THE EFFECT OF PRE-EXERCISE INGESTION OF PICKLE JUICE, HYPERTONIC SALINE, AND WATER ON AEROBIC PERFORMANCE IN COLLEGE-AGED MALES

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The effect of pre-exercise ingestion of pickle juice, hypertonic saline,

and water on aerobic performance in college-aged males

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MASTER OF SCIENCE

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ABSTRACT

Pickle juice (PJ) is commonly ingested by athletes pre-exercise to prevent muscle cramps. Some scientists fear PJ may negatively impact performance due to its high sodium concentration. The purpose of this study was to determine if ingesting 2 $mL*kg^{-1}$ body weight of PJ, hypertonic saline or deionized water (DIW) and 5 $mL*kg^{-1}$ of DIW affected aerobic performance, core temperature, plasma volume changes or sweat volume. On three separate days, subjects rested for 65 minutes. During this period, two blood samples were taken and they ingested PJ, hypertonic saline, or DIW followed by 5 $mL*kg^{-1}$ body mass of DIW. Subjects exercised at progressing intensities until complete exhaustion. No differences were observed between drinks for time to exhaustion, core temperature, plasma volume or sweat volume ($P>0.05$). Ingesting PJ or hypertonic saline diluted by a moderate amount of DIW does not impact aerobic performance, core temperature, plasma volume changes or sweat volume.

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DEDICATION

I dedicate this Thesis to my loving and supportive fiancé, family and friends for encouraging me to battle through the hard times and do what it takes to reach my goals. Without your faith and encouragement none of this would have been possible.

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INTRODUCTION

Sweat output commonly exceeds fluid intake during exercise;[1] athletes can incur significant fluid losses during exercise with some athletes losing 1-2.5 L of sweat per hour of exercise.[2] If fluid is not replaced, plasma volume may be reduced and performance deficits can occur.[3] In fact, athletes may experience performance deficits[4] and impaired mental acuity at hypohydration levels as low as 2%.[5]

Adding sodium (Na^+) to rehydration beverages has many positive physiological effects for an exercising individual. Adding Na^+ can help maintain plasma Na^+ concentration ($[Na^+]_p$),[6] increase the osmotic drive to drink[7] and *ad libitum* water consumption, and decrease urine output.[8] All of these effects would help maintain or expand plasma volume. Some researchers[9] have observed plasma volume expansions up to 5% before exercise when subjects ingest a large volume (10 $mL*kg^{-1}$ body weight) of a Na^+ drink (164 $mmol*L^{-1}$). Plasma volume expansion may allow athletes to sweat at higher rates and increase blood flow, thereby improving thermoregulation.[1] This may explain why some subjects are able to exercise longer when they ingest beverages containing Na^+.[9-11]

Many athletes use strategies with little or no scientific support to improve performance. Common performance aids used include hyperhydration,[12] carbohydrate loading,[13] taking drugs (e.g. anabolic steroids and amphetamines),[14] nutritional supplements (e.g. caffeine, creatine, and whey protein),[15-16] and drinking sport drinks.[17-18] Another common anecdotal strategy is ingesting PJ, a salty brine, prior to competition.[19]

Nineteen percent (63 of 337) of athletic trainers polled have given athletes pickle juice (PJ) to prevent exercise-associated muscle cramps.[19] The majority of these clinicians have athletes ingest between 70 and 200 mL and provide it 30 minutes prior to exercise.[19] Ingesting small volumes (1 mL*kg^{-1} body mass) of PJ reduces electrically induced muscle cramp duration;[20] preventing muscle cramps may allow athletes to perform better. Some scientists[2, 21-22] urge against drinking PJ because they are concerned the high Na^+ may negatively impact performance by accelerating dehydration, prolonging rehydration, or causing stomach upset and nausea. No experimental studies have investigated the effects of consuming PJ on aerobic performance or thermoregulation.

Therefore, the purpose of this study was to determine if ingesting 2 mL*kg^{-1} of PJ, hypertonic saline or deionized (DIW) with moderate volumes of water (5 mL*kg^{-1} body mass) prior to exercise delays time to exhaustion or affects rectal temperature, changes in plasma volume, or sweat volume. We hypothesized that PJ and hypertonic saline would delay time to exhaustion, increase plasma volume and sweat rate, and reduce final rectal temperature during exercise when compared to DIW.

METHODS

Experimental Design

A crossover, factorial, repeated measures design guided data collection. The independent variables were time (pre and 30 minutes post-ingestion) and drink (PJ [strained from whole dill pickles, Pinnacle Foods Group LLC, Cherry Hill, NJ], a hypertonic saline drink with a similar $[Na^+]$ as PJ, and DIW). The dependent variables were time to exhaustion (minutes), sweat volume (L), change in plasma volume (percent change compared to pre-ingestion), and rectal temperature (°C). Urine specific gravity was measured to ensure subjects began testing euhydrated. Plasma potassium concentration ($[K^+]_p$), $[Na^+]_p$, plasma osmolality (OSM_p), and plasma glucose concentration were measured and are reported descriptively to characterize the extracellular fluid space before and after drink ingestion.

Subjects

Twelve healthy men volunteered for this study. Nine males (age= 21.9 ± 2.6 y, ht= 72.4 ± 3.2 cm, mass= 82.6 ± 16.0 kg) completed testing. Three subjects discontinued participation due to time conflicts (n = 2) or inability to perform the exercise testing protocol (n = 1). Volunteers were excluded if they self-reported: (1) any injury that limited their ability to exercise in the 3 months prior to data collection, (2) any surgery within the 6 months prior to data collection, (3) any neurologic, cardiovascular, or blood borne diseases, (4) living a sedentary lifestyle (exercising less than 30 minutes, 3 times per week)[23], (5) a food allergy to pickles or (6) a history of heat related illness (e.g., heat stroke, heat exhaustion, heat syncope). All subjects provided written informed consent prior to participation and the study was approved by North Dakota State University's institutional review board.

Testing Procedures

Subjects completed three days of testing at least 48 hours apart. Twenty-four hours prior to testing, subjects were instructed to drink water consistently and avoid exercise, high Na^+ foods, alcohol and caffeine. Subjects were asked to keep their diets consistent until they completed the experiment and consume a similar meal the night before testing. Subjects also fasted 12 hours and self-reported compliance prior to testing. During the 12 hour fast subjects were encouraged to drink water.

Subjects reported to a human performance lab, provided written consent, voided their bladders, and were weighed in shorts and socks to the nearest hundredth of a kilogram (body weight 1 [BW1]; DA150, Denver Instruments, Bohemia, NY). Urine specific gravity was assessed with a refractometer (SUR-NE, Atago USA Inc., Bellouce, WA) to determine if subjects were euhydrated (urine specific gravity $\leq$ 1.02).[24] If hypohydrated, subjects were excused and asked to return at least 24 hours later. If euhydrated, subjects donned a heart rate monitor (Polar Electric Inc., Lake Success, NY) and inserted a rectal thermistor (Yellow Spring Instruments 4600, Advanced Industrial Systems Inc., Prospect, KY) at least 10 cm past the anal sphincter. Subjects were seated with their arm resting on a padded treatment table. The cubital fossa was cleaned with isopropyl alcohol and a sterile catheter was inserted into a superficial forearm vein. Subjects remained seated for 30 minutes. Following the 30 minute rest period, a 5-mL baseline blood sample was collected. Subjects then had 1 minute to ingest 2 $mL*kg^{-1}$ body weight of PJ, hypertonic saline solution, or DIW and 4 minutes to ingest 5 $mL*kg^{-1}$ body weight of DIW. They sat for 30 minutes and a second 5-mL blood sample was collected.

Subjects were weighed (BW2) and entered an environmental chamber (38.3 ± 1^{o}C, 21.1 ± 4.7% relative humidity) and began performance testing by exercising for 30 minutes on a treadmill (TrackMaster, TMX425C, Newton, KS) at 50% of their age-predicted heart rate maximum (HR_{max}). Following this 30 minutes, the treadmill's speed increased so subjects exercised at 10% more of their HR_{max}. Thus, after the first 30 minutes, subjects exercised at 60% of their HR_{max}. Exercise intensity increased every 10 minutes thereafter by 10% increments up to 90% of subjects HR_{max}. Treadmill speed was then increased so the subjects ran at 95% of their HR_{max} and no further adjustments were made. The exercise protocol was terminated if subjects were too fatigued to continue or their core temperature exceeded 39.5°C. Rectal temperature was recorded every 10 minutes during exercise; only the subject's final rectal temperature was used for analysis. To ensure maximal effort, the primary investigator provided verbal encouragement during testing.

Following performance testing, subjects exited the environmental chamber, towel dried, and were weighed (BW3). Body weight 3 was subtracted from BW2 to calculate sweat volume lost assuming 1 kg of mass lost was equivalent to 1 L of fluid lost. Subjects then removed the rectal thermistor and were excused. Subjects were asked to report for subsequent testing sessions at least 48 hours later. Testing occurred at the same time of day and only varied in the treatment fluid ingested. Treatment fluid order was counter balanced using half of the total possible combinations of fluid orders and randomly assigned.

To minimize bias, several precautions were taken. First, subjects were not told what they would be drinking or any potential effects the drinks may have on performance. Second, subjects were not told that the primary purpose of the study was to determine the effects of the fluids on performance. Third, the investigator was blinded to the drink ingested each day. Fourth, to prevent olfactory detection of the drinks, subjects and the investigator wore nose plugs prior to ingestion. Subjects removed the nose plugs after ingesting the fluid. Fifth, visual detection of the drinks was prevented by using opaque bottles and having a research assistant prepare the drinks. Sixth, the researchers attempted to blind subjects to the exact time they spent running on the treadmill. Finally, subjects were instructed not to make any faces, gestures, or remarks regarding the contents of the water bottles.

Blood Analysis Procedures

One mL of whole blood was analyzed for hematocrit and hemoglobin concentration ([Hb]). Blood for hematocrit analysis was drawn into heparinized micro-capillary tubes and centrifuged at 3000 rpm (IEC Micro-MB, International Equipment Co., Needham Heights, MA) for 5 minutes and read using a micro-capillary reader (Model IEC 2201, Damon/IEC, Needham heights, MA). Hemoglobin concentration was measured by mixing 20 μL of whole blood with 5 mL of cyanomethemoglobin reagent and the absorbance read at 540 nm on a standard spectrophotometer (iMark Spectrophotometer, Biorad, Hercules, CA). Hematocrit and [Hb] were measured in triplicate immediately following sampling and averaged for each blood sample for statistical analysis and calculations. Changes in plasma volume were calculated by inserting hematocrit and [Hb] into the Dill and Costill equation.[25]

The remaining blood was centrifuged at 3000 rpm for 15 minutes at 3°C. Plasma was removed, analyzed for OSM_p using freezing point depression osmometry (model 3D3, Advanced Instruments Inc, Norwood, MA), and then frozen (-80°C). Samples were later thawed and analyzed in duplicate for $[Na^+]_p$, $[K^+]_p$, and plasma glucose concentration with an ion-selective electrode analyzer (NOVA 16, Nova Biomedical, Waltham, MA).

Statistical Analysis

Differences in time to exhaustion, percent change in plasma volume, rectal temperature, and sweat volume were analyzed between drinks over time using separate repeated measures analysis of variances (NCSS 2007, Kaysville, UT). Tukey-Kramer multiple comparison tests were used when significant F-values were observed for interactions or main level effects. Greenhouse Geisser corrections were used to correct P-values when sphericity was violated. Significance was accepted when $P < 0.05$.

RESULTS

Data are reported as means ± SD. Subjects self-reported compliance with all pre-testing instructions and were similarly euhydrated prior to testing (urine specific gravities; PJ = 1.006 ± 0.003, hypertonic saline = 1.007 ± 0.005, DIW = 1.006 ± 0.003; $F_{2,16} = 0.1$, $P = 0.83$).

The composition of each treatment drink can be found in Table 1. Subjects ingested 166 ± 33.7 mL of PJ, 164.9 ± 33.4 mL of hypertonic saline, and 165.6 ± 33 mL of DIW. As a result, they ingested 1.5 ± 0.3 g, 1.5 ± 0.3 g, and 0 ± 0 g of Na^+, respectively. Subjects also ingested 415 ± 84.3 mL, 412.2 ± 83.4 mL, and 413.9 ± 82.6 mL of DIW after ingesting PJ, hypertonic saline, and DIW treatments, respectively, before exercise. Based on the Na^+ content ingested and the volume of DIW consumed after each treatment drink, the stomach contents had a $[Na^+]$ of 157.7 ± 1.6 $mmol*L^{-1}$ (3.6 ± 0.04 $g*L^{-1}$) for PJ, 159.1 ± 1.4 $mmol*L^{-1}$ (3.7 ± 0.03 $g*L^{-1}$) for hypertonic saline, and 0 ± 0 $mmol*L^{-1}$ (0 ± 0 $g*L^{-1}$) for DIW.

Subjects lost similar volumes of sweat ($F_{2,16} = 0.6$, $P = 0.59$) during exercise on each testing day (PJ = 1.1 ± 0.3 L, hypertonic saline = 1.1 ± 0.4 L, and DIW = 1.2 ± 0.3 L).

Plasma variables pre and post-treatment drink ingestion can be found in Table 2 with $[Na^+]_p$, $[K^+]_p$, and plasma glucose concentration being reported descriptively. For percent change in plasma volume, no significant interaction ($F_{2,16} = 1.3$, $P = 0.31$), main effect for treatment drink ($F_{2,16} = 1.3$, $P = 0.31$), or time effect was observed ($F_{1,8} = 1.5$, $P = 0.27$).

Time to exhaustion did not differ between treatment drinks (PJ = 77.4 ± 5.9 min, hypertonic saline = 77.4 ± 4.0 min, DIW = 75.7 ± 3.2 min; $F_{2,16} = 1.1$, $P = 0.4$).

For final rectal temperature during exercise, no interaction ($F_{2,16} = 0.7$, $P = 0.51$) or treatment drink effect was observed (PJ = 38.69 ± 0.3°C, hypertonic saline = 38.66 ± 0.4°C, DIW = 38.78 ± 0.4°C; $F_{2,16} = 0.3$, $P = 0.74$). However, a time effect was observed ($F_{1,8} = 250.2$,

$P < 0.001$). Rectal temperature was higher post-exercise than pre-exercise (pre-exercise = 36.67 ± 0.23°C, post-exercise = 38.71 ± 0.35°C, $P < 0.05$).

DISCUSSION

Three main points are noted from this investigation. First, ingesting 2 $mL*kg^{-1}$ body mass of PJ or hypertonic saline with water prior to exercise did not affect aerobic performance. Second, PJ and hypertonic saline ingestion did not alter final core temperature or sweat volume. Finally, ingesting PJ or hypertonic saline with moderate volumes of water did not cause plasma volume expansion in the timeframes studied in the current study. The clinical implications of these points are ingesting small volumes of PJ with water before exercise is unlikely to impact athletic performance or select thermoregulatory variables like rectal temperature or sweat loss.

Plasma Volume and Time to Exhaustion

Previous studies[9, 11, 26] examining performance following salt ingestion have attributed athletes' ability to exercise longer to plasma volume expansion prior to exercise. Scientists[26-27] have observed rapid plasma volume expansions when euhydrated subjects ingested large volumes of hypertonic Na^+ solutions before exercise. Greanleaf et al[26] and Sims et al[9] noted similar plasma volume expansions (~5%) when subjects ingested 10 $mL*kg^{-1}$ body weight (~757 mL) of a Na^+ (164 $mmol*L^{-1}$) drink 105 minutes before exercise. Following the high sodium ingestion, Greenleaf et al[26] noted subjects were able to exercise 6 minutes longer at 87–91% of peak VO_2. Sims et al's[9] subjects were able to exercise 11.5 minutes longer before core temperature reached 39.5ºC and 20.8 minutes longer to complete exhaustion when exercise intensity was 70% VO_{2max}. We did not observe a significant plasma volume expansion before exercise or delayed time to exhaustion. These results cannot be attributed to a lack of Na^+ ingested in the PJ and hypertonic saline trials. Our subjects ingested ~1.5 g of Na^+ in the PJ and hypertonic saline trials. This amount is more than double the amount recommended by the NATA that athletes ingest to offset Na^+ losses during exercise.[28] Rather, the lack of changes in plasma volume are likely due to the amount of time between ingestion of fluid and exercise onset and total volume of drink ingested (~750 mL). The other studies[9, 26] showing plasma volume expansion provided the hypertonic solutions 105 min prior to exercise whereas we only provided a 30 min period between ingestion and exercise to simulate the PJ ingestion strategy implemented by many athletic trainers before exercise or competition.[19] The longer duration between ingestion and exercise likely would have allowed more fluid to empty from the stomach and be absorbed into the extracellular space. Miller et al[29] observed gastric emptying rates of PJ were slower than DIW over the course of 30 minutes. While these authors[19] gave only PJ rather than a mixture of PJ and DIW as was done in the current study, the added Na^+ and acid may have delayed gastric emptying and thus absorption of fluid into the intravascular space. High Na^+ and acid concentrations have been shown to delay gastric emptying of fluids.[30]

Some authors[31] speculate ingesting PJ would cause dehydration, nausea, and abdominal cramps. As such, performance may be affected if athletes do not feel well at the onset of exercise. To date, no study has observed nausea or abdominal cramps following the ingestion of small amounts of pickle juice.[29, 32] These symptoms have been observed following ingestion of salt tablets and large volumes of water,[33-34] large volumes of isotonic and hypertonic Na^+ drinks,[35] or large volumes of PJ (i.e., 7 $ml*kg^{-1}$ body mass).[29] None of our subjects experienced upset stomach or abdominal cramping following PJ ingestion and finishing times were similar between trials.

Plasma Volume and Core Temperature

Hypohydration reduces the body's ability to dissipate heat storage by decreasing sweat rate and skin blood flow response.[1] Some authors have theorized that ingesting hypertonic solutions such as PJ may accelerate dehydration[21] or may cause overheating due to the lack hypotonic fluid needed to restore plasma volume.[2] We observed no differences in plasma volume changes when PJ, hypertonic saline or DIW were given as treatments prior to ingesting 5 ml*kg^{-1} body weight DIW.

