurance or fatigue. Several studies have shown that there is no relationship, but others have shown either a positive or negative relationship between the level of hydration and muscular endurance activities. Future
research controlling confounding factors such as muscle temperature, diet, fluid intake and exhaustive muscle endurance testing is necessary to resolve the issue.
CHAPTER III

METHODOLOGY

Setting

The testing for the muscular strength and endurance portion of the investigation took place in the Student Recreation Center at Eastern Illinois University. The temperature in the Student Recreation Center varied due to usage of the facility. The measurement of urine specific gravity, body composition, height and weight took place in the Human Performance Laboratory in the Lantz Building. Temperature in the laboratory was consistently 23 degrees Celsius. Urine collection took place in the men's lavatory, and the specimen was brought back to the Human Performance Laboratory. Testing took place between May 1 and June 30, 2000.

Subjects

Eight male Eastern Illinois University students volunteered for this study. All subjects participated in regular exercise each week, consisting of both cardiovascular and weight training exercise exceeding 40 minutes per week. The mean weight of subjects was 86.86 kilograms, mean height was 177.15 centimeters, mean age was 23.13 years old, and mean one-repetition maximum was 282.05 pounds. All subjects were recruited from the Student Recreation Center at Eastern Illinois University.
Procedures

Orientation/Preliminaries

Subjects were selected by the tester. They were informed of the study by the tester in the Student Recreation Center weight room, and volunteered for the study. Prior to data collection, there was a meeting to review the methodology and procedures of the investigation. Health history questionnaires and informed consent forms were filled out, and any questions left unanswered, were clarified to the subject's satisfaction. A Health History Questionnaire developed by the tester was issued to each subject (Appendix A). An informed consent was also given to all subjects prior to the start of the study (Appendix B).

Body Weight

When subjects arrived (each testing session this procedure was followed), they were asked to empty their bladders in the men's lavatory down the hall. They were then asked to remove all clothing except for their shorts (they were asked to wear the same shorts for subsequent testing). Weight was recorded using an electronic digital scale with the subjects' hands at their sides, and remaining as still as possible until the scale balanced. Their weight was recorded to the nearest tenth of a pound. An electronic force plate scale (AND Digital Scale, A&D Co, LTD. Model UC-300) was used to measure weight.
Height

Height was measured with subjects standing against the stadiometer attached to the wall with their heels against the wall, hands on their hips, as tall as they possibly could. A 90 degree marker was placed on the top of the head against the stadiometer, parallel to the ground, and the height was recorded to the nearest millimeter. A stadiometer, marked in centimeters, was used to measure height.

Body Composition/Body Water

The Quantum Body Composition Analysis System (RJL Systems) was used to measure whole body resistance and reactance for estimation of total body water, intra and extra cellular fluids. Subjects were asked to lie down on a testing table, with their shoes and socks off, and electrodes were placed on the subjects right wrist, just distal to the styloid process at the radius and ulna, and the hand, between the metacarpal phalangeal joint and the proximal interphalangeal joint of the second phalange, and on their right ankle, centered on a line bisecting the lateral and medial malleoli, and the foot, just below the metatarso-phalangeal joint of the second phalange. Each testing session this procedure was followed.
Muscular Endurance

Subject and tester then moved to the Student Recreation Center, and the subject was allowed to perform light warm-ups and stretches. A weight that the subject was comfortable with was selected and the subject lifted that weight on the free weight bench press, as many times as possible. The bar was lowered to within one inch of their chest and elbows were fully extended. When the subject could no longer complete a lift on his own, or the tester had to help with the last repetition, the trial was over. The weight and number of repetitions completed unassisted was recorded and then entered into the Bryzicki equation (weight lifted lbs./1.0278 - (.0278 x # of repetitions)) and a one repetition maximum was estimated (Brzycki, 1993). The one repetition maximum was then multiplied by .50 to establish 50 percent of the one rep max, and this was the resistance used for all subsequent muscle endurance tests. Maximal strength was estimated using the Bryzicki Equation (weight lifted in lbs./1.0278 - (.0278 x number of repetitions)). Muscular endurance testing was performed using 50 percent of the subject’s one repetition maximum (RM). Subjects lifted this weight (50 percent of the 1RM), as many times as possible with no encouragement, in each of the two states of hydration. Muscular endurance was determined by how many times the subject could lift the 50 percent of the 1RM weight. An Olympic weight bar and York free weights were used to test muscular endurance and strength.
Urine Specific Gravity

