AD LIBITUM FLUID INTAKE AND PLASMA RESPONSES FOLLOWING PICKLE JUICE, HYPERTONIC SALINE, AND DEIONIZED WATER INGESTION

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Hypertonic Saline, and Deionized Water Ingestion

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MASTER OF SCIENCE

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ABSTRACT

Some clinicians warn against pickle juice (PJ) ingestion due to its sodium. PJ drinking guidelines have been developed but never tested. The purpose of this study was to determine if drinking PJ, hypertonic saline (HS), or deionized water (DIW) affected *ad libitum* DIW ingestion, plasma variables, or perceptions of thirst, fullness, or nausea (perceptual indicators). On three days, subjects were dehydrated (~2%), given one of three treatment drinks, rated its palatability, and rehydrated with DIW *ad libitum*. Over 60 minutes of rehydration blood samples and perceptual indicators were collected. Subjects consumed more DIW *ad libitum* following HS and PJ than DIW. Plasma variables and perceptions of thirst, fullness and nausea didn't differ between treatment drinks. The rationale behind PJ drinking guidelines is questionable. Subjects drink more, not less, after PJ ingestion. Plasma variables and perceptual indicators didn't differ between PJ and DIW. Athletes should schedule their drinking to fully rehydrate.

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DEDICATION

I dedicate this Thesis to my loving and supportive family for allowing me to chase my dreams, wherever they may take me. None of this would have been possible without your confidence. I look forward to my next journey knowing you'll support me throughout.

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INTRODUCTION

Adding sodium (Na^+) to drinks improves rehydration[1,2] and *ad libitum* fluid consumption in hypohydrated individuals.[3] Furthermore, drinks containing Na^+ can more effectively restore plasma volume and plasma sodium concentration ($[Na^+]_p$) than drinks without Na^+.[4] To aid in rehydration and minimize electrolyte loss, the National Athletic Trainers' Association (NATA) recommends athletes replace 150% of their fluid losses and add 0.3 to 0.7 g of Na^+ to every liter of an athlete's rehydration beverage.[5] Some scientists[6] and clinicians[7] have experimented with atypical high Na^+ fluids (e.g., chicken noodle soup and pickle juice).

Pickle juice, a salty ($[Na^+]$ ranging from 415.2 to 978.5 $mmol \cdot L^{-1}$), acidic brine,[8-10] has been advocated as a treatment for exercise-associated muscle cramps (EAMCs).[7,11,12] In fact, 25% (92 of 370) of athletic trainers use or have used pickle juice as a treatment for EAMCs.[12] While limited experimental data on pickle juice's effectiveness for treating EAMCs exist,[7] pickle juice has been shown to reduce electrically-induced muscle cramp duration in 3% hypohydrated males without altering $[Na^+]_p$.[9]

Some clinicians[13] have expressed concern about athletes ingesting pickle juice because of its high Na^+ content. They[13] fear drinking pickle juice will increase $[Na^+]_p$ and cause a rapid plasma volume restoration thereby decreasing thirst and delaying rehydration. This led to the creation of pickle juice drinking guidelines[13] and the recommendation that athletes drink to a prescribed, rather than *ad libitum*, drinking schedule.[14] However, these guidelines[13] are theoretical, based on mathematical equations rather than scientific evidence, and fail to consider $[Na^+]_p$ during rehydration. These fluid ingestion estimates must therefore be considered "target volumes." Data comparing actual *ad libitum* fluid ingestion post-pickle juice consumption to the drinking guidelines is non-existent. Moreover, observations of *ad libitum* fluid ingestion

following pickle juice consumption is sparse.[14] However, the experimental design prevents valid conclusions because these authors[14] provided different fluids to ingest *ad libitum*, tested fluids with different [Na^+], and did not control the temperature of the fluids ingested. As a result, the validity of their[14] *ad libitum* fluid ingestion volumes is questionable because [Na^+],[3] flavoring,[15] and temperature[16] affect fluid ingestion.

Therefore, the purpose of our study was to answer the following question: Does ingesting small volumes (1 $mL \cdot kg^{-1}$ body mass) of pickle juice, hypertonic saline, or DIW immediately prior to *ad libitum* DIW consumption affect *ad libitum* fluid consumed, changes in plasma volume, $[Na^+]_p$, plasma osmolality (OSM_p), perceptions of thirst, fullness, and nausea, or palatability in hypohydrated males? We hypothesized *ad libitum* fluid ingestion, changes in plasma volume, $[Na^+]_p$, OSM_p, and perceptual indicators (i.e., thirst, fullness, and nausea) would be higher following pickle juice and hypertonic saline consumption than DIW. We also hypothesized palatability would be lower following pickle juice and hypertonic saline ingestion than DIW.