Plasma volume expansion may delay the rise in temperature that occurs during exercise. Subjects were able to exercise longer and at a core temperatures 0.4°C lower when they ingested a high (164 mmol*L^{-1}) Na^+ drink than a low Na^+ drink (10 mmol*L^{-1}).[9] Since sweat rates and volumes were similar between Na^+ trials, subjects' core temperatures may have been lower because of the 4.5% increase in plasma volume prior to exercise.[9] The authors speculated that an expansion of the extracellular space may have reduced cardiac stress and total work during exercise thereby decreasing the amount of heat produced.[9] Since plasma volume changes and sweat volumes were similar between treatment drinks in the current study, it is not surprising that rectal temperatures remained consistent between trials.

Three limitations must be addressed. First, our subjects were instructed to come to each session well-hydrated. It is possible subjects over hydrated before reporting to the laboratory and the effects of our treatment drinks were masked by the hyperhydration prior to testing. It is noteworthy that the NATA recommends athletes consume moderate to large volumes (500 to 600 mL) of fluids 2-3 hours before exercise and an additional 200 to 300 mL 10 to 20 minutes before exercise.[28] Second, our method of aerobic testing may have incorporated more anaerobic fatigue than other protocols.[9, 11, 26] With our protocol slowly accelerating to 95% of subject's maximum heart rate, anaerobic failure may have caused subjects to terminate exercise earlier. This protocol was chosen to replicate a moderate distance race; incorporating a warm up, maintenance or pacing period, and sprinting to finish period. Finally, due to our blinding and termination protocol, we were unable to measure distance run for this study.

SUMMARY

The data from this study indicate that drinking small volumes of PJ and hypertonic saline diluted with large amounts of DIW have no effect on aerobic performance, rectal temperature, sweat volume or plasma volume when ingested 30 minutes prior to exercise compared to DIW alone. Failure of PJ and hypertonic saline to expand plasma volume is most likely due to the amount of time allowed for absorption. Allowing a longer period of time between ingestion and exercise (e.g., 1-2.5 hours), may allow for better absorption and may be effective to increase plasma volume and enhance performance and core temperature maintenance. Future research may wish to evaluate this possibility.

REFERENCES

1. Sawka M, Montain S, Latzka W. Hydration effects on thermoregulation and performance in the heat. *Comp Biochem Physiol A Mol Integr Physiol.* 2001;128:679-690.
2. Bergeron M. Sodium: the forgotten nutrient. *Sports Med.* 2000;13:2-8.
3. Sawka M, Latzka W, Matott R, Montain S. Hydration effects on temperature regulation. *Int J Sports Med.* 1998;19:S108-S110.
4. Knicker A, Renshaw I, Oldham A, Cairns S. Interactive Processes Link the Multiple Symptoms of Fatigue in Sports Competition. *Sports Med.* 2011;41:307-328.
5. McGregor S, Nicholas C, Lakomy H. The influence of intermittent high-intensity shuttle running and fluid ingestion on the performance of a soccer skill. *J Sports Sci.* 1999;17:895-903.
6. Passe D. Physiological and psychological determinants of fluid intake. In: Maughan R, Murray R, eds. *Sports drinks: basic science and practical aspects*. Boca Raton (FL): CRC Press; 2001:45-88.
7. Nose H, Mack G, Shi X, Nadel E. Role of osmolality and plasma volume during rehydration in humans. *J Appl Physiol.* 1988;65:325-331.
8. Vrijens D, Rehrer N. Sodium-free fluid ingestion decreases plasma sodium druing exercise in the heat. *J Appl Physiol.* 1999;86:1847-1851.
9. Sims S, Vliet L, Cotter J, Rehrer N. Sodium Loading Aids Fluid Balance and Reduces Physiological Strain of Trained Men Exercising in the Heat. *Med Sci Sports Exerc.* 2007;39:123-130.

10. Oopik V, Saaremets I, Medijainen L, Karelson K, Janson T, Timpmann S. Effects of sodium citrate ingestion before exercise on endurance performance in well trained college runners. *J Sports Med.* 2003;37:485-489.

11. Sims S, Rehrer N, Bell M, Cotter J. Preexercise sodium loading aids fluid balance and endurance for women exercising in the heat. *J Appl Physiol.* 2007;103:534-541.

12. Latzka W, Sawka M, Montain S, et al. Hyperhydration: tolerance and cardiovascular effects during uncompensable exercise-heat stress. *J Appl Physiol.* 1998;84:1858-1864.

13. Sullo A, Monda M, Brizzi G, et al. The effect of a carbohydrate loading on running performance during a 25-km treadmill time trial by level of aerobic capacity in athletes. *Eur Rev Med Pharmacol Sci* 1998;2:195-202.

14. Tokish J, Kocher M, Hawkins R. Ergogenic aids: a review of basic science, performance, side effects, and status in sports. *Am J Sports Med.* 2004;32:1543-1553.

15. Froiland K, Koszewski W. Nutritional supplement use among college athletes and their sources of information. *Int J Sport Nutr Exerc Metab.* 2004;14:104-120.

16. Bishop P. Dietary Supplements and Team-Sport performance. *Sports Med.* 2010;40:995-1017.

17. Bachle L, Eckerson J, Albertson L, Ebersole K, Goodwin J, Petzel D. The effect of fluid replacement on endurance performance. *J Strength Cond Res.* 2001;15:217-224.

18. Below P, Mora-Rodriguez R, Gonzalez-Alonso J, Coyle E. Fluid and carbohydrate ingestion independently improve performance during 1 hour of intense exercise *Med Sci Sports Exerc.* 1995;27:200-210.

19. Miller K, Knight K, RB W. Athletic trainers' perceptions of pickle juice's effects on exercise associated muscle cramps. *Athl Ther Today.* 2008;13:31–34.

20. Miller K, Mack G, Knight K, et al. Reflex inhibition of electrically induced muscle cramps in hypohydrated humans. *Med Sci Sports Exerc.* 2010 42:953-961.

21. Dale R, Leaver-Dunn D, Bishop P. A compositional analysis of a common acetic acid solution with practical implications for ingestion. *J Athl Train.* 2003;38:57-61.

22. Burns J, Clarkson R. Why don't athletes drink enough during exercise, and what can be done about it? *Sports Sci Exch.* 2001;12:1-4.

23. Thompson W, Gordon N, Pescatello L, eds. *ACSM's Guidelines for Exercise Testing and Prescription*. Eighth ed. Baltimore 2009:18-39.

24. Sawka M, Burke L, Eichner E, Maughan R, Montain S, Stachenfeld N. Exercise and fluid replacement. *Med Sci Sports Exerc.* 2007;39:377-390.

25. Dill D, Costill D. Calculation of percentage changes in volume of blood, plasma and cells in dehydration. *J Appl Physiol.* 1974;37:247-248.

26. Greenleaf J, Looft-Wilson R, Wisherd L, Mckenzie M, Jensen C, Whittam J. Pre-exercise hypervolemia and cycle ergometer endurance in men. *Biol Sport.* 1997;14:103-114.

27. Greenleaf J, Brock P. Na^+ and Ca^{2+} ingestion: plasma volume-electrolyte distribution at rest and exercise. *J Appl Physiol.* 1980;48:838-847.

28. Casa D, Armstrong L, Hillman S, et al. National Athletic Trainers' Association Position Statement: Fluid Replacement for Athletes. *J Athl Train.* 2000;35:212-224.

29. Miller K, Mack G, Knight K. Gastric emptying after pickle juice ingestion in rested euhydrated humans *J Athl Train.* 2010;45(601-608).

30. Maughan R, Leiper J. Limitations to fluid replacement during exercise. *Can J Appl Physiol.* 1999;24:173-187.

31. Institute GSS. Why don't athletes drink enough during exercise, and what can be done about it? *Sports Sci Exch.* 2001;12:1-4.

32. Miller K, Mack G, Knight K. Electrolyte and Plasma Changes After Ingestion of Pickle Juice, Water, and a Common Carbohydrate-Electrolyte Solution. *J Athl Train.* 2009;44:454-461.

33. Grigoriev A, Katkovskiy B, Savilov A, Georgiyevskiy V, Dorokhova B, Mikhaylow V. Effects of hyperhydration on human endurance of orthostatic and LBNP tests. *Kosm Biol Aviakosm Med.* 1978;12:20-24.

34. Kakurin L, Katkovskiy B, Tishler V, et al. Substantiation of a set of preventive measures referable to the objectives of missions in the salyut orbital station. *Kosm Biol Aviakosm Med.* 1978;12:20-27.

35. Fortney S, Steinmann L, Young J, Hoskin C, Barrows L. Fluid-Loading solutions and plasma volume: astro-ade and salt tablets with water. *NASA.* 1994;24:1-15.

Table 1. Treatment Drink Composition.

	Pickle Juice	Hypertonic Saline	Deionized Water
OSM (mOsmol*kg^{-1} H_2O)	853 ± 2.8	726.5 ± 2.1	0 ± 0
Specific Gravity	1.02 ± 0	1.012 ± 0	1.0 ± 0
pH	3.82 ± 0.01	5.89 ± 0.04	5.86 ± 0.11
[Na^+] (mmol*L^{-1})	395 ± 0	402.5 ± 3.5	ND
[K^+] (mmol*L^{-1})	29.5 ± 0.7	0	ND
[Cl^-] (mmol*L^{-1})	317.5 ± 17.68	390 ± 0	ND
[Glucose] (mmol*L^{-1})	26.63 ± 2.3	ND	ND

OSM = osmolality, [Na^+] = sodium concentration, [K^+] = potassium concentration, [Cl^-] = chloride concentration, [Glucose] = glucose concentration. ND = non-detectable. Pickle juice, hypertonic saline and deionized water characteristics were measured in duplicate. Data are means ± SD.

Table 2. Plasma Variables Pre and Post-Ingestion.

	Pickle Juice	Hypertonic Saline	Deionized Water
Δ Plasma Volume (% from pre)			
Pre	0	0	0
Post	-0.9 ± 4.1	1.9 ± 3.1	1.0 ± 3.3
OSM_p (mOsmol*kg H_2O^{-1})			
Pre	284 ± 4	283 ± 2	284 ± 4
Post	285 ± 3	284 ± 2	282 ± 4
$[Na^+]_p$ (mmol*L^{-1})			
Pre	141.5 ± 1.2	140.7 ± 1.5	141.6 ± 1.4
Post	141.6 ± 1.2	141 ± 0.5	140.4 ± 1.5
$[K^+]_p$ (mmol*L^{-1})			
Pre	4 ± 0.2	3.9 ± 0.2	4 ± 0.2
Post	4 ± 0.2	4 ± 0.3	4 ± 0.1
$[Glucose]_p$ (mmol*L^{-1})			
Pre	5.5 ± 0.4	5.2 ± 0.3	5.4 ± 0.3
Post	5.4 ±0.4	5.2 ± 0.3	5.3 ± 0.2

Values are means ± SD (n = 9). Δ Plasma Volume = change in plasma volume, OSM_p = plasma osmolality, $[Na^+]_p$ = plasma sodium concentration, $[K^+]_p$ = plasma potassium concentration , $[Glucose]_p$ = plasma glucose concentration. OSMp, $[Na^+]_p$, $[K^+]_p$, and $[Glucose]_p$ are reported descriptively for each drink.

APPENDIX A. PROSPECTUS

Introduction

During exercise, sweat output commonly exceeds fluid intake.[1] Athletes can lose between 1 to 2.5 L of sweat per hour thereby incurring significant fluid deficits.[2] If fluid is not replaced, plasma volume may be reduced and performance deficits can occur.[3] In fact, athletes may experience performance deficits[4] and impaired mental acuity at hypohydration levels as low as 2%.[5]

Researchers have observed several positive effects on performance by adding sodium (Na^+) to drinks. Adding Na^+ to drinks can maintain plasma Na^+ concentration,[6] increase the osmotic drive to drink,[7] increase *ad libitum* water consumption, and decrease urine output.[8] All of these benefits would help to maintain or expand plasma volume. In fact some researchers[9] have observed plasma volume can expand (~5%) before exercise when subjects ingest 10 $mL*kg^{-1}$ body mass of a high (164 $mmol*L^{-1}$) Na^+ drink. These authors also observed subjects were able to exercise ~21 minutes longer after ingestion of the high Na^+ drink. Plasma volume steadily decreased between both groups throughout exercise but remained consistently higher in the high Na^+ group which may explain the improvement in performance. Oopik et al[10] observed similar performance effects following ingestion of Na^+ citrate (164 $mmol*L^{-1}$) solution prior to a 5 km run. Subjects were able to self select speed of the run and reduced finish time by ~ 31 seconds in the high Na^+ group.[10] The authors speculate the reduced finish time may be because of the ability to retain fluids and increase plasma volume.

Adding Na^+ to drinks may enhance thermoregulation, thereby enhancing performance. Sims et al[11] observed reduced heat storage in athletes that had consumed a high (164 mmol $Na*L^{-1}$) Na^+ drink prior to exercise. Sawka et al[1] theorized that increasing plasma volume allows for a greater sweat rate and skin and skin blood flow response, enhancing thermoregulation. Similarly, Sims et al[9] observed subjects were able to exercise longer (~21 minutes) at lower core temperatures following ingestion of the high Na^+ drink.

Many athletes use strategies with little or no scientific support to improve performance. Common performance aids used prior to exercise include hyperhydration,[12] carbohydrate loading,[13] taking drugs (e.g. anabolic steroids, amphetamines, and erythropoietin), [14] nutritional supplements (e.g. caffeine, creatine, whey protein, and Na^+ bicarbonate),[15-16] and sport drinks.[17-18] Another common anecdotal strategy is ingesting pickle juice, a salty brine, prior to competition.[19]

Nineteen percent (63 of 337) of athletic trainers have administered pickle juice to athletes to prevent exercise-associated muscle cramps[19] with the majority providing it 30 minutes prior to exercise. Ingesting small volumes (1 $mL*kg^{-1}$ body mass) of pickle juice has been shown to effectively reduce the duration (~41 s) of muscle cramps compared to deionized water.[20] Athletes that do not develop muscle cramps during exercise are capable of performing at a higher level.[36] However, no experimental studies have investigated the effects of consuming pickle juice on performance or rectal temperature.

Research Question

1. Does ingesting 2 $mL*kg^{-1}$ of deionized water, pickle juice, or hypertonic saline 30 minutes prior to exercise delay time to exhaustion or affect rectal temperature, plasma volume, or sweat volume?

Research Hypotheses

1. Time to exhaustion will be longer in the pickle juice and hypertonic saline trials than in the deionized water trial.
2. Rectal temperature during exercise will be higher in the deionized water trial than the pickle juice and hypertonic saline trial.
3. Plasma volume will expand more in the pickle juice and hypertonic saline trial than the deionized water trial.

Assumptions

1. Conditions for performance testing to complete exhaustion are similar to those of athletic competition.
2. Following ingestion, a 30-minute wait period before performance testing is optimal for seeing performance effects.
3. The 2 $mL*kg^{-1}$ bolus of each treatment fluid will be fully absorbed by the start of endurance testing.
4. 2 $mL*kg^{-1}$ of the treatment fluids is enough to show effects on performance, core temperature, plasma volume and sweat volume.
5. Subjects will give maximal effort.

Limitations

1. Blood electrolytes (e.g., Na^+) will not be measured.
2. Only one aspect of human performance (i.e., endurance) will be measured.

Delimitations

1. Healthy, college-aged, physically active (i.e., exercise 3 or more times per week for 30 minutes or longer) male volunteers free of any neurologic, cardiovascular, or blood borne diseases will be recruited.

2. Subjects will be euhydrated (urine specific gravity < 1.01) prior to fluid ingestion.
3. Subjects will undergo performance testing in a hot environment (38-40^{o}C) with low relative humidity (19-20%).
4. Subjects will ingest 2 mL*kg^{-1} body mass of each treatment drink followed by 5 mL*kg^{-1} body mass of deionized water 30 minutes prior to performance testing.
5. Subjects and the primary investigator will be blinded to the fluid ingested each day.
6. Subjects will not be told until the end of the study that endurance performance was the primary dependent variable examined.
7. All subjects cannot have had an injury that interfered with their ability to exercise within 3 months prior to data collection or any surgery in the past year.
8. Subjects will self-report not having a history of total cholesterol > 200 mg/dl
9. Subjects will self-report not having a history of blood pressure > 140/90.
10. Subjects cannot have a body mass index > 30.
11. Subjects cannot have an allergy to pickles.
12. Subjects cannot have a history of heat related illness (e.g., heat stroke, heat exhaustions, heat syncope) in the 6 months preceding testing.

Definitions of Terms

1. Dehydration: the process of losing more water than taken in.
2. Electrolyte: an inorganic compound which dissociates in biological fluid into ions capable of conducting electrical current. In regards to physiology, these ions are able to conduct electrical currents and have a major influence on controlling fluid balance in the body. Examples include (Na^{+}), potassium (K^{+}), magnesium (Mg^{2+}), chloride (Cl^{-}), and calcium (Ca^{2+}).

3. Euhydrated: a normal state of hydration. For this study, subjects will be considered euhydrated if they have urine specific gravity less than 1.01.[28]
4. Hyperhydration: abnormal increased water content in the body.
5. Hypertonic saline: For this study, sodium will be added to deionized water so that the Na^+ is similar to Na^+ of pickle juice.
6. Hypohydration: abnormal decreased water content in the body.
7. Hypervolemia: an abnormal increase in plasma volume in the body.
8. Muscle cramp: a spasmodic, painful, involuntary skeletal muscle contraction.
9. Pickle Juice: a highly salty and acidic brine brought about through the process of pickling cucumbers.
10. Plasma: the clear, yellowish fluid portion of blood in which cells are suspended. Contains fibrin and other clotting materials.
11. Plasma volume: the volume of blood that is plasma expressed as a percentage.
12. Plasma sodium concentration: amount of sodium in a given volume of plasma.
13. Sodium citrate: a white, crystalline powder (NaCHO*2HO), that dissolves in water but not alcohol, with a salty taste. Commonly used as a food additive and for medical purposes.
14. Sweat volume: the amount of sweat lost per hour of exercise.