A Clinical Refractometer (Atago Co., Ltd., Japan, A300Cl-E01) was used to test urine specific gravity. Distilled water was used first to zero the refractometer, and then the window was wiped clean. Two or three drops of urine were then placed on the refractometer window. Readings were obtained by holding the refractometer up to a light source and reading the numbers from within the window.

Design

States of hydration were randomly assigned to subjects. Subjects were assigned their first (of normal and water restricted) state of hydration, and a date for testing was established allowing three to four days for rest. All subjects were tested in both (water restriction and normal hydration) states of hydration after baseline values were established. Half the subjects first were tested under normal hydration while the other half were first tested under water restriction.

For the next two sessions, testing procedures were identical, other than the two different states of hydration (normal hydration and fluid restriction). When subjects arrived, they were asked to produce a mid-stream urine specimen (beginning a stream and emptying a portion of their bladder before collecting a sample) and empty their bladder completely. Weight and BIA measures were recorded following the same procedures used in the baseline testing described above. Muscular endurance was measured using 50 percent of the subject’s one rep max. The subject was asked to lift the sub-maximal weight as many times as possible. No
encouragement was given to the subject. The tester also served as the spotter. Total repetitions were counted until fatigue was reached and the spotter was required to help the subject lift the last repetition. The subject was then instructed to cool down and stretch to discourage muscle soreness. Subjects were reminded of the next hydration status for the final testing date, and the next testing session was scheduled three to five days after the first. This allowed time for muscle recovery, to ensure fatigue and delayed onset muscle soreness (DOMS) were not factors.

During the final testing session, the subject followed an almost identical procedure as was followed for the second testing date. The only difference was the hydration status. The two states of hydration were randomly selected for each of the subjects according to the following guidelines:

**Normal Hydration Session**

Test subjects were asked to refrain from such things as alcohol, caffeine, smoking, cardiovascular exercise, chocolate, upper body weight lifting, and any other substances that might result in altering the hydration status for 48 hours prior to testing. In this state of hydration, the subjects were asked to consume eight 10oz. glasses of water per 24 hour time period. The subjects were asked to refrain from all other liquid intake during this time.

**Water Restriction Session**

Test subjects were asked to refrain from such things as alcohol, caffeine, smoking, cardiovascular exercise, chocolate, upper body weight lifting, and any other
substances that might result in altering the status of hydration for 48 hours prior to testing. In this phase of the investigation, subjects were asked to go through a 24 hours period of water deprivation. This required that no liquid be consumed for 24 hours prior to the test, other than that occurring naturally in foods. In the case of desperate thirst, the subject was allowed to take small sips of water to wet the mouth, but the subject was asked to keep track of how much water was taken in during this time period. They were also instructed to refrain from medications that might influence hydration such as diuretics and laxatives. During water restriction, subjects were asked also to refrain from eating foods high in water content such as oranges or watermelon. A list of common symptoms was provided to subjects. Subjects were also instructed that if symptoms of severe dehydration should develop, they were to immediately terminate the test protocol for water restriction and resume drinking water. If symptoms persisted, they were to contact their health care provider for further treatment.

Data Analysis

The statistical analysis used for this study included: 1) descriptive statistics (mean and standard deviation at baseline and at each state of hydration) for height, weight, urine specific gravity, body water data, and maximal repetitions at a sub-maximal weight; and 2) repeated measures analysis of variance (ANOVA) using Stat View Software. This was used to determine if there was a statistically significant difference in muscular endurance with each hydration level. A level of $p < .05$ was established to denote statistical significance.
The purpose of this study was to compare muscular endurance performance under two fluid intake conditions (normal fluid intake and fluid restriction) in eight male subjects of college age.