METHODS

Experimental Design

A 3x6 factorial, crossover design with repeated measures guided data collection. The independent variables were treatment drink (pickle juice strained from whole kosher dill pickles, Pinnacle Foods Corp, Cherry Hill, NJ], hypertonic saline, or DIW) and time (-105 and -0.5 minutes pre-ingestion, 15, 30, 45, and 60 minutes post-ingestion). The hypertonic saline solution contained a $[Na^+]$ similar to pickle juice and was added as a treatment drink in this study to determine if ingredients in pickle juice (e.g., acetic acid, carbohydrates), other than its Na^+ content, affect *ad libitum* DIW ingestion. The dependent variables were volume of fluid consumed *ad libitum* (mL), hematocrit (%), hemoglobin concentration ($g \cdot dL^{-1}$), OSM_p ($mOsm \cdot kg^{-1}$ H_2O), and $[Na^+]_p$ ($mmol \cdot L^{-1}$). Perceptual indicators were quantified using 100-mm visual analog scales (e.g., 0 = no thirst, fullness, or nausea, 100 = extreme thirst, fullness, or nausea). Palatability of the treatment drinks was assessed using a single 100-mm visual analog scale (e.g., 0 = unpalatable, 100 = palatable). Thirst and palatability were measured to test the hypothesis that pickle juice impedes thirst[13] and is unpalatable.[17] Nausea and fullness were measured to characterize gastrointestinal distress. Urine specific gravity was used to characterize hydration status before exercise; body mass measures pre- and post-exercise were used to determine percent hypohydration.

Subjects

Sample size was estimated *a priori* using other scientists[6] *ad libitum* fluid ingestion data. We estimated 15 subjects would be needed to achieve significance at an alpha level of 0.05 with 80% power. A convenience sample of 15 healthy males (age = 22 ± 2 yrs, ht = 178.47 ± 6.26 cm, mass = 82.97 ± 8.36 kg) completed this study.

Volunteers were excluded if they: (1) were female, (2) had a history of heat-related illnesses (e.g., heat exhaustion, heat stroke, heat syncope) in the six months prior to data collection, (3) had a lower extremity injury or surgery in the 12 months prior to data collection, (4) self-reported a history of heart disease, asthma, diabetes, high blood pressure or cholesterol, (5) self-reported a history of chest pain, dizziness, fainting, blackouts, or unreasonable breathlessness during exercise, (6) had any food allergies, (7) smoked, (8) were not between the ages of 18-30, (9) did not meet current ACSM guidelines for physical activity,[18] or (10) were heat acclimated.[19] The study's procedures were approved by our university's institutional review board prior to data collection, and all subjects provided written consent.

Procedures

Twenty-four hours prior to each testing session, subjects were instructed to drink water consistently, avoid alcohol and caffeine, and refrain from strenuous exercise. Twelve hours prior to testing, subjects were instructed to fast, during which they were only allowed to drink water. Subjects self-reported compliance prior to testing each day. If subjects were noncompliant with pretesting instructions, they were excused and rescheduled for a different day at least 48 hours later.

On each testing day, subjects reported to a laboratory and voided their bladders completely. Urine was collected and analyzed with a refractometer (SUR-Ne; Atago USA Inc., Bellevue, WA) to ensure subjects were euhydrated (urine specific gravity < 1.02).[20] Subjects inserted a rectal thermometer (YSI; Advanced Instruments Inc., Norwood, MA) and donned a heart rate monitor (Polar Electric Inc., Lake Success, NY). Next, a venous catheter was inserted into a superficial forearm vein, subjects were weighed nude to the nearest tenth kilogram (DA-150, Denver Instrument, Bohemia, NY), and donned a sweat suit (i.e., sweatshirt and

sweatpants). Next, subjects were seated and asked to minimize movement as much as possible for 30 minutes to allow for body fluid compartment equilibration.[21]

After equilibration, a 5-mL blood sample was collected (-105 minutes pre-ingestion). Subjects then exercised in an environmental chamber (36 ± 2°C, 16 ± 1% RH) at an intensity that kept their heart rate between 80 and 90% of their age-predicted maximal heart rate. This was considered hard exercise.[22] Subjects alternated between treadmill running and cycling on a standard cycle ergometer (Monark 818E, Stockholm, Sweden) every 15 minutes for 60 minutes. Exercise was terminated if rectal temperature exceeded 39°C, subjects showed signs and symptoms of heat illness (e.g., dizziness, nausea, confusion), or requested to stop. No fluid was administered during exercise. Following exercise, subjects biked at a self-selected pace for 5 minutes to cool down. After the 5-minute cool down, subjects exited the environmental chamber, towel dried, voided their bladders completely, and were weighed nude. Subjects changed into dry clothing, were seated in a climate controlled room (21 ± 2°C), and instructed to minimize movement as much as possible for 30 minutes.