<u>Abbreviations</u>

1. BMI: body mass index
2. Kg: kilogram
3. L: liter
4. Mg: milligram

5. mmol: millimole
6. Na^+: sodium
7. U_{sg}: urine specific gravity

Literature Review

This literature review will discuss ingesting hypertonic drinks with an emphasis on pickle juice and possible performance effects in healthy populations and is organized by the following topics:

Databases and Key Words searched
Dehydration and Exercise
Dehydration and Performance
Thermoregulation
    Hydration
    Sodium
Sodium
Sodium and Sports Drinks
Sodium and Performance
    Sodium and sodium chloride
    Sodium bicarbonate
    Sodium citrate
Pickle Juice
    Pickle juice background
    Physiological effects of pickle juice
    Pickle juice and performance
Summary

<u>Databases and Key Words Searched</u>

The following databases were used in searching for this literature review: CINAHL, MEDLINE, sport discus (SPORTDiscus), pub med (Medline and EBSCO), and Google Scholar. Journal articles written in English between the years 1990 and 2012 were searched. Additional references were obtained from the citations of others research.

The following key words were searched:

Acetic acid
Competition
Dehydration
Electrolytes
Electrolyte depletion
Electrolyte loading
Endurance
Exercise
Hyperhydration
Hypertonic
Hypertonic saline
Hypohydration
Ingestion
Loading
Muscle cramps
Performance
Pickle juice
Pre-exercise
Pre-ingestion
Prevention
Running
Saline
Salt
Sodium
Sodium bicarbonate
Sodium chloride
Sodium citrate
Sodium loading
Sports
Sport drinks

Dehydration and Exercise

Dehydration is the process of losing water and electrolytes mostly commonly by sweating. Sweat evaporation is the body's primary source of heat loss during exercise. In fact, in hot, dry conditions, evaporation of sweat may account for 98% of cooling.[37] Bergeron et al[2] considers a sweat loss of 1 to 2.5 L per hour in adults to be common during exercise in warm to hot conditions. Additionally, highly trained endurance athletes can lose more than 3.5 L per hour.[38] Contributing factors that may affect sweat rate include: a person's genetic predisposition, metabolic efficiency[24], intensity of exercise, heat acclimation, cardio respiratory fitness, and environmental (e.g., temperature, humidity, and solar radiation). [2, 39]

To assess levels of dehydration, total body weight, body weight, urine color, urine specific gravity, plasma osmolality, and urine osmolality may be used.[24] According to Casa et al[28] a well hydrated person will be within 1% of normal body weight, have clear to light yellow urine, and have a specific gravity less than 1.01. Minimal dehydration occurs when a person loses 1-3% body weight, has urine is notably yellow, and has a urine specific gravity is between 1.01 and 1.02. Significant dehydration is a body weight loss of 3-5%, a medium to dark yellow urine color, and a urine specific gravity of 1.021 to 1.03. A dilution method of total body weight and plasma osmolality is the most valid and precise measure of hydration status but not practical in most settings.[24] Plasma and urine osmolality less than 290 and 700 mOsmol*kg^{-1} H_2O, respectively, represent euhydration, a normal state of body water content.[24]

Dehydration and Performance

When dehydration exceeds 2% bodyweight it may begin to negatively affect performance[4] and impair mental acuity.[5] McGregor et al[5] examined the effects of dehydration during a 90 minute intermittent exercise protocol. The exercise protocol consisted of an intermittent shuttle test in which one group was allowed to ingest fluid during the test while the control group was to refrain from ingesting any fluids. In comparison to the fluid ingestion trial, the no fluid groups soccer skill test dropped by 5%. Additionally, the no fluid group also experienced higher responses of heart rate, perceived exertion, serum aldosterone, osmolality, sodium, and cortisol. McGregor et al[5] observed that dehydration may cause deterioration of motor skills and increase a person’s rate of perceived exertion. Additionally, hypohydrated people may experience exhaustion sooner, have reduced muscle strength and endurance, and impaired general cognitive function and decision making skills.[4, 40-41] Furthermore, poor hydration tactics during exercise may lead to a decrease in performance and an increased risk for heat illness.[3, 42-43]

Thermoregulation

Normal core body temperatures are ~ 36-37ºC. Hyperthermia conditions occur when the core temperature exceeds 40ºC. This is a medical emergency and accounts for hundreds of deaths each year. According to the American college of sports medicine,[24] dehydration is a risk factor for heat exhaustion and heat stroke. Over a 22 year period, the U.S. Army reported dehydration in 17% of all heat stroke hospitalizations.[24, 44] Authors[45] have observed a linear correlation between dehydration and core temperature. To date, researchers have conflicting views on the quantity of fluid that must be replaced to prevent progressive hyperthermia.[46]

Hydration. Hyperhydration, often referred to as overhydration, is an increased amount of water in the body compared to normal conditions. Latzka et al[12] speculates that hyperhydration should allow for an increased total body water volume, allowing plasma volume to be maintained or expand. Hyperhydration onset by high water or glycerol water ingestion showed no reduction in core temperatures when exercising to exhaustion at 55% VO_{2max} in a hot climate (~35ºC).[12] Although a decrease in core temperature was not observed, total body water increased by ~1.5 L for glycerol and water hyperhydration. The control group for this study also began well hydrated which may explain why no change was observed for core temperature. Other authors speculate that partial rehydration may reduce the increase in core temperature associated with dehydration.[47-48]

Sodium. Few studies[9, 11] have found a significant difference in core temperature for high sodium drinks ingested prior to exercise when compared to a control. Sims et al[11] observed reduced core temperatures in athletes that had ingested a high (164 mmol*L^{-1}) sodium drink prior to exercise. The ethical termination temperature for this study was 39.5ºC in which 6 out of 8 subjects in the low (10 mmol*L^{-1}) sodium group reached and 5 out of 8 subjects in the high sodium group reached. Of the subjects in the high sodium group that were terminated due to core temperature exceeding 39.5ºC, average times were ~15 minutes longer at the stopping point in comparison to low sodium. Moreover, the high sodium drink ingested 90 minutes prior to exercise delayed the rise in core temperature, allowing subjects to exercise longer. Sawka et al[1] theorizes that sodium drinks improve thermoregulation by increase plasma volume, allowing a greater sweat rate and skin blood flow response. Subsequently, Nelson et al[49] observed no reduction in core temperature following a high (12 mL*kg^{-1}) sodium citrate plus Gatorade solution (170 mmol*L^{-1}) in comparison to plain Gatorade. Following ingestion of a treatment drink, subjects exercised for 62 minutes at a moderate to intense level. A limitation to this study is the undetermined influence Gatorade had on core temperature due to no true control. Montain and Coyle[46] observed consuming ~ 80% of fluid losses with a commercial sports drink drastically reduced core temperature by ~ 1ºC. If a carbohydrate-electrolyte drink has a primary effect on core temperature it may mask the effect of adding sodium to the drink. Also, the addition of sodium to the drink content may have a time dependent relationship greater than 62 minutes.

Sodium

Sodium is a cation primarily located in the extracellular space. Normal plasma sodium concentrations range from 140-144 mmol*L^{-1}. Normal total body exchangeable sodium content, is approximately 2548mmol.

Sodium is an essential electrolyte and required for the human body to function. Some of the common roles of sodium in the body include, maintaining fluid balance inside and outside of cells, regulating blood pressure and blood volume, and action potential generation and signaling of muscle contractions.[50] The hormone aldosterone is responsible for regulating excretion and reabsorption of sodium. Increased levels of aldosterone in the plasma signal the kidneys to reabsorb sodium back into the blood instead of excreting. Dramatic increases in dietary sodium create a positive balance (i.e., more sodium than what is needed). The kidneys will adjust to excrete the excess sodium but may take several days before fully regulated.

Sodium and Sports Drinks

Commercial sports drinks are hypotonic, meaning they have lower sodium concentrations than blood. The more common sports drinks carbohydrate and sodium concentrations range from 4-6% and 0-800 mg, respectively.[51] Murray et al[52] observed significantly faster gastric emptying with 4% and 6%carbohydrate drinks in comparison to 8%, supporting commercial sports drinks quantities for faster absorption.

Clinical observations suggest a growing number of collegiate athletes are adding sodium to their sports drinks to prevent and treat muscle cramps and enhance hydration. Many researchers support the addition of sodium to beverages and diet for obtaining these anecdotal effects.[2, 9, 11] The NATA position statement on replacement of fluids for athletes[28] suggests adding 0.3 to 0.7 g/L of sodium chloride (i.e., salt) to drinks to offset salt loss in sweat and minimize medical events associated with electrolyte imbalances, primarily sodium loss. Furthermore, they state that adding this amount to any hydration drink would be acceptable to stimulate thirst, increase voluntary fluid intake, and decrease the risk of hyponatremia.

Currently, research has conflicting views on the addition of sodium to sports drinks. Jeukendrup et al[53] observed no effect of sodium on fluid delivery when adding increasing amounts of sodium (0-60mmol) to a 6% carbohydrate drink. Significant findings of this study include the use of 3% carbohydrates for a maximal amount of reabsorption. The use of a 6% carbohydrate drink with sodium addition in this trial may have explained why Jeukendrup et al did not observe a benefit of adding sodium on performance. Below et al[18] observed increases in performance and plasma volume when subjects ingested a water with electrolytes, mainly sodium, or 6% carbohydrate sport drink. Some authors speculates that higher osmolality from carbohydrates reduces fluid delivery[30] and may promote dehydration.[54] Maughan et al[30] observed longer gastric emptying times with increased carbohydrate concentrations (above 6%) which may mask the fluid delivery of addition sodium drinks. Shirreffs et al[55] speculates that sodium may stimulate the uptake of carbohydrates and water in the small intestine allowing for greater absorption, aiding recovery but showing little immediate performance effects. Overall, adding sodium to hydration beverages may help to maintain extracellular fluid volume, maintain plasma sodium concentrations, and the drive to drink.[55-56]

Sodium and Performance

Sodium and sodium chloride. The addition of sodium or sodium chloride (i.e., table salt) to drinks prior to exercise can effectively produce hyperhydration[26] and maintain or increase plasma volume.[9, 11] Sims et al[9] observed a plasma volume expansion of ~ 5% prior to exercise when consuming 10 $mL*kg^{-1}$ of high (164 $mmol*L^{-1}$) sodium drink in comparison to a low (10 $mmol*L^{-1}$) sodium drink. Additionally, subjects were able to exercise ~ 21 minutes longer following high sodium ingestion. Authors[10] speculate that the ingestion of sodium prior to exercise may enhance performance by allowing retention of water and increasing plasma volume.

Sodium chloride solution, oral or intravenous, is a supported method for increasing plasma sodium concentrations and expanding plasma volume prior to, during, or following exercise.[57] Sodium chloride is one of the most effective solutions used for treatment of hyponatremia (plasma sodium concentrations < 135 mmol*L^{-1} body mass), and can prevent performance detriments. Hyponatremia is a serious medical emergency, commonly attributed to prolonged intense exercise and rehydrating with excessive hypotonic solutions or water.[24, 57] Bob Murray[58] suggests people may lose 5 to 7% of their total body sodium stores through prolonged exercise. Other researchers[2] agree that athletes commonly lose between 1 and 3.5 L of sweat per hour during intense exercise, including a substantial loss of sodium chloride. Hydration through prolonged exercise with only water may significantly lower plasma sodium concentrations. Costas et al[59] observed significantly higher serum sodium concentrations of 137.3 mmol*L^{-1} and 136.7 mmol*L^{-1} following ingesting of high (36.2 mmol*L^{-1}) sodium and low (19.9 mmol*L^{-1}) sodium, respectively, in comparison to water (~134.5 mmol*L^{-1}). Subjects performed various activities at a moderate exercise intensity for a 3 hour duration in a warm environment (~30ºC). Nose et al[60] observed 1 L of 0.9% sodium chloride saline infusion during exercise may effectively restored plasma volume to pre-exercise conditions and maintained plasma volume through the duration of exercise. Additionally, forearm blood flow was significantly higher (~ 5mL*min^{-1}) in subjects receiving saline infusion suggesting a reduced cardiac load. Below et al[61] observed similar performance effects of ingesting sodium (~620 mg) solution in comparison to commonly used carbohydrate drinks. Notably, the sodium solution maintained plasma volume and improved cycling times by ~6.5%. Moreover, adding sodium or sodium chloride to drinks may improve performance by maintaining plasma sodium concentrations,[6] increase the osmotic drive to drink,[7] increase *ad libitum* water consumption, and decrease urine output.[8]

Sodium bicarbonate. Previous studies examining pre-exercise ingestion of sodium bicarbonate suggest a delay in the onset of fatigue, enhancing performance.[62] Acute sodium bicarbonate loading suggests a possible enhancement in performance lasting 1 to 7 minutes.[62] To examine the short term effects of bicarbonate loading, Joyce et al[63] recorded 200m swim times following ingestion of acute sodium bicarbonate loading (0.3g*kg^{-1} body weight with 400-600 mL of water consumed in 3 equal doses over 15 minutes) or chronic sodium loading (0.1g*kg^{-1} body weight consumed 3 timers per day for 3 days). No significant changes were observed between acute loading, chronic loading, and a placebo during the 200m swim times.

Sodium citrate. Authors[10] speculate that sodium citrate may enhance performance by increasing retention of water and plasma volume. Ingesting 1 L of a sodium citrate (0.5g*kg^{-1} body mass) solution 2 hours prior to a 5 km run reduced time to completion by 30.5 seconds in well trained college runners.[10] To date, this is the only study that has observed a performance effect during exercise on a treadmill. Observationally, sodium citrate appears to have a positive role in performance during cycling in comparison to other forms of exercise. Potteiger[64] observed endurance athletes were able to exercise on a cycle ergometer for a longer duration following intravenous sodium citrate infusion. Greenleaf et al[26] observed pre exercise ingestion of sodium citrate (164 mmol*L^{-1}) can effectively induce hyperhydration and hypervolemia. This further supports the theory that sodium citrate enhances performance by retaining water, thereby increasing plasma volume.

Pickle Juice

Pickle juice background. Pickle juice is a highly salty and acid brine brought about through the process of pickling cucumbers. Miller et al[20, 32] analyzed the composition of pickle juice, finding osmolality (778 to1323 mOsm*kg^{-1} H_2O), pH (~3.15), specific gravity (~1.022), Sodium concentrations (515-978.5 mmol*L^{-1}), Potassium concentrations (7-26.6 mmol*L^{-1}), magnesium concentrations (12.4-16.8 mmol*L^{-1}), and calcium concentrations (23.4-47.6 mmol*L^{-1}). Possible explanations for the variations in electrolyte concentrations may include evaporation of fluid, the length of time the pickles have been in the brine, or the brand of pickles used.

Nineteen percent (63 of 337) of athletic trainers have administered small volumes (100 to 200mL) of pickle juice to athletes to prevent exercise-associated muscle cramps.[19] Additionally, the majority of athletic trainers that provide pickle juice to athletes do so 30 to 60 minutes prior to exercise.

Physiological effects of pickle juice. Currently, only two researchers[20, 65] have observed physiological effects in humans following ingestion of pickle juice. Miller et al[20] observed no changes in plasma osmolality, plasma volume, or plasma concentrations between pickle juice and deionized water following ingestion of 1 mL*kg^{-1} in hypohydrated men. Both drinks increased plasma osmolality almost immediately following ingestion but quickly returned to pre-ingestion levels. Since the increase occurred similarly for both drinks, this shift is likely due to a shift of hypotonic fluid out of the intravascular space and not because of the fluid ingested. Another study by Miller et al[32] observed electrolyte and plasma changes following 1 mL*kg^{-1} ingestion of pickle juice, water, and a carbohydrate-electrolyte solution in euhydrated men. No significant changes were observed for plasma sodium concentration, plasma magnesium concentration, plasma calcium concentration, plasma osmolality, and plasma volume. Both studies administered 1 $mL*kg^{-1}$ of pickle juice which may not be enough to show significant changes under these conditions. The majority of athletic trainers using pickle juice administer 1-2 $mL*kg^{-1}$. Further scientific evidence is needed to observe the effects of ingestion increased amounts of pickle juice.

Williams and Conway[65] reported 2 oz of pickle juice relieved exercise-associated muscle cramps within 30 seconds following ingestion of a collegiate athlete during competition. The athlete was able to return to play without cramps until the last 5 minutes of the game. Using the previously mentioned method, the athletes cramps resolved and did not return for the remainder of play. Miller et al[20] produced electrically-induced muscle cramps in hypohydrated (~3% body weight) college aged males. Following cramp, subjects ingested 1 $mL*kg^{-1}$ of pickle juice, deionized water, or nothing. The duration of a muscle cramp was approximately 49 seconds shorter following ingestion of pickle juice (~85 s) compared to water (~134 s). Additionally, With no changes to plasma sodium concentrations, Miller et al[20] speculates that sodium may not be the active ingredient in pickle juice responsible for reducing cramp duration. Williams and Conway[66] examine the role of vinegar in reducing cramping in athletes. An athlete experiencing exercise associated muscle cramps for the first time ingested one capful of vinegar, relieving the cramps in 35 seconds with no reoccurrence during practice.

Miller et al[29] observed effects of ingesting 7 $mL*kg^{-1}$ of pickle juice or deionized water on gastric emptying. Following ingestion, gastric emptying was fastest during the first 5 minutes for pickle juice (40%, ~219 of 547mL ingested was emptied) and deionized water (55.8%, ~305 of 546 mL ingested was emptied). After the 5 minute emptying period, pickle juice did not empty further for the duration of the study while deionized water continued to empty. Gastric volumes for deionized water were significantly lower than pickle juice at 20 and 30 minutes. The gastric emptying rate was faster for deionized water than pickle juice throughout the study. Both pickle juice and deionized water had the highest gastric emptying rates during the first 5 minutes, suggesting a volume response of the stomach may be responsible for the immediate emptying of fluids. Plasma sodium concentrations following gastric emptying were higher for pickle juice at 20 and 30 minutes in comparison to deionized water.[29] With similar plasma sodium concentrations at 10 minutes post ingestion for pickle juice and deionized water, it may take between 10 and 20 minutes before sodium ingested is observed in the blood.