Presentation of Findings

Subjects were eight college age males 19 to 28 years old. Their weights ranged from 62.59 to 139.55 kgs, with heights ranging from 165.0 to 190.4 cms. One repetition maximums for the bench press strength test ranged from 163 to 386 lbs. There were four variables measured at baseline. These were weight, height, age and a one repetition maximum on the bench press. The characteristics of the subjects are shown in Table 1.

Urine Specific Gravity

The mean value for urine specific gravity was slightly lower for the fluid restriction condition. However, a One Factor ANOVA showed no statistical significance for urine specific gravity values between either the water restriction or normal fluid intake conditions (p = .5158) (Table 2).
Table 1: Characteristics of Subjects at Baseline (n=8)

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\bar{x} \pm SD$</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>23.125 ± 3.044</td>
<td>19-28</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>177.15 ± 7.871</td>
<td>165-190.4</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>86.861 ± 23.821</td>
<td>62.59-139.55</td>
</tr>
<tr>
<td>1 RM (lbs)</td>
<td>282.05 ± 70.609</td>
<td>163-386</td>
</tr>
<tr>
<td>50% 1 RM (lbs)</td>
<td>140.625 ± 34.583</td>
<td>80-190</td>
</tr>
</tbody>
</table>
Table 2: Hydration Indices (n=8)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline ((\bar{x} \pm SD))</th>
<th>Normal Fluid Intake ((\bar{x} \pm SD))</th>
<th>Water Restriction ((\bar{x} \pm SD))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urine Specific Gravity</td>
<td>-</td>
<td>1.04 ± 3.01E-3</td>
<td>1.02 ± .07</td>
</tr>
<tr>
<td>Intracellular Water</td>
<td>33.87</td>
<td>32.51</td>
<td>32.09</td>
</tr>
<tr>
<td>Extra-cellular Water</td>
<td>19.55</td>
<td>18.2</td>
<td>18.04</td>
</tr>
<tr>
<td>Total Body Water</td>
<td>53.42</td>
<td>50.74</td>
<td>50.15</td>
</tr>
</tbody>
</table>
Total Body Water/Water Compartments

The mean values for these variables was slightly lower during the fluid restriction condition with an average of 1.78, 1.51, and 3.27 liters less water for intracellular, extracellular and total body water respectively, compared to the normal hydration status and 0.42, 0.16, and 0.4 liters respectively at the normal intake condition (both compared to baseline). A decrease in intracellular, extra-cellular and total body water was also seen when comparing water restriction to normal hydration (0.13, 0.16, 0.4 respectively). A Two-factor Repeated Measures ANOVA showed no statistical significance between the fluid intake condition and intracellular and extra-cellular water volume or total body water (p = .8428).

Body Weight and Body Composition

Body weight decreased an average of 1.37 kgs during the water restriction condition as compared to baseline weight and 0.87 kgs as compared to normal fluid intake. The weight loss observed between the normal fluid intake and water restriction conditions represented approximately one percent of the total body weight. Mean changes in fat-free mass were 0.85 kgs between baseline and water restriction condition, 0.67 kgs between normal fluid intake and water restriction, and .18 kgs between baseline and normal fluid intake. Loss of fat-free mass was approximately one percent of total body mass. A Two-factor Repeated Measures ANOVA showed no statistical significance between state of hydration and body weight or fat-free mass (p = .9874) (Table 2).
Muscle Endurance

Subjects were able to complete a mean of 27.25 reps (SD ± 3.69) for the normal fluid intake condition, and the mean of 27 reps (SD ± 4.31) during the water restriction condition. A One Factor ANOVA showed no statistically significant difference between water restriction and normal fluid intake conditions and the maximal number of bench press repetitions performed at 50 percent of 1RM (p = .9026).

Summary

Muscular endurance performance was not statistically different between the normal fluid intake and water restriction conditions. Mean values for fat-free mass were lower for intra- and extra-cellular water, total body water, and urine specific gravity. Mean values for maximum repetitions were not statistically different in the water restriction condition as compared to the normal water intake condition. Hydration levels remained the same as did muscular endurance.
CHAPTER V

DISCUSSION

This study was conducted to explore the relationship between normal fluid intake and fluid restriction and the effects on muscular endurance. Eight male Eastern Illinois University students served as subjects for this study.