Pickle juice and performance. To date, the use of pickle juice to prevent muscle cramps, hyperhydrate, and enhance performance is primarily supported by anecdotal evidence. Some researchers[21] express concern over ingesting a hypertonic solution such as pickle juice prior to exercise. Although not supported by scientific evidence, Dale et al[21] theorized that high salt and low fluid ingestion may prolong rehydration by rapidly increasing plasma osmolality and increase risk of hyperthermia and poor performance. Bergeron et al[2] speculates that increasing dietary sodium and ingesting salty solutions during practice or competition in the heat is harmless and may enhance well being and performance. Other researchers[39, 58] support increasing sodium to hydration fluids for restoring sodium lost during long periods of exercise or competition. Sharp[67] observed a restoration of plasma volume (1%) within 2 hours following the ingestion of chicken broth (sodium = 41 mmol) and chicken noodle soup (sodium = 59 mmol) in comparison to only water (5.5%). To date, no experimental studies have investigated performance effects of consuming pickle juice or a hypertonic solution with concentrations similar to pickle juice prior to exercise.

Summary

My literature review focused on performance effects influenced by dehydration, sodium, and pickle juice. Dehydration is the primary factor negatively influencing performance and thermoregulation. To reduce the performance detriments of dehydration, researchers have explored various rehydration drinks. Various carbohydrate and electrolyte, mainly sodium, drinks have been explored to maximize aiding hydration. A 2-6% carbohydrate solution is widely supported, yet the desired amount of sodium is still conflicted. Sweat sodium losses are not consistent between humans and also widely affected by environmental factors. Some researchers suggest increasing dietary sodium intake or ingesting hypertonic solutions to restore plasma sodium lost due to exercise. Athletes commonly ingest pickle juice in attempts to prevent and treat muscle cramps and aid hydration. With a rising popularity of pickle juice in the athletic community, researchers have begun to examine the physiological effects of ingesting pickle juice. Ingestion of small volumes (1-3 oz) of pickle juice has no effect on plasma volume and electrolyte concentrations in college-aged males. To date, no scientific research has explored possible performance variables following ingestion of pickle juice prior to exercise. Overall, a lack of scientific support has lead to many assumptions and speculation of pickle juices influence on hydration and performance.

Methods

Experimental Design

A crossover, factorial, repeated measures design will guide data collection. The independent variables will be time (pre and post-ingestion) and drink (pickle juice [strained from whole dill pickles, Pinnacle Foods Group LLC, Cherry Hill, NJ], a hypertonic saline drink with a similar Na^+ as pickle juice, and deionized water). The dependent variables will be time to exhaustion (minutes), sweat volume (L), change in plasma volume (percent change compared to baseline), and rectal temperature (^{o}C). Urine specific gravity (U_{sg}) will be measured to ensure subjects begin testing euhydrated. Free water clearance and osmolar clearance will be calculated (Appendix A) to estimate fluid and solute retention.

Subjects

Sample size was estimated *a priori* using time to exhaustion data.[68] Eighteen subjects will be needed to achieve significance with an α-level of 0.05 and power of 80% (Appendix B). A convenience sample of healthy males between the ages 18 and 30 years will be recruited for this study. Volunteers will be excluded if they self-report: (1) any injury that limited their ability to exercise in the 3 months prior to data collection, (2) any surgery within 6 months prior to data collection, (3) any neurologic, cardiovascular, or blood borne diseases, (4) a total cholesterol > 200 mg/dl, (5) blood pressure > 140/90 mmHg, (6) a body mass index > 30, (7) living a sedentary lifestyle (exercising less than 30 minutes 3 times per week)[23], (8) food allergy to pickles or (9) history of heat related illness (e.g., heat stroke, heat exhaustion, heat syncope) within the 6 months prior to data collection. All subjects will provide written informed consent prior to participation and all procedures will be approved by our university's institutional review board.

Testing procedures

Subjects will undergo three days of testing at least 48 hours apart. Twenty-four hours prior to testing days, subjects will be instructed to drink water consistently and avoid exercise, high sodium foods, alcohol and caffine. Subjects will be asked to keep their diets consistent until they complete the experiment, consume a similar meal the night before testing, and record their meal the night before testing using a food log. Subjects will fast 12 hours and self-report compliance prior to testing. During the 12 hour fast subjects will be encouraged to drink water.

A timeline for experimental procedures can be found in Appendix C. Subjects will report to a human performance lab, provide written consent, void their bladders, and be weighed. Urine specific gravity will be assessed with a refractometer (SUR-NE, Atago USA Inc., Bellouce, WA) to determine if subjects are euhydrated (urine specific gravity ≤ 1.01).[28] If hypohydrated, subjects will be asked to return at least 24 hours later. If euhydrated, subjects will don a heart rate monitor (Polar Electric Inc., Lake Success, NY) and insert a rectal thermistor (Yellow Spring Instruments 4600, Advanced Industrial Systems Inc., Prospect, KY) at least 10 cm past the anal sphincter. Subjects will be seated with their arm resting on a padded treatment table. The cubital fossa will be cleaned with isopropyl alcohol and a sterile catheter will be inserted into a superficial forearm vein. Subjects will remain seated for 30 minutes. Following the 30 minute rest period, a 5 mL baseline blood sample will be collected. Subjects will then have 1 minute to ingest 2 $mL*kg^{-1}$ body weight of pickle juice, hypertonic saline solution, or deionized water and 4 minutes to ingest 5 $mL*kg^{-1}$ body weight of deionized water. They will sit for 30 minutes to ensure gastric emptying of the drinks[29] and a second 5 mL blood sample will be collected.

Subjects will void their bladders, be weighed and report nausea and gastric fullness on seperate 100 mm visual analog scale (0 = no gastric fullness or nausea, 100 = extremely full or nauseous). They will enter an environmental chamber (38-40^{o}C, 20% relative humidity) and begin performance testing by exercising for 30 minutes on a treadmill (TrackMaster, TMX425C, Newton, KS) at 50% of their age predicted heart rate maximum (HR_{max}). Following the 30 minutes of exercise, the treadmill’s speed will increase so subjects exercise at 10% more of their

HR_{max}. Thus, after the first 30 minutes of running, subjects will exercise at 60% of their HR_{max}. Exercise intensity will increase every 10 minutes by 10% increments until subjects become too fatigued to continue or core temperature exceeds 39.5^{o}C. Rectal temperature will be recorded every 10 minutes during exercise. To ensure maximal effort, the primary investigator will provide verbal encouragement during testing.

Following testing, subjects will exit the environmental chamber, towel dry, and be weighed. Subjects will remove the rectal thermistor and be excused. Subjects will be asked to report for subsequent testing sessions at least 48 hours later. Testing will occur at the same time of day and will only vary in the treatment fluid ingested. Treatment fluid order will be counter balanced and randomly assigned.

To minimize bias, several precautions will be taken. First, subjects will not be told what they are going to drink or any potential effects the drinks may have on performance. Moreover, subjects will not be told that the primary purpose of the study is to determine the effects of the fluids on performance. Second, the investigator will be blinded to the drink ingested each day. Third, to prevent olfactory detection of the drinks, subjects and the investigator will wear nose plugs prior to ingestion. Subjects will remove the nose plugs after ingesting the fluid. Fourth, visual detection of the drinks will be prevented by using opaque bottles and having a research assistant prepare the drinks. Finally, subjects will be instructed not to make any faces, gestures, or remarks regarding the contents of the water bottles.

Blood Analysis Procedures

Whole blood will be analyzed for hematocrit and hemoglobin concentration [Hb]. Blood for hematocrit analysis will be drawn into heparinized micro-capillary tubes and centrifuged at 3000 rpm (IEC Micro-MB, International Equipment Co., Needham Heights, MA) for 5 minutes and read using a micro-capillary reader (Model IEC 2201, Damon/IEC, Needham heights, MA). Hemoglobin concentration will be measured by mixing 20 μL of whole blood with 5 mL of cyanomethemoglobin reagent and the absorbance read at 540 nm on a standard spectrophotometer (iMark Spectrophotometer, Biorad, Hercules, CA). Hematocrit and [Hb] will be measured in triplicate immediately following sampling and averaged for each blood sample for statistical analysis and calculations. Changes in plasma volume will be calculated by inserting hematocrit and [Hb] into the Dill and Costill equation.[25]

Statistical Analysis

Means and standard deviations will be calculated for time to exhaustion, plasma volume changes, rectal temperature, and sweat volume. Separate repeated measures ANOVA's will be used to determine differences between drinks for each dependent variable over time (NCSS 2007, Kaysville, UT). Tukey-Kramer multiple comparison tests will be used when significant F-values are observed for interactions or main level effects. Significance will be accepted when $P < 0.05$.

References

1. Sawka M, Montain S, Latzka W. Hydration effects on thermoregulation and performance in the heat. *Comp Biochem Physiol A Mol Integr Physiol.* 2001;128:679-690.
2. Bergeron M. Sodium: the forgotten nutrient. *Sports Med.* 2000;13:2-8.
3. Sawka M, Latzka W, Matott R, Montain S. Hydration effects on temperature regulation. *Int J Sports Med.* 1998;19:S108-S110.
4. Knicker A, Renshaw I, Oldham A, Cairns S. Interactive Processes Link the Multiple Symptoms of Fatigue in Sports Competition. *Sports Med.* 2011;41:307-328.

5. McGregor S, Nicholas C, Lakomy H. The influence of intermittent high-intensity shuttle running and fluid ingestion on the performance of a soccer skill. *J Sports Sci.* 1999;17:895-903.

6. Passe D. Physiological and psychological determinants of fluid intake. In: Maughan R, Murray R, eds. *Sports drinks: basic science and practical aspects*. Boca Raton (FL): CRC Press; 2001:45-88.

7. Nose H, Mack G, Shi X, Nadel E. Role of osmolality and plasma volume during rehydration in humans. *J Appl Physiol.* 1988;65:325-331.

8. Vrijens D, Rehrer N. Sodium-free fluid ingestion decreases plasma sodium druing exercise in the heat. *J Appl Physiol.* 1999;86:1847-1851.

9. Sims S, Vliet L, Cotter J, Rehrer N. Sodium Loading Aids Fluid Balance and Reduces Physiological Strain of Trained Men Exercising in the Heat. *Med Sci Sports Exerc.* 2007;39:123-130.

10. Oopik V, Saaremets I, Medijainen L, Karelson K, Janson T, Timpmann S. Effects of sodium citrate ingestion before exercise on endurance performance in well trained college runners. *J Sports Med.* 2003;37:485-489.

11. Sims S, Rehrer N, Bell M, Cotter J. Preexercise sodium loading aids fluid balance and endurance for women exercising in the heat. *J Appl Physiol.* 2007;103:534-541.

12. Latzka W, Sawka M, Montain S, et al. Hyperhydration: tolerance and cardiovascular effects during uncompensable exercise-heat stress. *J Appl Physiol.* 1998;84:1858-1864.

13. Sullo A, Monda M, Brizzi G, et al. The effect of a carbohydrate loading on running performance during a 25-km treadmill time trial by level of aerobic capacity in athletes. *Eur Rev Med Pharmacol Sci* 1998;2:195-202.

14. Tokish J, Kocher M, Hawkins R. Ergogenic aids: a review of basic science, performance, side effects, and status in sports. *Am J Sports Med.* 2004;32:1543-1553.

15. Froiland K, Koszewski W. Nutritional supplement use among college athletes and their sources of information. *Int J Sport Nutr Exerc Metab.* 2004;14:104-120.

16. Bishop P. Dietary Supplements and Team-Sport performance. *Sports Med.* 2010;40:995-1017.

17. Bachle L, Eckerson J, Albertson L, Ebersole K, Goodwin J, Petzel D. The effect of fluid replacement on endurance performance. *J Strength Cond Res.* 2001;15:217-224.

18. Below P, Mora-Rodriguez R, Gonzalez-Alonso J, Coyle E. Fluid and carbohydrate ingestion independently improve performance during 1 hour of intense exercise *Med Sci Sports Exerc.* 1995;27:200-210.

19. Miller K, Knight K, RB W. Athletic trainers' perceptions of pickle juice's effects on exercise associated muscle cramps. *Athl Ther Today.* 2008;13:31–34.

20. Miller K, Mack G, Knight K, et al. Reflex inhibition of electrically induced muscle cramps in hypohydrated humans. *Med Sci Sports Exerc.* 2010 42:953-961.

21. Dale R, Leaver-Dunn D, Bishop P. A compositional analysis of a common acetic acid solution with practical implications for ingestion. *J Athl Train.* 2003;38:57-61.

22. Burns J, Clarkson R. Why don't athletes drink enough during exercise, and what can be done about it? *Sports Sci Exch.* 2001;12:1-4.

23. . In: Thompson W, Gordon N, Pescatello L, eds. *ACSM's Guidelines for Exercise Testing and Prescription*. Eighth ed. Baltimore 2009:18-39.

24. Sawka M, Burke L, Eichner E, Maughan R, Montain S, Stachenfeld N. Exercise and fluid replacement. *Med Sci Sports Exerc.* 2007;39:377-390.

25. Dill D, Costill D. Calculation of percentage changes in volume of blood, plasma and cells in dehydration. *J Appl Physiol.* 1974;37:247-248.

26. Greenleaf J, Looft-Wilson R, Wisherd L, Mckenzie M, Jensen C, Whittam J. Pre-exercise hypervolemia and cycle ergometer endurance in men. *Biol Sport.* 1997;14:103-114.

27. Greenleaf J, Brock P. Na^{+} and Ca^{2+} ingestion: plasma volume-electrolyte distribution at rest and exercise. *J Appl Physiol.* 1980;48:838-847.

28. Casa D, Armstrong L, Hillman S, et al. National Athletic Trainers' Association Position Statement: Fluid Replacement for Athletes. *J Athl Train.* 2000;35:212-224.

29. Miller K, Mack G, Knight K. Gastric emptying after pickle juice ingestion in rested euhydrated humans *J Athl Train.* 2010;45(601-608).

30. Maughan R, Leiper J. Limitations to fluid replacement during exercise. *Can J Appl Physiol.* 1999;24:173-187.

31. Institute GSS. Why don't athletes drink enough during exercise, and what can be done about it? *Sports Sci Exch.* 2001;12:1-4.

32. Miller K, Mack G, Knight K. Electrolyte and Plasma Changes After Ingestion of Pickle Juice, Water, and a Common Carbohydrate-Electrolyte Solution. *J Athl Train.* 2009;44:454-461.

33. Grigoriev A, Katkovskiy B, Savilov A, Georgiyevskiy V, Dorokhova B, Mikhaylow V. Effects of hyperhydration on human endurance of orthostatic and LBNP tests. *Kosm Biol Aviakosm Med.* 1978;12:20-24.

34. Kakurin L, Katkovskiy B, Tishler V, et al. Substantiation of a set of preventive measures referable to the objectives of missions in the salyut orbital station. *Kosm Biol Aviakosm Med.* 1978;12:20-27.

35. Fortney S, Steinmann L, Young J, Hoskin C, Barrows L. Fluid-Loading solutions and plasma volume: astro-ade and salt tablets with water. In: NASA, ed1994:(24) 21-15.

36. Wagner T, Behnia N, Ancheta W, Shen R, Farrokhi S, Powers C. Strengthening and neuromuscular reeducation of the gluteus maximus in a triathlete with exercise-associated cramping of the hamstrings. *J Orthop Sports Phys Ther.* 2010;40:112-119.

37. Armstrong L, Maresh C. The exertional heat illnesses: a risk of athletic participation. *Med Exer Nutr Health.* 1993;2:125-134.

38. Armstrong L, Hubbard R, Jones B, Daniels J. Preparing Alberto Salazar for the heat of the 1984 olympic marathon. *Physician Sportsmed.* 1986;14:73-81.

39. Bergeron M. Heat cramps: fluid and electrolyte challenges during tennis in the heat. *J Sci Med Sport.* 2003;6:19-27.

40. Kraft J, Green J, Bishop P, Richardson M, Neggers Y, Leeper J. Impact of dehydration on a full body resistance exercise protocol. *Eur J Appl Physiol.* 2010;109:259-267.

41. Wilson M-M, Morley J. Impaired cognitive function and mental performance in mild dehydration. *Eur J Clin Nutr.* 2003;57:S24-S29.

42. Gonzalez-Alonso J, Mora-Rodriguez R, Below P, Coyle E. Dehydration markedly impairs cardiovascular function in hyperthermic endurance athletes during exercise. *J Appl Physiol.* 1997;82:1229-1236.

43. Sawka M. Physiological consequences of hypohydration: exercise performance and thermoregulation. *Med Sci Sports Exerc.* 1992;24:657-670.

44. Carter R, Cheuvront S, Vernieuw C, Sawka M. Hospitolizations and death from heat illness in US Army soldiers, 1980-2002. *Med Sci Sports Exerc.* 2005;37:1338-1344.

45. Wyndham C, Strydom N. The danger of inadequate water intake during marathon running. *S Afr Med J.* 1969;43:893-896.

46. Montain S, Coyle E. Influence of graded dehydration on hyperthermia and cardiovascular drift during exercise. *J Appl Physiol.* 1992;73:1340-1350.

47. Costill D, Kammer W, Fisher A. Fluid ingestion during distance running. *Arch Enviorn Health.* 1970;21:520-525.

48. Gisolfi C, Copping J. Thermal effects of prolonged treadmill exercise in the heat. *med sci Sports.* 1974;6:108-113.

49. Nelson M, Stuart-Hill L, Sleivert G. Hypervolemia and blood alkalinity: effect on physiological strain in a warm enviornment. *Int J Sports Physiol Perform.* 2008;3:501-515.

50. U.S. Department of Health and Human Services (HSS) and U.S. Department of Agriculture (USDA). *Dietary Guidelines for Americans - 2005.* Vol 20102010.

51. Kovacs M. Hydration, dehydration, and performance: A literature review. *ITF Coach Sport Sci Review.* 2011;53:21-23.

52. Murray R, Bartoli W, Stofan J, Horn M, Eddy D. A comparison of the gastric emptying characteristics of selected sports drinks. *Int J Sport Nutr.* 1999;9:263-274.

53. Jeukendrup A, Currell K, Clarke J, Cole J, Blannin A. Effect of beverage glucose and sodium content on fluid delivery *Nut Metabol.* 2009;6:1-7.

54. Davis J, Burgess W, Slentz C, Bartoli W. Fluid availability and sports drinks differing in carbohydrate type and concentration. *AM J Clin Nutr.* 1990;51:1054-1057.

55. Shirreffs S, Taylor A, Leiper J, Maughan R. Post-exercise rehydration in man: effects of volume consumed and drink sodium content. *Med Sci Sports Exerc.* 1996;28:1260-1271.

56. Noakes T. Fluid and electrolyte disturbances in heat illness. *Int J Sports Med.* 1998;19:S146-149.

57. verbalis J. Hyponatremia: new understanding, new therapy. *Am J Med.* 2006;119:S1-3.

58. Murray B. The Role of Salt and Glucose Replacement Drinks in the Marathon. *Sports Med.* 2007;37:358-360.

59. Costas A, SKavouras S, Arnaoutis C, et al. Sodium replacement and plasma sodium drop during exercise in the heat when fluid intake matches fluid loss. *J Athl Train.* 2009;44:117-123.

60. Nose H, Mack G, Shi X, Morimoto K, Nadel E. Effect of saline infusion during exercise on thermal and circulatory regulation. *J Appl Physiol.* 1990;69:609-616.

61. Below P, Coyle E. Fluid and carbohydrate ingestion individually benefit intense exercise lasting one hour. *Med Sci Sports Exerc.* 1995;27:200-210.

62. Requena B, Zanbala M, Padial P, Reriche B. Sodium bicarbonate and sodium citrate: ergogenic aids? *J Strength Cond Res.* 2005;19:213-224.

63. Joyce S, Minahan C, Anderson M, Osborne M. Acute and chronic loading of sodium bicarbonate in highly trained swimmers. *Eur J Appl Physiol.* 2011;Online view only.

64. Potteiger J, Nickel G, Webster M. Sodium citrate ingestion enhances 30 km cycling performance. *Int J Sports Med.* 1996;17:7-11.

65. Williams R, Conway D. Treatment of acute muscle cramps with pickle juice: a case report. *J Athl Train.* 2000;35:S24.

66. Williams R, Conway D. Treatment of acture muscle cramps with vinegar: a case report. *J Athl Train.* 2001;36:S106.

67. Sharp R. Role of whole foods in promoting hydration after exercise in humans. *Am Coll Nutr*. 2007;26:592S-596S.

68. Vincent W. The t-Test: Comparing Means from Two Sets of Data *Statistics in Kinesiology*. Champaign (IL): Human Kinetics; 1995:117-148.

APPENDIX B. ADDITIONAL METHODS

Table B1. Sample Size Estimate.

Sample size Equation:

$$n = \frac{2*(SD)^2 * (Z_{\alpha} + Z_{\beta})^2}{\Delta^2}$$

Where n is number of subjects needed, SD is the standard deviation for each group (5 min was chosen from prior research[9]), Z_{α} is the z-score of α 0.05, Z_{β} is the z-score for 80% power, and Δ is hypothesized difference between groups (11.5 min).

My sample size Equation:

$$n = \frac{2*(21.5)^2 * (1.96-.84)^2}{(20.8)^2}$$

n = 2.96

Table B2. Subject Drink Order.

Subject	Experimental Day 1 Drink	Experimental Day 2 Drink	Experimental Day 3 Drink
1	Deionized Water	Pickle Juice	Hypertonic Saline
2	Pickle Juice	Hypertonic Saline	Deionized Water
3	Hypertonic Saline	Deionized Water	Pickle Juice
4	Deionized Water	Pickle Juice	Hypertonic Saline
5	Pickle Juice	Hypertonic Saline	Deionized Water
6	Hypertonic Saline	Deionized Water	Pickle Juice
7	Deionized Water	Pickle Juice	Hypertonic Saline
8	Pickle Juice	Hypertonic Saline	Deionized Water
9	Hypertonic Saline	Deionized Water	Pickle Juice

Table B3. Data Collection Sheet.

Name:____________________ Subject #: __________ Age (yrs):_________

Date: ____________________ Height (in):_________ Day in Study?: 1 2 3

BMI (kg/m^2):_______ Max Heart Rate (220-age):_______ Drink (circle): 1 2 3

****

Pre-Testing Questionnaire:	Answer	Decision
Have you ingested at least 34 oz (1 L) of water in the previous 12 hours?	Yes No	Reschedule if ’yes’
Are you well rested?	Yes No	Reschedule if ‘no’
Do you have any neurological, cardiovascular, or blood borne diseases?	Yes No	Disqualify if ‘yes’
Have you eaten within the last 12 hours?	Yes No	Reschedule if ‘yes’
Have you exercised strenuously, had alcohol, or caffeine within the last 24 hours?	Yes No	Reschedule if ‘yes’
Has your diet stayed consistent this past week?	Yes No	Reschedule if ‘no’
Do you have a history of heat illness such as heat fainting, heat stroke, or heat exhaustion?	Yes No	Disqualify if ‘yes’
FOR DAY 1		
Are you allergic to pickles?	Yes No	Disqualify if ‘yes’
Have you had an injury in the last 3 months that reduced your ability to exercise?	Yes No	Disqualify if ‘yes’
Have you had a surgery in the last 6 months?	Yes No	Disqualify if ‘yes’
Has a doctor ever told you that you have a total cholesterol greater than 200 mg/dl?	Yes No	Disqualify if ‘yes’
Has a doctor ever told you that you have high blood pressure (higher than 140/90 mmHg?	Yes No	Disqualify if ‘yes’
Do you smoke regularly	Yes No	Disqualify if ‘yes’
Do you exercise at least 3 timers per week for 30 minutes or more?	Yes No	Disqualify if ‘no’
Has a blood relative had any cardiac Problems (female < 45, male < 55)	Yes No	Disqualify if ‘yes’

Table B3. Continued.

Urine Sample 1:

Urine Spec. Gravity ____________ (reschedule if > 1.012)

Body Weight 1 (wearing shorts and socks): _________ (kg) __________ Rounded

Amount of treatment drink to ingest (2ml/kg):__________________________ (mL)

Amount of deionized water to ingest (5ml/kg): _____________________________ (mL)

Insert rectal thermistor
Attach heart rate monitor
Sit for 30 minutes
Insert venous catheter into superficial forearm vein

Blood sample 1 (pre-ingestion):

				AVG
Hct	______	_____	_____	___________
[Hb]	______	_____	_____	___________
Osmo	______	______		____________

Ingest 2 mL*kg^{-1} treatment drink: 1 minute to finish
Ingest 5 mL*kg^{-1} deionized water: 4 minutes to finish

Blood sample 2 (30 min post-ingestion):

				AVG
Hct	______	_____	_____	___________
[Hb]	______	_____	_____	___________
Osmo	______	_____		___________

Remove venous catheter

Urine Sample 2:

			AVG
Urine Osmolality	____________	___________	____________
Urine Volume	____________		____________
Urine Spec. Gravity	____________		____________

Body Weight 2 (wearing shorts and socks): __________________ (kg)

Visual analog scale for nausea and GI upset and fullness
Subject enters the heat chamber.

Core temp upon arrival	__________	**Chamber temp**	^{o}C	%
Core temp pre ingestion	__________	Pre exercise	______	______

Table B3. Continued.

Core temp post ingestion ___________ Post exercise ______ ______

Core temp pre exercise ___________

Exercise Protocol

	% of HR_{max}	HR Range	RPE	Rectal temp	TM speed	
0-**10** minutes	50%_____	________________	__________	_____________	_____	____
10-**20** minutes	50%_____	________________	__________	_____________	_____	____
20-**30** minutes	50%_____	________________	__________	_____________	_____	____
30-**40** minutes	60%_____	________________	__________	_____________	_____	____
40-**50** minutes	70%_____	________________	__________	_____________	_____	____
50-**60** minutes	80%_____	________________	__________	_____________	_____	____
60-**70** minutes	90%_____	________________	__________	_____________	_____	____
75 minutes	95%_____	________________	__________	_____________	_____	____
80 minutes	95%_____	________________	__________	_____________	_____	____
82.5 minutes	95%_____	________________	__________	_____________	_____	____
85 minute	95%_____	________________	__________	_____________	_____	____
87.5 minutes	95%_____	________________	__________	_____________	_____	____
90 minutes	95%_____	________________	__________	_____________	_____	____
92 minutes	95%_____	________________	__________	_____________	_____	____

Time of complete exhaustion: ____________ Rectal temp: ______________

Reason for stopping _____________________________

Subjects will perform a 5 minute cool down upon completion

Exit heat chamber

Towel dry

Body Weight 3 (wearing shorts and socks): ___________________ (kg)

Urine sample

Remove RT and HR monitor

Urine Sample 3:			AVG
Urine Osmolality	_____________	____________	_____________
Urine Volume	_____________		_____________
Urine Spec. Gravity	_____________		_____________

Excuse Subjects. Ask to return at least 48 hours later.

Table B4. Experimental Timeline.

OVERALL TIME (MIN)	POSTINGEST TIME (MIN)	PROCEDURE
0	-	US 1 (Urine specific gravity $\leq$ 1.01).
	-	BW 1
	-	Insert RT and Don a HR monitor
	-	Prep arm for veinipuncture
5	-	Subject is seated
35	-	BS1
36	-	Ingest 2 $mL*kg^{-1}$ body weight of Pickle juice,saline solution, or deionized water
40	0	Ingest 5 $mL*kg^{-1}$ body weight deionized water
70	30	BS 2
		US 2
		BW 2
		VAS
75	35	Enter environmental chamber
		Exercise at 50% of HR_{max}
105	65	Exercise at 60% of HR_{max}
115	75	Exercise at 70% of HR_{max}
125	85	Exercise at 80% of HR_{max}
135	95	Exercise at 90% of HR_{max}
145	105	Exercise at 100% of HR_{max}
		Subjects will continue exercise until too fatigued or rectal temperature exceeds 39.5^0C
<155	Completion	Towel dry and remove RT
		BW 3

BS = Blood Sample
BW = Body Weight
HR = Heart Rate
RT = Rectal Thermistor
US = Urine Sample
VAS = Visual Analog Scale

Table B5. Osmolar and Free Water Clearance.

Free water clearance (C_{H2O}):

$$C_{H2O} = \mathring{U} - C_{osm}$$

Osmolar clearance (C_{osm}):

$$C_{osm} = \frac{\mathring{U} * Osm_u}{Osm_p}$$

$\mathring{U}$ = urine flow rate ($mL*h^{-1}$)
Osm_u = urine osmolality
Osm_p = plasma osmolality

Table B6. Statistical Analysis.

1. ***Does ingesting 2 mL*kg^{-1} of deionized water, pickle juice, or hypertonic saline 30 minutes prior to exercise delay time to exhaustion?***

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subject	8	357.9877	44.74846			
B: drink	2	18.28987	9.144936	1.06	0.368535	0.203398
AB	16	137.625	8.601563			
S	0					
Total (Adjusted)	26	513.9025				
Total	27					

* Term significant at alpha = 0.05

Probability Levels for F-Tests with Geisser-Greenhouse Adjustments

Source Term	DF	F-Ratio	Regular Prob Level	Lower Bound Epsilon Prob Level	Geisser Greenhouse Epsilon Prob Level	Huynh Feldt Epsilon Prob Level
A: subject	8					
B: drink	2	1.06	0.368535	0.332655	0.364394	0.368535
AB	16					
S	0					

Power Values for F-Tests with Geisser-Greenhouse Adjustments Section

Source Term	DF	F-Ratio	Regular Power (Alpha=0.05)	Lower Bound Epsilon Power (Alpha=0.05)	Geisser Greenhouse Epsilon Power (Alpha=0.05)	Huynh Feldt Epsilon Power (Alpha=0.05)
A: subject	8					
B: drink	2	1.06	0.203398	0.149288	0.194166	0.203398
AB	16					
S	0					

Covariance Matrix Circularity Section

Source Term	Lower Bound Epsilon	Geisser Greenhouse Epsilon	Huynh Feldt Epsilon	Mauchly Test Statistic	Chi2 Value	DF	Prob Level	Covariance Matrix Circularity?
AB	0.500000	0.908888	1.000000	0.899754	0.7	2.0	0.690929	Okay

Table B6. Continued.

2. Does ingesting 2 mL*kg^{-1} of deionized water, pickle juice, or hypertonic saline 30 minutes prior to exercise affect rectal temperature?

Analysis of Variance Table

Source Term	**DF**	**Sum of Squares**	**Mean Square**	**F-Ratio**	**Prob Level**	**Power (Alpha=0.05)**
A: subject	8	0.4913333	6.141667E-02			
B: drink	2	5.813333E-02	2.906667E-02	0.30	0.744507	0.089644
AB	16	1.547433	9.671459E-02			
C: time	1	56.67227	56.67227	250.21	0.000000*	1.000000
AC	8	1.812	0.2265			
BC	2	5.391111E-02	2.695556E-02	0.71	0.508808	0.148260
ABC	16	0.6117222	3.823264E-02			
S	0					
Total (Adjusted)	53	61.2468				
Total	54					

* Term significant at alpha = 0.05

Probability Levels for F-Tests with Geisser-Greenhouse Adjustments

Source Term	**DF**	**F-Ratio**	**Regular Prob Level**	**Lower Bound Epsilon Prob Level**	**Geisser Greenhouse Epsilon Prob Level**	**Huynh Feldt Epsilon Prob Level**
A: subject	8					
B: drink	2	0.30	0.744507	0.598504	0.684311	0.719038
AB	16					
C: time	1	250.21	0.000000*	0.000000*	0.000000*	0.000000*
AC	8					
BC	2	0.71	0.508808	0.425475	0.505241	0.508808
ABC	16					
S	0					

Table B6. Continued.

Power Values for F-Tests with Geisser-Greenhouse Adjustments Section

Source Term	DF	F-Ratio	Regular Power (Alpha=0.05)	Lower Bound Epsilon Power (Alpha=0.05)	Geisser Greenhouse Epsilon Power (Alpha=0.05)	Huynh Feldt Epsilon Power (Alpha=0.05)
A: subject	8					
B: drink	2	0.30	0.089644	0.077415	0.084010	0.087129
AB	16					
C: time	1	250.21	1.000000	1.000000	1.000000	1.000000
AC	8					
BC	2	0.71	0.148260	0.115235	0.146508	0.148260
ABC	16					
S	0					

Covariance Matrix Circularity Section

Source Term	Lower Bound Epsilon	Geisser Greenhouse Epsilon	Huynh Feldt Epsilon	Mauchly Test Statistic	Chi2 Value	DF	Prob Level	Covariance Matrix Circularity?
AB	0.500000	0.749954	0.884540	0.666586	2.8	2.0	0.241822	Okay
AC	1.000000	1.000000	1.000000	1.000000	0.0	0.0	1.000000	Okay
ABC	0.500000	0.970960	1.000000	0.970091	0.2	2.0	0.899174	Okay

Table B6. Continued.

3. ***Does ingesting 2 mL*kg^{-1} of deionized water, pickle juice, or hypertonic saline 30 minutes prior to exercise affect plasma volume?***

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subject	8	32.13143	4.016429			
B: time	1	6.006977	6.006977	1.50	0.256150	0.190726
AB	8	32.13143	4.016429			
C: drink	2	18.40399	9.201995	1.25	0.312774	0.232992
AC	16	117.6965	7.35603			
BC	2	18.40399	9.201995	1.25	0.312774	0.232992
ABC	16	117.6965	7.35603			
S	0					
Total (Adjusted)	53	342.4708				
Total	54					

* Term significant at alpha = 0.05

Probability Levels for F-Tests with Geisser-Greenhouse Adjustments

Source Term	DF	F-Ratio	Regular Prob Level	Lower Bound Epsilon Prob Level	Geisser Greenhouse Epsilon Prob Level	Huynh Feldt Epsilon Prob Level
A: subject	8					
B: time	1	1.50	0.256150	0.256150	0.256150	0.256150
AB	8					
C: drink	2	1.25	0.312774	0.295829	0.309637	0.312597
AC	16					
BC	2	1.25	0.312774	0.295829	0.309637	0.312597
ABC	16					
S	0					

Table B6. Continued.

Power Values for F-Tests with Geisser-Greenhouse Adjustments Section

Source Term	DF	F-Ratio	Regular Power (Alpha=0.05)	Lower Bound Epsilon Power (Alpha=0.05)	Geisser Greenhouse Epsilon Power (Alpha=0.05)	Huynh Feldt Epsilon Power (Alpha=0.05)
A: subject	8					
B: time	1	1.50	0.190726	0.190726	0.190726	0.190726
AB	8					
C: drink	2	1.25	0.232992	0.167261	0.209049	0.230969
AC	16					
BC	2	1.25	0.232992	0.167261	0.209049	0.230969
ABC	16					
S	0					

Covariance Matrix Circularity Section

Source Term	Lower Bound Epsilon	Geisser Greenhouse Epsilon	Huynh Feldt Epsilon	Mauchly Test Statistic	Chi2 Value	DF	Prob Level	Covariance Matrix Circularity?
AB	1.000000	1.000000	1.000000	1.000000	0.0	0.0	1.000000	Okay
AC	0.500000	0.808604	0.983493	0.763300	1.9	2.0	0.388539	Okay
ABC	0.500000	0.808604	0.983493	0.763300	1.9	2.0	0.388539	Okay

4. Does ingesting 2 mL*kg^{-1} of deionized water, pickle juice, or hypertonic saline 30 minutes prior to exercise affect sweat volume?

_**Analysis of Variance Table**

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subject	8	1.5876	0.19845			
B: drink	2	6.106667E-02	3.053333E-02	0.55	0.587395	0.125240
AB	16	0.888	0.0555			
S	0					
Total (Adjusted)	26	2.536667				
Total	27					

* Term significant at alpha = 0.05

Table B6. Continued.