A free weight bench press test was used to evaluate muscular endurance, and a Urine Specific Gravity Test as well as a Bioelectrical Impedance Analysis for total body water were used to determine the level of hydration for each condition. The raw scores for the maximum number of repetitions performed and for the hydration status were analyzed using ANOVA. The .05 level of confidence was selected to determine if differences were statistically significant.

One explanation for the lack of significant findings was likely due to the small sample size of the subjects. Mean values may have reached significance with a greater number of subjects.

Another reason that results did not support the hypothesis may be due to the low level of induced dehydration. It is questionable that the subjects were dehydrated enough in the water restriction condition to have shown an effect on performance. While the subjects completed a 24-hour period of water deprivation, on average each subject lost only one percent of their baseline body weight. At such a level of hydration, the results appear to be consistent with the finding of studies such as Bijlani and Sharma (1980). Subjects in their study did not show impaired mechanical
function even with dehydration reaching a decrease of two percent of their body weight, but when they reached dehydration at three percent of their body weight, reduced endurance times for isometric contraction of the forearm extensors were recorded. This is also consistent with another study performed by Casterino, et al. (1988), which showed that the maximum number of leg extensions (on the Cybex II dynamometer) decreased significantly at a water loss of three percent body weight in sedentary and anaerobically trained subjects.

Randomization of trial conditions may also have had an effect on the results of this study. Four of the eight subjects were randomly assigned to be in the water restriction group and the others were in the normal hydration group. It is possible that those in the water restriction group did not fully rehydrate from their test prior to participating in their normal hydration condition, even though there were several days in between trials. The ambient outdoor temperature, activities and jobs of the subjects in the days between trials might account for this lack of complete rehydration.

Uncontrolled factors such as diet and exercise of the subjects may also be another reason that this study found no statistical significance between maximal repetitions at a normal fluid intake condition and a fluid restricted condition. Subjects were not placed on a regulated diet that required each to eat the same meals. This may account for differences in urine specific gravity, total body water and weight. While it was assumed that all subjects adhered to the test protocol and exercise restrictions, some subjects may have ingested foods higher in water content during the water restriction condition. It is possible that some subjects between trials, when they were not exercise restricted, may have been involved in higher level aerobic activity or
been involved in outdoor activities in the heat, which may have caused their baseline hydration to be low before they began their condition, thereby affecting subsequent results.

The fluid restriction trial did not produce a statistically significant decrease in body water. This may simply be due to the fact that subjects were only water restricted for 24 hours because of health concerns. Subjects could have been exercised to induce dehydration by sweating, but with this experiment an attempt was made to control the increase in muscle temperature that other studies experienced, and the increase in muscle fatigue that exercise induced dehydration might have caused, and may have resulted in sub-optimal performances. However, 24 hours of water deprivation only produced a one percent loss of body weight, and a one percent loss of fat-free mass, which was not enough to show a significant difference in muscle endurance.

The results are consistent with the findings of the study by Bijlani and Sharma (1980), which showed no decrease in muscular endurance until subjects reached a loss of three percent of their body weight. This is also consistent with the experiment by Greiwe et al. (1998), which found a decrease of four percent body weight was necessary to induce a decline in muscle endurance performance.

The research presented in this study has important implications for the world of sport. In athletics, sports such as wrestling and body building still use dehydration as a common practice to make weight class. While this is not a healthy practice, the connection between fluid restriction and muscular endurance performance may certainly have an impact. Fluid restriction alone for 24 hours may not decrease
muscular endurance performance, and the loss of only one percent body weight may
not be as detrimental to performance as it once was thought. However, health
concerns may arise when an athlete compounds their 24 hour fluid restriction with
excessive environmental heat, supplements, exercise, and sweating. Along with these,
if the athlete restricts his fluids for more than 24 hours and begins to lose a larger
percentage of his body weight, not only does his performance decline but dangerous
side effects and possibly death may result, as was the case with the three college
wrestlers that died due to excessive dehydration and creatine supplementation
of water restriction may not affect overall muscular endurance, as long as it is not
combined with other modes for loss of body water.