Probability Levels for F-Tests with Geisser-Greenhouse Adjustments

Source Term	DF	F-Ratio	Regular Prob Level	Lower Bound Epsilon Prob Level	Geisser Greenhouse Epsilon Prob Level	Huynh Feldt Epsilon Prob Level
A: subject	8					
B: drink	2	0.55	0.587395	0.479463	0.568878	0.587395
AB	16					
S	0					

Power Values for F-Tests with Geisser-Greenhouse Adjustments Section

Source Term	DF	F-Ratio	Regular Power (Alpha=0.05)	Lower Bound Epsilon Power (Alpha=0.05)	Geisser Greenhouse Epsilon Power (Alpha=0.05)	Huynh Feldt Epsilon Power (Alpha=0.05)
A: subject	8					
B: drink	2	0.55	0.125240	0.100652	0.120298	0.125240
AB	16					
S	0					

Covariance Matrix Circularity Section

Source Term	Lower Bound Epsilon	Geisser Greenhouse Epsilon	Huynh Feldt Epsilon	Mauchly Test Statistic	Chi2 Value	DF	Prob Level	Covariance Matrix Circularity?
AB	0.500000	0.890017	1.000000	0.876426	0.9	2.0	0.630237	Okay

Table B6. Continued.

5. Sodium between drinks.

Analysis of Variance Table

Source Term	**DF**	**Sum of Squares**	**Mean Square**	**F-Ratio**	**Prob Level**	**Power (Alpha=0.05)**
A: subject	8	28.75926	3.594908			
B: time	1	1.041667	1.041667	0.89	0.372364	0.133047
AB	8	9.333333	1.166667			
C: drink	2	4.731482	2.365741	1.35	0.287978	0.248221
AC	16	28.10185	1.756366			
BC	2	6.194445	3.097222	5.33	0.016877*	0.759930
ABC	16	9.305555	0.5815972			
S	0					
Total (Adjusted)	53	87.46759				
Total	54					

* Term significant at alpha = 0.05

Probability Levels for F-Tests with Geisser-Greenhouse Adjustments

Source Term	**DF**	**F-Ratio**	**Regular Prob Level**	**Lower Bound Epsilon Prob Level**	**Geisser Greenhouse Epsilon Prob Level**	**Huynh Feldt Epsilon Prob Level**
A: subject	8					
B: time	1	0.89	0.372364	0.372364	0.372364	0.372364
AB	8					
C: drink	2	1.35	0.287978	0.279271	0.288090	0.287978
AC	16					
BC	2	5.33	0.016877*	0.049870*	0.019107*	0.016877*
ABC	16					
S	0					

Table B6. Continued.

Power Values for F-Tests with Geisser-Greenhouse Adjustments Section

Source Term	**DF**	**F-Ratio**	**Regular Power (Alpha=0.05)**	**Lower Bound Epsilon Power (Alpha=0.05)**	**Geisser Greenhouse Epsilon Power (Alpha=0.05)**	**Huynh Feldt Epsilon Power (Alpha=0.05)**
A: subject	8					
B: time	1	0.89	0.133047	0.133047	0.133047	0.133047
AB	8					
C: drink	2	1.35	0.248221	0.176466	0.239121	0.248221
AC	16					
BC	2	5.33	0.759930	0.527299	0.739383	0.759930
ABC	16					
S	0					

Covariance Matrix Circularity Section

Source Term	**Lower Bound Epsilon**	**Geisser Greenhouse Epsilon**	**Huynh Feldt Epsilon**	**Mauchly Test Statistic**	**Chi2 Value**	**DF**	**Prob Level**	**Covariance Matrix Circularity?**
AB	1.000000	1.000000	1.000000	1.000000	0.0	0.0	1.000000	Okay
AC	0.500000	0.932443	1.000000	0.927548	0.5	2.0	0.768559	Okay
ABC	0.500000	0.941951	1.000000	0.938374	0.4	2.0	0.800416	Okay

6. Potassium between drinks.

Analysis of Variance Table

Source Term	**DF**	**Sum of Squares**	**Mean Square**	**F-Ratio**	**Prob Level**	**Power (Alpha=0.05)**
A: subject	8	1.760648	0.220081			
B: drink	2	0.0637037	3.185185E-02	0.81	0.460276	0.164916
AB	16	0.6254629	3.909143E-02			
C: time	1	7.041667E-02	7.041667E-02	5.50	0.047095*	0.539962
AC	8	0.1025	0.0128125			
BC	2	1.111111E-03	5.555556E-04	0.14	0.872691	0.067618
ABC	16	6.472223E-02	4.045139E-03			
S	0					
Total (Adjusted)	53	2.688565				
Total	54					

* Term significant at alpha = 0.05

Table B6. Continued.

Probability Levels for F-Tests with Geisser-Greenhouse Adjustments

Source Term	**DF**	**F-Ratio**	**Regular Prob Level**	**Lower Bound Epsilon Prob Level**	**Geisser Greenhouse Epsilon Prob Level**	**Huynh Feldt Epsilon Prob Level**
A: subject	8					
B: drink	2	0.81	0.460276	0.393071	0.437277	0.454850
AB	16					
C: time	1	5.50	0.047095*	0.047095*	0.047095*	0.047095*
AC	8					
BC	2	0.14	0.872691	0.720561	0.791018	0.818094
ABC	16					
S	0					

Power Values for F-Tests with Geisser-Greenhouse Adjustments Section

Source Term	**DF**	**F-Ratio**	**Regular Power (Alpha=0.05)**	**Lower Bound Epsilon Power (Alpha=0.05)**	**Geisser Greenhouse Epsilon Power (Alpha=0.05)**	**Huynh Feldt Epsilon Power (Alpha=0.05)**
A: subject	8					
B: drink	2	0.81	0.164916	0.125630	0.149016	0.160880
AB	16					
C: time	1	5.50	0.539962	0.539962	0.539962	0.539962
AC	8					
BC	2	0.14	0.067618	0.062440	0.064486	0.065402
ABC	16					
S	0					

Table B6. Continued.

Covariance Matrix Circularity Section

Source Term	Lower Bound Epsilon	Geisser Greenhouse Epsilon	Huynh Feldt Epsilon	Mauchly Test Statistic	Chi2 Value	DF	Prob Level	Covariance Matrix Circularity?
AB	0.500000	0.785653	0.944340	0.727173	2.2	2.0	0.327893	Okay
AC	1.000000	1.000000	1.000000	1.000000	0.0	0.0	1.000000	Okay
ABC	0.500000	0.674691	0.762669	0.517840	4.6	2.0	0.099927	Okay

7. Flow rate between drinks.

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subject	8	1378043	172255.4			
B: drink	2	69884.48	34942.24	0.65	0.534734	0.140178
AB	16	858625.1	53664.07			
S	0					
Total (Adjusted)	26	2306553				
Total	27					

* Term significant at alpha = 0.05

Probability Levels for F-Tests with Geisser-Greenhouse Adjustments

Source Term	DF	F-Ratio	Regular Prob Level	Lower Bound Epsilon Prob Level	Geisser Greenhouse Epsilon Prob Level	Huynh Feldt Epsilon Prob Level
A: subject	8					
B: drink	2	0.65	0.534734	0.443036	0.511400	0.534734
AB	16					
S	0					

Power Values for F-Tests with Geisser-Greenhouse Adjustments Section

Source Term	DF	F-Ratio	Regular Power (Alpha=0.05)	Lower Bound Epsilon Power (Alpha=0.05)	Geisser Greenhouse Epsilon Power (Alpha=0.05)	Huynh Feldt Epsilon Power (Alpha=0.05)
A: subject	8					
B: drink	2	0.65	0.140178	0.110147	0.131262	0.140178
AB	16					
S	0					

Table B6. Continued.

Covariance Matrix Circularity Section

Source Term	Lower Bound Epsilon	Geisser Greenhouse Epsilon	Huynh Feldt Epsilon	Mauchly Test Statistic	Chi2 Value	DF	Prob Level	Covariance Matrix Circularity?
AB	0.500000	0.840054	1.000000	0.809600	1.5	2.0	0.477471	Okay

8. Free water clearance.

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subject	8	1078737	134842.1			
B: drink	2	9996.483	4998.242	0.11	0.900591	0.063440
AB	16	758801.5	47425.09			
S	0					
Total (Adjusted)	26	1847535				
Total	27					

* Term significant at alpha = 0.05

Probability Levels for F-Tests with Geisser-Greenhouse Adjustments

Source Term	DF	F-Ratio	Regular Prob Level	Lower Bound Epsilon Prob Level	Geisser Greenhouse Epsilon Prob Level	Huynh Feldt Epsilon Prob Level
A: subject	8					
B: drink	2	0.11	0.900591	0.753778	0.844284	0.876397
AB	16					
S	0					

Power Values for F-Tests with Geisser-Greenhouse Adjustments Section

Source Term	DF	F-Ratio	Regular Power (Alpha=0.05)	Lower Bound Epsilon Power (Alpha=0.05)	Geisser Greenhouse Epsilon Power (Alpha=0.05)	Huynh Feldt Epsilon Power (Alpha=0.05)
A: subject	8					
B: drink	2	0.11	0.063440	0.059533	0.061626	0.062583
AB	16					
S	0					

Table B6. Continued.

Covariance Matrix Circularity Section

Source Term	Lower Bound Epsilon	Geisser Greenhouse Epsilon	Huynh Feldt Epsilon	Mauchly Test Statistic	Chi2 Value	DF	Prob Level	Covariance Matrix Circularity?
AB	0.500000	0.743243	0.873443	0.654545	3.0	2.0	0.226875	Okay

9. Fullness between drinks.

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subject	8	7995.333	999.4167			
B: drink	2	213.5556	106.7778	0.52	0.604438	0.120781
AB	16	3287.778	205.4861			
S	0					
Total (Adjusted)	26	11496.67				
Total	27					

* Term significant at alpha = 0.05

Probability Levels for F-Tests with Geisser-Greenhouse Adjustments

Source Term	DF	F-Ratio	Regular Prob Level	Lower Bound Epsilon Prob Level	Geisser Greenhouse Epsilon Prob Level	Huynh Feldt Epsilon Prob Level
A: subject	8					
B: drink	2	0.52	0.604438	0.491522	0.558635	0.586566
AB	16					
S	0					

Power Values for F-Tests with Geisser-Greenhouse Adjustments Section

Source Term	DF	F-Ratio	Regular Power (Alpha=0.05)	Lower Bound Epsilon Power (Alpha=0.05)	Geisser Greenhouse Epsilon Power (Alpha=0.05)	Huynh Feldt Epsilon Power (Alpha=0.05)
A: subject	8					
B: drink	2	0.52	0.120781	0.097793	0.110386	0.116518
AB	16					
S	0					

Table B6. Continued.

Covariance Matrix Circularity Section

Source Term	Lower Bound Epsilon	Geisser Greenhouse Epsilon	Huynh Feldt Epsilon	Mauchly Test Statistic	Chi2 Value	DF	Prob Level	Covariance Matrix Circularity?
AB	0.500000	0.758126	0.898112	0.680958	2.7	2.0	0.260568	Okay

10. Plasma glucose between drinks.

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subject	8	3.753148	0.4691435			
B: drink	2	0.3692593	0.1846296	3.06	0.074995	0.508917
AB	16	0.9657407	0.0603588			
C: time	1	0.1557407	0.1557407	17.57	0.003033*	0.954634
AC	8	7.092593E-02	8.865741E-03			
BC	2	1.592593E-02	7.962963E-03	0.54	0.594861	0.123265
ABC	16	0.2374074	1.483796E-02			
S	0					
Total (Adjusted)	53	5.568148				
Total	54					

* Term significant at alpha = 0.05

Probability Levels for F-Tests with Geisser-Greenhouse Adjustments

Source Term	DF	F-Ratio	Regular Prob Level	Lower Bound Epsilon Prob Level	Geisser Greenhouse Epsilon Prob Level	Huynh Feldt Epsilon Prob Level
A: subject	8					
B: drink	2	3.06	0.074995	0.118420	0.088117	0.074995
AB	16					
C: time	1	17.57	0.003033*	0.003033*	0.003033*	0.003033*
AC	8					
BC	2	0.54	0.594861	0.484727	0.560467	0.592085
ABC	16					
S	0					

Table B6. Continued.

Power Values for F-Tests with Geisser-Greenhouse Adjustments Section

Source Term	DF	F-Ratio	Regular Power (Alpha=0.05)	Lower Bound Epsilon Power (Alpha=0.05)	Geisser Greenhouse Epsilon Power (Alpha=0.05)	Huynh Feldt Epsilon Power (Alpha=0.05)
A: subject	8					
B: drink	2	3.06	0.508917	0.337985	0.453830	0.508917
AB	16					
C: time	1	17.57	0.954634	0.954634	0.954634	0.954634
AC	8					
BC	2	0.54	0.123265	0.099388	0.114788	0.122540
ABC	16					
S	0					

Covariance Matrix Circularity Section

Source Term	Lower Bound Epsilon	Geisser Greenhouse Epsilon	Huynh Feldt Epsilon	Mauchly Test Statistic	Chi2 Value	DF	Prob Level	Covariance Matrix Circularity?
AB	0.500000	0.825124	1.000000	0.788061	1.7	2.0	0.434469	Okay
AC	1.000000	1.000000	1.000000	1.000000	0.0	0.0	1.000000	Okay
ABC	0.500000	0.808367	0.983086	0.762938	1.9	2.0	0.387893	Okay

11. Hypohydration between drinks.

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subject	8	3.920737	0.4900921			
B: drink	2	0.1144884	5.724418E-02	0.62	0.549150	0.135902
AB	16	1.471552	9.197199E-02			
S	0					
Total (Adjusted)	26	5.506777				
Total	27					

* Term significant at alpha = 0.05

Table B6. Continued.

Probability Levels for F-Tests with Geisser-Greenhouse Adjustments

Source Term	DF	F-Ratio	Regular Prob Level	Lower Bound Epsilon Prob Level	Geisser Greenhouse Epsilon Prob Level	Huynh Feldt Epsilon Prob Level
A: subject	8					
B: drink	2	0.62	0.549150	0.452897	0.518820	0.546185
AB	16					
S	0					

Power Values for F-Tests with Geisser-Greenhouse Adjustments Section

Source Term	DF	F-Ratio	Regular Power (Alpha=0.05)	Lower Bound Epsilon Power (Alpha=0.05)	Geisser Greenhouse Epsilon Power (Alpha=0.05)	Huynh Feldt Epsilon Power (Alpha=0.05)
A: subject	8					
B: drink	2	0.62	0.135902	0.107442	0.125619	0.134833
AB	16					
S	0					

Covariance Matrix Circularity Section

Source Term	Lower Bound Epsilon	Geisser Greenhouse Epsilon	Huynh Feldt Epsilon	Mauchly Test Statistic	Chi2 Value	DF	Prob Level	Covariance Matrix Circularity?
AB	0.500000	0.806148	0.979277	0.759533	1.9	2.0	0.381868	Okay

12. Nausea between drinks.

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subject	8	249.1852	31.14815			
B: drink	2	24.96296	12.48148	1.00	0.389744	0.193524
AB	16	199.7037	12.48148			
S	0					
Total (Adjusted)	26	473.8518				
Total	27					

* Term significant at alpha = 0.05

Table B6. Continued.

Probability Levels for F-Tests with Geisser-Greenhouse Adjustments

Source Term	DF	F-Ratio	Regular Prob Level	Lower Bound Epsilon Prob Level	Geisser Greenhouse Epsilon Prob Level	Huynh Feldt Epsilon Prob Level
A: subject	8					
B: drink	2	1.00	0.389744	0.346594	0.346594	0.346594
AB	16					
S	0					

Power Values for F-Tests with Geisser-Greenhouse Adjustments Section

Source Term	DF	F-Ratio	Regular Power (Alpha=0.05)	Lower Bound Epsilon Power (Alpha=0.05)	Geisser Greenhouse Epsilon Power (Alpha=0.05)	Huynh Feldt Epsilon Power (Alpha=0.05)
A: subject	8					
B: drink	2	1.00	0.193524	0.143256	0.143256	0.143256
AB	16					
S	0					

Covariance Matrix Circularity Section

Source Term	Lower Bound Epsilon	Geisser Greenhouse Epsilon	Huynh Feldt Epsilon	Mauchly Test Statistic	Chi2 Value	DF	Prob Level	Covariance Matrix Circularity?
AB	0.500000	0.500000	0.500000	0.000000	0.0	2.0	1.000000	Okay

13. Osmolar clearance.

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subject	8	346257.4	43282.17			
B: drink	2	44412.32	22206.16	0.92	0.419705	0.180644
AB	16	387429.7	24214.35			
S	0					
Total (Adjusted)	26	778099.4				
Total	27					

* Term significant at alpha = 0.05

Table B6. Continued.

Probability Levels for F-Tests with Geisser-Greenhouse Adjustments

Source Term	DF	F-Ratio	Regular Prob Level	Lower Bound Epsilon Prob Level	Geisser Greenhouse Epsilon Prob Level	Huynh Feldt Epsilon Prob Level
A: subject	8					
B: drink	2	0.92	0.419705	0.366288	0.376427	0.380595
AB	16					
S	0					

Power Values for F-Tests with Geisser-Greenhouse Adjustments Section

Source Term	DF	F-Ratio	Regular Power (Alpha=0.05)	Lower Bound Epsilon Power (Alpha=0.05)	Geisser Greenhouse Epsilon Power (Alpha=0.05)	Huynh Feldt Epsilon Power (Alpha=0.05)
A: subject	8					
B: drink	2	0.92	0.180644	0.135351	0.141935	0.144853
AB	16					
S	0					

Covariance Matrix Circularity Section

Source Term	Lower Bound Epsilon	Geisser Greenhouse Epsilon	Huynh Feldt Epsilon	Mauchly Test Statistic	Chi2 Value	DF	Prob Level	Covariance Matrix Circularity?
AB	0.500000	0.566187	0.596375	0.233798	10.2	2.0	0.006179	Violated

Table B6. Continued.

14. Plasma Osmolality.

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subject	8	333.1759	41.64699			
B: drink	2	22.00926	11.00463	1.32	0.293500	0.244701
AB	16	132.9074	8.306713			
C: time	1	5.041667	5.041667	3.29	0.107146	0.359120
AC	8	12.25	1.53125			
BC	2	17.52778	8.763889	4.12	0.036093*	0.642088
ABC	16	34.05556	2.128472			
S	0					
Total (Adjusted)	53	556.9676				
Total	54					

* Term significant at alpha = 0.05

Probability Levels for F-Tests with Geisser-Greenhouse Adjustments

Source Term	DF	F-Ratio	Regular Prob Level	Lower Bound Epsilon Prob Level	Geisser Greenhouse Epsilon Prob Level	Huynh Feldt Epsilon Prob Level
A: subject	8					
B: drink	2	1.32	0.293500	0.282972	0.292055	0.293376
AB	16					
C: time	1	3.29	0.107146	0.107146	0.107146	0.107146
AC	8					
BC	2	4.12	0.036093*	0.076958	0.060350	0.053475
ABC	16					
S	0					

Table B6. Continued.

Power Values for F-Tests with Geisser-Greenhouse Adjustments Section

Source Term	**DF (Alpha=0.05)**	**F-Ratio**	**Regular Power (Alpha=0.05)**	**Lower Bound Epsilon Power**	**Geisser Greenhouse Epsilon Power (Alpha=0.05)**	**Huynh Feldt Epsilon Power (Alpha=0.05)**
A: subject	8					
B: drink	2	1.32	0.244701	0.174340	0.214200	0.234624
AB	16					
C: time	1	3.29	0.359120	0.359120	0.359120	0.359120
AC	8					
BC	2	4.12	0.642088	0.431005	0.507389	0.542132
ABC	16					
S	0					

Covariance Matrix Circularity Section

Source Term	**Lower Bound Epsilon**	**Geisser Greenhouse Epsilon**	**Huynh Feldt Epsilon**	**Mauchly Test Statistic**	**Chi2 Value**	**DF**	**Prob Level**	**Covariance Matrix Circularity?**
AB	0.500000	0.773458	0.923762	0.707104	2.4	2.0	0.297298	Okay
AC	1.000000	1.000000	1.000000	1.000000	0.0	0.0	1.000000	Okay
ABC	0.500000	0.660054	0.739606	0.484973	5.1	2.0	0.079435	Okay

15. Urine specific gravity.

Analysis of Variance Table

Source Term	**DF**	**Sum of Squares**	**Mean Square**	**F-Ratio**	**Prob Level**	**Power (Alpha=0.05)**
A: subject	8	2.916296E-04	3.64537E-05			
B: drink	2	1.407407E-06	7.037037E-07	0.08	0.923406	0.060164
AB	16	1.405926E-04	8.787037E-06			
S	0					
Total (Adjusted)	26	4.336296E-04				
Total	27					

* Term significant at alpha = 0.05

Table B6. Continued.

Probability Levels for F-Tests with Geisser-Greenhouse Adjustments

Source Term	DF	F-Ratio	Regular Prob Level	Lower Bound Epsilon Prob Level	Geisser Greenhouse Epsilon Prob Level	Huynh Feldt Epsilon Prob Level
A: subject	8					
B: drink	2	0.08	0.923406	0.784368	0.830775	0.848680
AB	16					
S	0					

Power Values for F-Tests with Geisser-Greenhouse Adjustments Section

Source Term	DF	F-Ratio	Regular Power (Alpha=0.05)	Lower Bound Epsilon Power (Alpha=0.05)	Geisser Greenhouse Epsilon Power (Alpha=0.05)	Huynh Feldt Epsilon Power (Alpha=0.05)
A: subject	8					
B: drink	2	0.08	0.060164	0.057235	0.057999	0.058332
AB	16					
S	0					

Covariance Matrix Circularity Section

Source Term	Lower Bound Epsilon	Geisser Greenhouse Epsilon	Huynh Feldt Epsilon	Mauchly Test Statistic	Chi2 Value	DF	Prob Level	Covariance Matrix Circularity?
AB	0.500000	0.610683	0.663281	0.362488	7.1	2.0	0.028677	Violated

Figure B1. Perceptions of Fullness and Nausea Visual Analog Scale.

Fullness

No Fullness
(Feeling of being
very hungry)

Extreme Fullness
(Feeling after eating
a large meal)

Nausea

No Nausea
(Feeling of calmness
in your stomach)

Extreme Nausea
(Feeling of sickness
in your stomach)

Figure B2. Institutional Review Board Approval Letter.

NDSU **NORTH DAKOTA STATE UNIVERSITY**

Institutional Review Board

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February 14, 2012

Kevin Miller
Department of Health, Nutrition and Exercise Science
1 BBFH

Notice of IRB Approval

Protocol **#HE12125**, **"The effect of pre-exercise ingestion of pickle juice, hypertonic saline, and water on aerobic performance in college-aged males"**
Co-investigator(s) and research team: **Jarett Peikert, Jay Albrecht, Jared Tucker, Jim Deal**

Approval period: 2/14/2012 to 2/13/2013 **Continuing Review Report Due: 1/1/2013**

Research site(s): **NDSU** Funding agency: **n/a**
Review Type: ☐ Expedited category # ☒ Full Board
IRB approval is based on original submission, with revised: protocol and consent form (received 2/14/2012).

Additional approval is required:

- o prior to implementation of any proposed changes to the protocol (*Protocol Amendment Request Form*).
- o for continuation of the project beyond the approval period (*Continuing Review/Completion Report Form).* A reminder is typically sent two months prior to the expiration date; timely submission of the report is your responsibility. To avoid a lapse in approval, suspension of recruitment, and/or data collection, a report must be received, and the protocol reviewed and approved prior to the expiration date.

A report is required for:

- o any research-related injuries, adverse events, or other unanticipated problems involving risks to participants or others within 72 hours of known occurrence (*Report of Unanticipated Problem or Serious Adverse Event Form*).
- o any significant new findings that may affect risks to participants.
- o closure of the project (*Continuing Review/Completion Report Form*).

Research records are subject to random or directed audits at any time to verify compliance with IRB regulations and NDSU policies.

Thank you for cooperating with NDSU IRB procedures, and best wishes for a successful study.

Sincerely,

Teryl Grosz

Teryl Grosz, MS, CIP
Manager, Human Research Protection Program

Figure B3. Institutional Review Board Consent to be a Research Subject.

Note: The title of the informed consent was altered to prevent biasing subjects

NDSU North Dakota State University
Dept. of Health, Nutrition, and Exercise Sciences
PO Box 6050
Fargo, ND 58108-6050
701-231-5686

Title of Research Study: The effect of ingesting three drinks on core temperature in college-aged males.

This study is being conducted by: Kevin C. Miller, PhD, ATC; Jarett R. Peikert, ATC; Jay Albrecht, PhD, ATC, Jared Tucker, PhD, and Jim Deal, PhD.

Why am I being asked to take part in this research study? You are being asked to volunteer in this study because you: (1) are a healthy, college aged male (18-26), (2) have no history of cardiovascular, neurological, or blood borne diseases, (3) have no food allergies (especially to pickles), (4) have no history of heat related illnesses such as heat fainting, heat exhaustion, or heat stroke, (5) have not had any injury that limited their ability to exercise in the last 3 months, (6) have not had a surgery in the last 6 months, (7) have never been informed by a physician that you have a cholesterol > 200 mg/dl or a blood pressure > 140/90 mmHg, (8) do not have a body mass index > 30, (9) do not live a sedentary lifestyle (exercising less than 30 minutes 3 times per week), (10) do not smoke, (11) have not had your father or brother pass away or have a heart attack before the age of 55, and (12) have not had your mother or sister pass away or have a heart attack before the age of 45. If you are known to be sensitive to pickles or exercise in the heat, you should not take part in this study.

What is the reason for doing the study? The purpose of this study is to observe core temperature during exercise following the ingestion of three separate drinks. This study will examine multiple variables of exercise and may help people who suffer from muscle cramps or exercise for long durations in the heat.

What will I be asked to do? You will come to a laboratory (Room 14 Bentson Bunker Fieldhouse) on 3 days separated by at least 48 hours. We ask that you drink water prior to coming in each day, to maintain a consistent diet, not eat for 12 hours prior to participating, and avoid exercising, alcohol, or caffeine for 24 hours prior to each testing session.
On the first day of testing, you will provide written consent by signing your name to the end of this form. We will then ask you questions about your health history (e.g., do you have a history of heat illness? do you have any food allergies?, etc) as well as questions to determine if you have followed the instructions we provided you prior to coming in for testing (e.g., drink water, fasted for 12 hours, etc).
You will then give us a urine sample and be weighed. You will don a heart rate monitor, insert rectal thermistor, and sit for 30 minutes. During this time, your forearm will be prepared for venipuncture (needle stick).

Figure B3. Continued .

A trained phlebotomist (person experienced in taking blood samples) will clean your arm with alcohol twice to remove any dirt or contaminants from the needle stick site. This makes the risk of infection very small. We will use universal precautions (eg, wear gloves, use alcohol to clean your arm) when dealing with your blood to minimize risk of infection and contamination. A sterile 20 gauge catheter will then be inserted into a superficial vein in your forearm. A catheter is a small flexible tube that remains in your arm so the needle can be retracted. By retracting the needle, you can move your arm more comfortably and do not have to worry about the needle hurting you. The purpose of the catheter is to allow us to collect small volumes of your blood.

After 30 minutes of sitting, we will collect a 5 ml (< ¼ oz) blood sample. You will then have 1 minute to ingest the treatment drink (2 ml/kg body weight) and 4 minutes to ingest water (5 ml/kg body weight). For example, a 70 kg person will ingest 140 ml/kg of treatment drink and 350 ml/kg of water (490 ml total). A 16 oz pop bottle has about 473 ml. After drinking the fluids, you will remain seated for another 30 minutes before a second 5 ml blood sample will be collected. We will then remove the catheter from your right arm, collect a second urine sample and weigh you.

You will then exercise in a hot enviornment on a treadmill for 30 minutes at a low intensity. Following the 30 minutes of exercise, the speed of the treadmill will increase to a slightly higher intensity and continue to increase every 10 minutes. The primary investigator will monitor your heart rate and rectal temperature continuously during the exercise duration and make any adjustments to the treadmill needed. You will continue with the exercise protocol until you are exhuasted to the point you can no longer continue or you are stopped by the primary investigator because your core temperature exceeds 39.5ºC. Following the exercise protocol, you will complete a 5 minute cool down at a comfortable walking speed. Upon exiting the heat chamber, you will towel dry, be weighed, and provide a urine sample. Following this urine sample, you will be excused and asked to return a minimum of 48 hours later for the next testing session. After completing all 3 days of the study, one of the investigators will explain your results and further details of the study.

Where is the study going to take place, and how long will it take? You will report to Room 14 in the Bentson Bunker Fieldhouse each day. Each session will last about 2-2.5 hours. Total participation time will be about 6-7.5 hours.

What are the risks and discomforts? There are 4 risks if you participate in this study. First, you could develop an infection at the site where we insert the catheter to take your blood. This risk will be near zero because universal precautions will taken when handling your blood or touching you. These precautions include: the investigator will wear non-latex gloves at all times, alcohol will be used to disinfect and clean your arm, and sterile catheters will be used and disposed of following veinipuncture. You will also be taught the signs of an infection (e.g., redness, swelling, increase in body temperature, pussy discharge, pain) and what to do if you suspect an infection has occurred (see a physician immediately). Secondly, you could develop a heat related illness such as heat fainting, exhaustion, or stroke. This risk is small because your core temperature will be continuously monitored by an investigator to make sure it does not exceed safe levels (i.e., >103°F). Regardless, if you have a history of heat related illnesses, you should not participate in this study. Should a medical emergency arise, the primary investigator

Figure B3. Continued

will provide emergency care since he is a certified and licensed athletic trainer. Such care will likely involve removing you from the heat chamber and having you drink cool liquids while ice packs are placed under your arms, legs, and head. If your core temperature exceeds 104°F you will be brought across the hall by the investigators and submerged in a cold whirl pool. This is the safest and most effective treatment for heat stroke. Further information on the treatment of heat illnesses can be provided to you by the primary investigator, an expert in the care and prevention of heat illnesses, if you wish. Third, you could have a cardiovascular event. If you have an unknown heart condition, the extra stress placed on your heart during intense exercise could cause an event. To minimize the chances of this happening, we have extensive exclusion criteria to remove risk factors associated with exercise and cardiovascular events. Fourth, you may experience nausea, stomach upset, vomiting, or general discomfort following the needle stick or ingestion of the fluids.

What are the benefits to me? You are not likely to gain any benefit from being in this research study. However, if you are a student, you may gain some benefit by seeing how experimental research is performed.

What are the benefits to other people? Some researchers have observed that 95% of the population suffers from muscle cramping. Thus, this research can potentially help many people who suffer from frequent muscle cramps. Further benefits are hoped to be observed during this study.

Do I have to take part in the study? Your participation in this research is your choice. If you decide to participate in the study, you may change your mind and stop participating at any time without penalty or loss of benefits to which you are already entitled.

What will it cost me to participate? There is no monetary cost to you. This study will require about 2-2.5 hours of your time on 3 days (6-7.5 hours total).

What are the alternatives to being in this research study? You can choose not to participate. You can ask the research team about other studies you can participate in now or at a later date.

Who will see the information that I give? We will keep private all research records that identify you. When we write about the study, we will write about the combined information from all subjects that we have gathered. We may publish the results of the study; however, we will keep your name and other identifying information private. We will make every effort to prevent anyone who is not on the research team from knowing your information or even that you gave us information. For example, your name will be kept separate from your research records and these two things will be stored in different places under lock and key.

Can my taking part in the study end early? If you fail to show up to all sessions you may be removed from the study and may not receive your monetary compensation.

Figure B3. Continued

Will I receive any compensation for taking part in this study? You will receive $45 for your time upon completion of the study. If you elect to drop out of the study prior to the study's completion, you will receive $5.63 for every hour of the study that you complete.

What happens if I am injured because of this research? If you receive an injury in the course of taking part in the research, you should contact Dr. Margret Fitzgerald, chair of the department of Health, Nutrition, and Exercise Sciences, at the following phone number (701) 231-5590. Treatment for the injury will be available including first aid, emergency treatment and follow-up care as needed. Payment for this treatment must be provided by you and your third party payer (such as health insurance or Medicare). This does not mean that you are releasing or waiving any legal right you might have against the researcher or NDSU as a result of your participation in this research.

What if I have questions?

Before you decide whether to accept this invitation to take part in the research study, please ask any questions that might come to mind now. Later, if you have any questions about the study, you can contact the researchers Jarett R Peikert at (612) 227-6316 or Jarett.peikert@my.ndsu.edu, Dr. Kevin C. Miller at (701) 231-5686 or Kevin.C.Miller@ndsu.edu.

What are my rights as a research participant?

You have rights as a participant in research. If you have questions about your rights, complaints about this research, or wish to notify someone about any research related injuries you incur as a result of this study, you may talk to the researcher or contact the NDSU Human Research Protection Program by:
Telephone: 701.231.8908
Email: ndsu.irb@ndsu.edu
Mail: NDSU HRPP Office, NDSU Dept. 4000, PO Box 6050, Fargo, ND 58108-6050.

The role of the Human Research Protection Program is to see that your rights are protected in this research; more information about your rights can be found at: www.ndsu.edu/research/irb .

Documentation of Informed Consent:

You are freely making a decision whether to be in this research study. Signing this form means that you have read and understood this consent form you have had your questions answered, and you have decided to be in the study.

You may request a copy of this informed consent if you wish to have one for your records.

___________________________________ ____________

Your signature Date

____

Your printed name

Figure B3. Continued

Signature of researcher explaining study Date

Printed name of researcher explaining study

Figure B4. Institutional Biosafety Committee Approval Letter.

NDSU NORTH DAKOTA STATE UNIVERSITY

701.231.8114
Fax 701.231.8098

Institutional Biosafety Committee

Office of the Vice President for Research, Creative Activities and Technology Transfer
NDSU Dept. 4000
1735 NDSU Research Park Drive
Research 1, P.O. Box 6050
Fargo, ND 58108-6050

March 20, 2012

Dr. Kevin Miller
Dept. of Health, Nutrition & Exercise Science
BBFH

Re: IBC Project **#B12016: "Laboratory research performed in Room 14 BBFH"**

Approval Date: **March 20, 2012**

Co-Investigators and research team: Kevin Miller, Scott Allen, Kyle Braulick, Jarett Peikert, Mike McKenney

The project referenced above has been reviewed and accepted under the categorization of "***human blood and tissue***" by the Institutional Biosafety Committee (IBC). A copy of the *IBC Protocol Form* is being forwarded to you with the committee approval.

No further reporting to the NDSU IBC is required for this project unless there are unexpected events concerning exposure or containment of the agent(s) involved, or you decide to make a change in the project. Although, no further reporting is necessary an annual update will be sent to you to help track and monitor the work over the course of the project. If you decide to make changes, please notify the NDSU IBC before any change is implemented.

Thank you for complying with NDSU IBC procedures, and best wishes for success with your project.

NDSU, Institutional Biosafety Committee

APPENDIX C. ADDITIONAL RESULTS

Table C1. Hematocrit, Hemoglobin, and Changes in Plasma Volume Data.