It was hypothesized that muscular endurance performance would decline as a
result of water restriction. The results of the experiment were as follows:

1. There was no significant difference in muscle endurance performance between the
   water restriction condition and the normal hydration condition.
2. There was no difference in measures of hydration including urine specific gravity,
   intra- and extra-cellular water, and total body water after 24 hours of fluid
   restriction.
3. A 24 hour period of water deprivation produced an approximate one percent
decrease in body weight.
Directions for Future Research

The first step in future studies should be similar methodology with a more controlled surrounding such as control of diet, environment, exercise programs and fluid consumption. Because the subjects in this study were not clinically dehydrated (they were only fluid restricted), a future study using similar methodology could be used with a longer period of fluid restriction or chemical dehydration (radionuclide solution) as was used in a study by Maw et al. (1996). It is possible to use heat to dehydrate subjects by sweating if means allow, however it has been debated whether or not heat decreases performance. I would not recommend exercise induced sweating for subjects, as it may exhaust muscle groups and cause early fatigue. Other forms of evaluating hydration could be used as well.

The studies that have been examined in this project do not conclusively or convincingly suggest an answer to the question. More so, it leaves researchers even more perplexed. It would be of interest to perform a study such as this with female subjects. Although this may make matters more complicated due to water retention and the menstrual cycle. The study would have to be performed over several months on the same day of the cycle to get accurate results. Studies with trained versus and sedentary subjects as well as endurance vs. anaerobically trained athletes are also possible future studies. Dehydration, muscle endurance and different supplementation mixtures may also be considered for further studies.
REFERENCES


APPENDIX A
Health History Questionnaire
Health History Questionnaire

General

Name: ___________________________ Date: ___________________________
Address: ___________________________
Birth Date: ___________ Age: ___________ Phone: ___________________________
E-mail: ___________________________ Gender: ___________________________

Medical History

Check ALL that apply to you, either recently or in the past, to the best of your ability and knowledge:

_ heart disease
_ peripheral vascular disease
_ irregular heart beats
_ hypertension
_ defective heart valves
_ cancer
_ heart murmurs
_ joint pain (shoulder/knee, etc.)
_ pulmonary disease (bronchitis, emphysema, etc.)
_ diabetes
_ asthma (exercise induced? Y N)
_ epilepsy
_ allergies
_ high cholesterol
_ renal problems (kidney)
_ light headedness/fainting
_ liver problems
_ fatigue

List all surgeries that you have had, and their dates to the best of your ability:
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

List all medications that you are currently taking:
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

List all supplements you are currently taking:
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

Physician’s name: ___________________________ Phone: ___________________________
Emergency contact: ___________________________ Relationship: ___________________________
Home phone: ___________________________ Work Phone: ___________________________
Family History

Has anyone in your family ever had heart disease or a heart attack prior to the age 50?
Yes___ No___

If yes, please specify: ___________________________________________________________

Any family history of the following:

__ diabetes
__ high cholesterol
__ hypertension
__ stroke
__ renal problems
__ liver problems

Exercise History

Do you currently exercise on a regular basis? Yes___ No___
If yes, please specify what you do on a regular weekly basis:

__________________________________________________________

How many total minutes of exercise do you get per week?
__ <40 minutes
__ 41-60 minutes
__ 61-80 minutes
__ 81-100 minutes
__ >100 minutes

I have read, understood, and accurately completed this questionnaire to the best of my knowledge. Any questions I had were answered to my full satisfaction.

Name: ____________________________ Date: ____________________________
Signature: ____________________________ Witness: ____________________________
Date: ____________________________
Eastern Illinois University

The Effects of Two States of Hydration of Muscular Endurance in Men

I, ____________________________, understand the terms of this study, and the expectations of me while participating in this experiment. Any questions that I had have been fully answered to my satisfaction. I understand that I may discontinue participation in this study at any time, with no questions asked, and no repercussions, if I experience discomfort, and do not think I can continue with the conditions of this study. I understand as well, that I will be asked to discontinue participation in this study if I do not comply with the procedures of each hydration condition.

Signature: ___________________________ Date: ________________
Witness: ___________________________ Date: ________________

The risks of participating in this study are minimal, although participants may expect some mild physical and/or psychological discomfort, for example:

**Risks of Participation:**
- **Muscular Endurance:** There is a small but possible risk of muscular injury while lifting weights. If injury occurs while testing, stop immediately and inform the tester of the injury. There is also the possibility of light to moderate muscle soreness and fatigue following the testing, as a result of lifting weights. This may persist for several days (usually 2-4) and may cause slight discomfort in the subject.
- **Hydration:** While in the water restriction segment of testing, participants may experience one or more of the following (at dehydration of 1-5% of body weight):
  * Thirst
  * Vague discomfort
  * Economy of movement
  * Anorexia
  * Flushed skin
  * Impatience
  * Sleepiness
  * Increased pulse rate
  * Increased rectal temperature
  * Nausea

***If symptoms are severe or make you uncomfortable to the point of desiring to terminate participation, begin re-hydration immediately and consult your health care provider if symptoms do not subside.

Thank you for your cooperation and participation in this experiment!

Investigator:
Melissa L. Petrucci Graduate Student, Physical Education
APPENDIX C
Subject Information
Hydration Status

Water Restriction:

Test subjects are asked to refrain from such things as alcohol, caffeine, smoking, cardiovascular exercise, chocolate, upper body weight lifting, and any other substances that might result in altering the status of the subject for 48 hours prior to testing. In the water restriction phase of testing, subjects are asked to go through a 24 hour period of water deprivation. This means, specifically, that there should be NO water intake for all 24 hours prior to the test, other than that occurring naturally in foods. In the case of desperate thirst, the subject may take small sips of water to wet the mouth, but the subject is asked to keep track of how much water is taken in during this time period. Please also refrain from drugs that may influence hydration such as diuretic and laxatives. During dehydration, please also refrain from eating foods with a high water content such as oranges and watermelon.

***Water restriction may result in some discomfort. If you experience severe side effects, please begin re-hydration immediately, and if symptoms continue, consult your health care provider immediately.

Normal Hydration:

Test subjects are asked to refrain from such things as alcohol, caffeine, smoking, cardiovascular exercise, chocolate, upper body weight lifting, and any other substances that might result in altering the status of the subject for 48 hours prior to testing. In the normal hydration phase of the test, subjects are asked to consume 8 10oz glasses of water in a 24 hour time period. The subjects are asked to refrain from all other liquid intake during this time, as to eliminate the influence of other liquids on the level of hydration.

***Please arrive for testing for both status one and two in the same gym shorts, to assure an accurate weight on each subject.
Methodology and Conditions

1. Meeting prior to beginning of experiment
   - Health History Questionnaire and Informed Consent Forms explained and signed
     * Height
     * Age
     * Exercise history
     * Sign up for initial estimated one-rep max test

2. Estimated one-rep max bench press testing (from sub-maximal trial)
   - Lift one weight as many times as possible and plug number into Bryzicki equation, then calculate 50% of one-rep max to be used in subsequent testing

3. 2 Testing Conditions (randomly selected) (same procedures for both conditions)
   - Procedures
     * Collect urine sample (to be measured for urine specific gravity)
     * Take weight (in gym shorts only)
     * Estimate total body water with Bioelectrical Impedance Analysis
     * Perform maximum reps of bench press at sub max weight, determined prior to first condition, in varsity weight room
     * Receive instructions for the next test condition

***There will be no encouragement from either your tester or peers during testing. You are expected, as subjects, to give a maximal effort to failure or muscle fatigue during tests one and two. Testing may result in muscle soreness. There will be a rest period between testing dates to allow for recovery of your muscles.
APPENDIX D
Raw Data
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<tr>
<th>Name</th>
<th>Rob</th>
<th>Brandon</th>
<th>Jeremy</th>
<th>Jason</th>
<th>Heath</th>
<th>Dylan</th>
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<tr>
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<td>Height/cm</td>
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<td>165cm</td>
<td>183.6cm</td>
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<td>65&quot;</td>
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<td>222 lbs.</td>
<td>243 lbs.</td>
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<td>115 lbs.</td>
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