Subject #	Fluid	Time	Hct	Hb (abs)	Hb g/dl	Δ PV
1	DIW	0	47	0.232667	16.81509	0
1	DIW	30	47.75	0.231667	16.74209	-0.98528077
1	PJ	0	45.167	0.228	16.47445	0
1	PJ	30	46.58	0.230333	16.64477	-3.573789491
1	SALINE	0	44.83	0.236333	17.2598	0
1	SALINE	30	45.66	0.227	16.57353	2.574050244
2	DIW	0	45.5	0.235	16.9854	0
2	DIW	30	45.08	0.232667	16.81509	1.791325888
2	PJ	0	46.75	0.242667	17.54501	0
2	PJ	30	47	0.235	16.9854	2.809705485
2	SALINE	0	48.08	0.242667	17.54501	0
2	SALINE	30	46.875	0.238667	17.25304	4.052440169
3	DIW	0	45.08	0.222	16.0365	0
3	DIW	30	45	0.212	15.30657	4.921330059
3	PJ	0	45.33	0.214333	15.64216	0
3	PJ	30	45.83	0.219667	16.03431	-3.337945463
3	SALINE	0	43.5	0.218	15.74453	0
3	SALINE	30	44.125	0.222	16.0365	-2.906719138
4	DIW	0	43.25	0.220	16.05882	0
4	DIW	30	43.58	0.217	15.81373	0.959396533
4	PJ	0	43.5	0.219667	16.03431	0
4	PJ	30	44.5	0.219	15.98529	-1.468684615
4	SALINE	0	41.75	0.216333	15.78922	0
4	SALINE	30	42.67	0.208	15.17647	2.394300828
5	DIW	0	41.08	0.205333	14.81995	0
5	DIW	30	39.875	0.209333	15.11192	0.073576565
5	PJ	0	42.83	0.222333	16.06083	0
5	PJ	30	42.67	0.211333	15.25791	5.556913169
5	SALINE	0	44	0.222	16.0365	0
5	SALINE	30	44.25	0.226667	16.37713	-2.517071864
6	DIW	0	44.58	0.215	15.52555	0
6	DIW	30	45.92	0.206333	14.89294	1.727067828
6	PJ	0	46.75	0.223333	16.13382	0
6	PJ	30	46.25	0.227667	16.45012	-1.00187974
6	SALINE	0	47.42	0.241667	17.47202	0

Table C1. Continued

Subject #	Fluid	Time	Hct	Hb (abs)	Hb g/dl	Δ PV
6	SALINE	30	47.17	0.238333	17.22871	1.89441054
7	DIW	0	47.33	0.237	17.13139	0
7	DIW	30	45.25	0.234	16.91241	5.295027164
7	PJ	0	46.33	0.240667	17.39903	0
7	PJ	30	45.875	0.234	16.91241	3.749450122
7	SALINE	0	46.25	0.229333	16.7451	0
7	SALINE	30	45.58	0.23	16.79412	0.950987659
8	DIW	0	46.167	0.230667	16.84314	0
8	DIW	30	46.167	0.245	17.89706	-5.88879759
8	PJ	0	47.167	0.246	17.78832	0
8	PJ	30	48.167	0.258	18.66423	-6.496928979
8	SALINE	0	46.25	0.234333	16.93674	0
8	SALINE	30	45.75	0.221	15.9635	7.083577021
9	DIW	0	47.83	0.262	19.14706	0
9	DIW	30	48	0.257333	18.80392	1.493013436
9	PJ	0	47.33	0.238	17.35784	0
9	PJ	30	47.83	0.246	17.9951	-4.456958896
9	SALINE	0	47.917	0.240333	17.55392	0
9	SALINE	30	47.917	0.232667	16.9902	3.317945759

Hct = hematocrit, Hb (abs) = hemoglobin absorption, Hb = hemoglobin, Δ PV = change in plasma volume, DIW = deionized water, PJ = pickle juice.

Table C2. Plasma Electrolyte, Osmolality, and Glucose Data.

Subject	Fluid	Time	[Na]p	[K]p	[Cl]p	Glucose	OSMp
1	DIW	0	139	4	104	5.3	276
1	DIW	30	138	4.1	104	5.2	273.5
1	PJ	0	139	4	104	5.2	275.5
1	PJ	30	141	4.2	106	5.2	279
1	SALINE	0	139.5	3.8	103	5.15	280
1	SALINE	30	141	4	104.5	4.85	282.5
2	DIW	0	143	3.8	109	5.75	288.5
2	DIW	30	142	4.1	106.5	5.55	286
2	PJ	0	142	3.7	105	5.65	285.5
2	PJ	30	142.5	3.9	106	5.4	287.5
2	SALINE	0	141	3.8	106	5.4	283
2	SALINE	30	141	3.9	105.5	5.3	283
3	DIW	0	142	3.9	106	5.2	287.5
3	DIW	30	141	3.9	104	4.9	285
3	PJ	0	143	4	106	5.15	287
3	PJ	30	143	4	107	5	286.5
3	SALINE	0	141	3.8	104	4.8	286.5
3	SALINE	30	141	3.8	105	5	286.5
4	DIW	0	141	4.2	105.5	5.5	283
4	DIW	30	139	4.1	104.5	5.35	279.5
4	PJ	0	142	4.3	107	5	286
4	PJ	30	142	4.3	106	4.85	286.5
4	SALINE	0	140	3.8	106.5	5.2	281
4	SALINE	30	140	3.9	106.5	5	282.5
5	DIW	0	141.5	4	108.5	5.25	283.5
5	DIW	30	141.5	4	108	5.2	282.5
5	PJ	0	140.5	4.1	105.5	5.55	283
5	PJ	30	139	4.3	106	5.3	280.5
5	SALINE	0	141.5	4.05	106	5.2	284
5	SALINE	30	142	4.1	106	4.9	283
6	DIW	0	141	4.3	104	5.35	285.5
6	DIW	30	139	4.3	102.5	5.3	281.5
6	PJ	0	141	4.1	104	5.55	286.5
6	PJ	30	140.5	4.2	103	5.5	285
6	SALINE	0	141	4.4	102	4.95	287
6	SALINE	30	141	4.6	103	5.2	287.5
7	DIW	0	144	4	109.5	5.6	285
7	DIW	30	140	4.05	107	5.4	279
7	PJ	0	142	4.1	107	5.5	283
7	PJ	30	142	4	107	5.6	285.5
7	SALINE	0	142.5	4	107	5.8	285

Table C2. Continued.

Subject	Fluid	Time	[Na]p	[K]p	[Cl]p	Glucose	OSMp
7	SALINE	30	141	3.8	107	5.6	283
8	DIW	0	141	3.7	103	4.85	280.5
8	DIW	30	141	3.9	103	4.9	282
8	PJ	0	142	3.65	103.5	5.25	285.5
8	PJ	30	142	3.8	103.5	5.2	283.5
8	SALINE	0	142	3.9	105	5.1	282.5
8	SALINE	30	141	4	104	4.95	281.5
9	DIW	0	142	3.8	102.5	5.9	286.5
9	DIW	30	142	3.9	103	5.5	287
9	PJ	0	142	3.6	104	6.2	287
9	PJ	30	142	3.6	103.5	6.2	287
9	SALINE	0	137.5	3.5	102	5.6	282
9	SALINE	30	141	3.5	104	5.7	283

[Na]p = plasma sodium concentration, [K]p = plasma potassium concentration, [Cl]p = plasma chloride concentration, Glucose = plasma glucose concentration, OSMp = plasma osmolality. DIW = deionized water, PJ = pickle juice.

Table C3. Urine Data.

Subject #	Fluid	Time	$Urine_{sg}$	$Urine_{vol}$	Urine Osmo
1	DIW	arrival	1.008	NM	NM
1	DIW	Pre-exercise	1.001	845	71.5
1	DIW	Post-exercise	1.001	560	65
1	PJ	arrival	1.002	NM	NM
1	PJ	Pre-exercise	1.001	960	67
1	PJ	Post-exercise	1.002	642	84.5
1	SALINE	arrival	1.002	NM	NM
1	SALINE	Pre-exercise	1.001	920	64
1	SALINE	Post-exercise	1.001	530	80.5
2	DIW	arrival	1.002	NM	NM
2	DIW	Pre-exercise	1.004	450	167
2	DIW	Post-exercise	1.002	590	101.5
2	PJ	arrival	1.002	NM	NM
2	PJ	Pre-exercise	1.001	960	65.5
2	PJ	Post-exercise	1.003	560	110
2	SALINE	arrival	1.003	NM	NM
2	SALINE	Pre-exercise	1.001	670	95
2	SALINE	Post-exercise	1.003	360	159
3	DIW	arrival	1.007	NM	NM
3	DIW	Pre-exercise	1.003	470	138
3	DIW	Post-exercise	1.002	480	111.5
3	PJ	arrival	1.011	NM	NM
3	PJ	Pre-exercise	1.005	300	231.5
3	PJ	Post-exercise	1.003	455	146.5
3	SALINE	arrival	1.011	NM	NM
3	SALINE	Pre-exercise	1.004	235	189
3	SALINE	Post-exercise	1.005	185	245
4	DIW	arrival	1.003	NM	NM
4	DIW	Pre-exercise	1.003	240	196
4	DIW	Post-exercise	1.002	175	154.5
4	PJ	arrival	1.001	NM	NM
4	PJ	Pre-exercise	1.001	712	91
4	PJ	Post-exercise	1.002	310	141
4	SALINE	arrival	1.001	NM	NM
4	SALINE	Pre-exercise	1.001	690	79
4	SALINE	Post-exercise	1.001	260	113
5	DIW	arrival	1.005	NM	NM

Table C3. Continued.

Subject #	Fluid	Time	$Urine_{sg}$	$Urine_{vol}$	Urine Osmo
5	DIW	Pre-exercise	1.001	1020	87
5	DIW	Post-exercise	1.002	131	290
5	PJ	arrival	1.007	NM	NM
5	PJ	Pre-exercise	1.003	216	187
5	PJ	Post-exercise	1.012	63	527.5
5	SALINE	arrival	1.012	NM	NM
5	SALINE	Pre-exercise	1.001	500	122.5
5	SALINE	Post-exercise	1.002	233	120.5
6	DIW	arrival	1.007	NM	NM
6	DIW	Pre-exercise	1.006	325	263.5
6	DIW	Post-exercise	1.002	440	110
6	PJ	arrival	1.004	NM	NM
6	PJ	Pre-exercise	1.009	118	398.5
6	PJ	Post-exercise	1.004	160	245
6	SALINE	arrival	1.002	NM	NM
6	SALINE	Pre-exercise	1.002	700	121
6	SALINE	Post-exercise	1.006	220	264.5
7	DIW	arrival	1.012	NM	NM
7	DIW	Pre-exercise	1.018	81	957.5
7	DIW	Post-exercise	1.008	83	415.5
7	PJ	arrival	1.012	NM	NM
7	PJ	Pre-exercise	1.016	61	678.5
7	PJ	Post-exercise	1.014	74	519.5
7	SALINE	arrival	1.012	NM	NM
7	SALINE	Pre-exercise	1.019	55	705.5
7	SALINE	Post-exercise	1.024	31	848.5
8	DIW	arrival	1.002	NM	NM
8	DIW	Pre-exercise	1.001	608	84.5
8	DIW	Post-exercise	1.002	228	98.5
8	PJ	arrival	1.012	NM	NM
8	PJ	Pre-exercise	1.004	340	187.5
8	PJ	Post-exercise	1.004	345	135.5
8	SALINE	arrival	1.011	NM	NM
8	SALINE	Pre-exercise	1.004	410	191.5
8	SALINE	Post-exercise	1.014	55	597
9	DIW	arrival	1.008	NM	NM
9	DIW	Pre-exercise	1.004	930	110

Table C3. Continued.

Subject #	Fluid	Time	$Urine_{sg}$	$Urine_{vol}$	Urine Osmo
9	DIW	Post-exercise	1.004	602	108.5
9	PJ	arrival	1.006	NM	NM
9	PJ	Pre-exercise	1.003	437	198
9	PJ	Post-exercise	1.003	387	180
9	SALINE	arrival	1.005	NM	NM
9	SALINE	Pre-exercise	1.001	1095	87
9	SALINE	Post-exercise	1.002	590	113.5

DIW = Deionized water, PJ = Pickle Juice, SALINE = Hypertonic Saline, NM = Not Measured, $Urine_{sg}$ = Urine specific Gravity, $Urine_{vol}$ = Urine volume, Osmo = Osmolality.

Table C4. Fluid Volume, Osmolar Clearance, Water Clearance, and Sweat Volume Data.

Subject #	Fluid	Volume of Fluid (mL)	Volume of DIW (mL)	Osmolar Clearance	Free Water Clearance	Sweat Volume
1	DIW	146	365	203.0470074	577.1930665	1.08
1	PJ	146	365	214.2130991	672.2134937	0.97
1	SALINE	146	365	193.3066585	656.185493	0.89
2	DIW	162	405	241.5686048	173.9438606	1.03
2	PJ	164	410	202.6559924	683.7706004	0.67
2	SALINE	160	400	207.6746637	410.9772292	0.74
3	DIW	162	405	209.2199011	224.759785	1.27
3	PJ	162	405	223.6353054	53.37300485	1.38
3	SALINE	162	405	143.1451321	73.84471098	1.28
4	DIW	136	340	154.4352108	67.17143737	1.19
4	PJ	138	345	209.0005524	448.4325039	1.56
4	SALINE	136	340	178.642094	458.4770196	1.42
5	DIW	138	345	289.537308	652.2909468	1.83
5	PJ	136	340	132.3740866	67.07189681	0.94
5	SALINE	136	340	199.4915815	262.1889356	1.13
6	DIW	170	425	278.9218009	21.17053517	1.46
6	PJ	168	420	151.9482272	-42.99162512	1.26
6	SALINE	166	415	272.2669438	374.0857802	1.22
7	DIW	244	610	253.9488419	-179.1565981	1.19
7	PJ	246	615	134.4468889	-78.12186579	1.21
7	SALINE	244	610	126.1574526	-75.37259568	1.22
8	DIW	150	375	168.6705653	392.7329435	0.7
8	PJ	150	375	206.9042739	107.0384777	0.79
8	SALINE	150	375	257.0840128	121.4940113	0.52
9	DIW	182	455	329.4152879	529.3104739	1.11
9	PJ	184	460	278.378874	125.1298979	1.06
9	SALINE	184	460	1066.230169	-55.14983631	1.72

DIW = Deionized water, PJ = Pickle Juice, SALINE = Hypertonic Saline.

Table C5. Core Temperatures, Time to Exhaustion, Reason for Termination Data.

Subject #	Drink	Core Temp Pre-exercise	Core temp at finish	Finish Time (min)	Reason for Termination
1	DIW	36.63	38.4	76.3	exhaustion
1	PJ	36.81	38.5	72.667	exhaustion
1	SALINE	36.66	37.99	73.5	exhaustion
2	DIW	36.62	38.64	71.58	exhaustion
2	PJ	36.67	38.87	75.5	exhaustion
2	SALINE	36.43	38.9	75.833	exhaustion
3	DIW	36.53	38.59	75.3	exhaustion
3	PJ	36.65	39.01	77.23	exhaustion
3	SALINE	36.51	38.75	77.417	exhaustion
4	DIW	36.69	39.14	83.25	exhaustion
4	PJ	36.42	38.46	91.167	exhaustion
4	SALINE	36.66	38.95	84.967	exhaustion
5	DIW	36.42	38.79	73.867	exhaustion
5	PJ	36.32	39.17	81.67	exhaustion
5	SALINE	36.48	38.66	79.33	exhaustion
6	DIW	36.87	39.47	76.58	exhaustion
6	PJ	36.75	38.73	74.83	exhaustion
6	SALINE	36.82	38.67	75.15	exhaustion
7	DIW	36.97	38.59	74.02	exhaustion
7	PJ	36.74	38.72	74.367	exhaustion
7	SALINE	37	38.2	73.567	exhaustion
8	DIW	36.71	38.34	75.417	exhaustion
8	PJ	37.1	38.3	77.58	Exhaustion
8	SALINE	36.93	38.49	74.8	Exhaustion
9	DIW	36.62	39.1	74.83	exhaustion
9	PJ	36.05	38.41	71.667	exhaustion
9	SALINE	36.82	39.36	82.467	Exhaustion

DIW = Deionized water, PJ = Pickle Juice, SALINE = Hypertonic Saline.

Table C6. Environmental Chamber Temperature and Humidity, Nausea and Fullness Data.

Subject #	Drink	Temp Start	Temp End	Humidity Start	Humidity End	Nausea (0-100)	Fullness (0-100)
1	DIW	38	38	16	20	0	52
1	PJ	39	42	16	32	0	30
1	SALINE	37	38	16	21	0	39
2	DIW	37	37	16	29	8	20
2	PJ	37	37	16	23	0	23
2	SALINE	36	37	16	25	21	14
3	DIW	36	38	16	33	0	15
3	PJ	39	39	16	20	0	45
3	SALINE	37	40	16	27	0	32
4	DIW	38	39	16	24	0	4
4	PJ	40	38	16	22	0	15
4	SALINE	38	40	16	22	0	13
5	DIW	37	38	16	31	0	24
5	PJ	38	38	20	39	0	19
5	SALINE	38	38	16	38	0	24
6	DIW	36	38	26	48	0	25
6	PJ	37	37	16	35	0	22
6	SALINE	35	39	16	16	0	24
7	DIW	39	39	16	20	0	42
7	PJ	39	39	16	16	0	74
7	SALINE	39	40	16	27	0	62
8	DIW	40	39	16	16	0	88
8	PJ	39	38	20	26	0	69
8	SALINE	38	40	16	18	0	28
9	DIW	39	39	20	20	0	35
9	PJ	39	40	16	19	0	54
9	SALINE	39	39	16	20	0	56

DIW = Deionized water, PJ = Pickle Juice, SALINE = Hypertonic Saline.

APPENDIX D. RECOMMENDATIONS FOR FUTURE RESEARCH

Table D1. Recommendations for Future Research.

1. Determine if ingesting 2 mL*kg^{-1} pickle juice or hypertonic saline with a moderate amount of water 60, 90, and 120 minutes pre-exercise reduces time to exhaustion and affects core temperature, plasma volume or sweat volume.
2. Determine if ingesting 2 mL*kg^{-1} pickle juice or hypertonic saline with a moderate amount of water 60, 90, and 120 minutes pre-exercise affects strength or anaerobic performance.
3. Determine if varying amounts of pickle juice or hypertonic saline affect aerobic performance.
4. Determine if varying amounts of pickle juice or hypertonic saline ingested pre-exercise increase the amount of *ad libitum* ingestion of water during exercise.
5. Determine the gastric emptying rate following the ingestion of 2 mL*kg^{-1} pickle juice and hypertonic saline.