Following this equilibration period, a 5-mL blood sample was collected (-0.5 minutes pre-ingestion). Subjects rated their perceived thirst, nausea, and fullness by making marks on separate 100-mm visual analog scales. The distance between zero and the subjects' marks were measured and used for data analysis. Subjects then had 30 seconds to consume 1 $mL \cdot kg^{-1}$ body mass (pre-exercise body mass) of chilled (5 ± 1°C) pickle juice, hypertonic saline, or DIW. Immediately after consuming the treatment drink, subjects rated the treatment drink's palatability. Subjects were then given pre-weighed opaque wattle bottles containing room temperature (21 ± 2°C) DIW. Subjects were instructed to drink as much or as little DIW as they pleased during the 60-minute rehydration period. The volume of DIW consumed *ad libitum* was

determined by subtracting the water bottles mass at the end of the rehydration period from the water bottles initial mass. Since DIW has a specific gravity of 1, it was assumed that a 1 g change in mass was equivalent to 1 mL consumed.

At 15, 30, 45, and 60 minutes post-treatment drink ingestion, 5-mL blood samples were collected and subjects rated their perceived thirst, fullness, and nausea. Following the last blood sample, subjects were weighed nude, and the venous catheter, rectal thermometer, and heart rate monitor were removed. Subjects were then excused. The same procedures were used on subsequent testing days with the exception that subjects ingested a different treatment drink. Subjects were randomly assigned a treatment drink order on the first day of testing, and treatment drink order was counterbalanced *a priori*. Testing days were separated by at least 72 hours and each subject was tested at approximately the same time of day.

To minimize bias, subjects were told the purpose of the study was to determine the effect of the treatment drinks on core temperature, heart rate, and blood variables following exercise in the heat. To minimize visual analog scale bias, subjects were not allowed to see their prior visual analog scale ratings. Subjects were told not to spray themselves with the DIW or spit during the rehydration period.

Blood Analysis. For each 5-mL blood sample, 1 mL of whole blood was used to measure hematocrit and hemoglobin concentration (0.5 mL for each). The remaining 4 mL of blood was sealed in a 6-mL lithium heparin vacutainer and placed on ice until the final blood sample was drawn.

To determine hematocrit, blood was drawn into heperanized microcapillary tubes and centrifuged at 3000 rpm for 5 minutes and read using a microcapillary reader (IEC 2201; Damon/IEC, Needham Heights, MA). The cyanmethemoglobin procedure was used to

determine hemoglobin concentration. Hemoglobin concentration and hematocrit were performed in triplicate immediately after sampling. Changes in plasma volume were calculated from hemoglobin concentration and hematocrit measurements using the Dill and Costill equation.[23]

The remaining blood was centrifuged at 3000 rpm for 15 minutes at 3°C. Plasma was drawn off the packed red blood cells and analyzed in duplicate for OSM_p using freezing point depression osmometry (3D3; Advanced Instruments Inc., Norwood, MA). Plasma [Na^+] was measured in duplicate with an ion-selective electrode system (16; NOVA Biomedical, Waltham, MA).

Treatment Drink Analysis. Pickle juice, hypertonic saline, and DIW were analyzed in duplicate and averaged for [Na^+], potassium concentration, chloride concentration, glucose concentration, pH, specific gravity, and osmolality (Table 1.). Electrolyte and glucose concentration were measured with an ion-selective electrode analyzer. Drink pH was measured using a pH meter (AB 15; Fischer Scientific, Pittsburg, PA.). Specific gravity was measured using a refractometer. Osmolality was measured using freezing point depression osmometry.

Statistical Design

Means and standard deviations for all dependent variables were calculated and used for statistical analysis. Differences in *ad libitum* fluid ingested, plasma variables, and perceptual indicators of thirst, fullness, and nausea between treatment drinks and over time were analyzed with separate repeated measures ANOVAs (NCSS 2007, Kaysvilles, UT). Geisser-Greenhouse adjustments to *P*-values were made when sphericity was violated. Upon identification of significant F-values, Tukey-Kramer post hoc tests were used to identify differences between drinks at each time point. Significance was accepted when $P < 0.05$.

RESULTS

Subjects were similarly euhydrated prior to exercise each day (pickle juice = 1.008 ± 0.004, hypertonic saline = 1.007 ± 0.004, DIW = 1.01 ± 0.004, $F_{2,28} = 2.8$, $P = 0.08$, power = 0.5). Subjects were similarly hypohydrated ($F_{2,28} = 1.9$, $P = 0.17$, power = 0.4), and lost similar volumes of fluid prior to treatment drink ingestion ($F_{2,28} = 1.7$, $P = 0.20$, power = 0.3). Therefore, subject's hypohydration and fluid lost data were combined. Subjects lost 1610 ± 410 mL of fluid and were 1.95 ± 0.51% hypohydrated post-exercise. Subjects ingested 83 ± 8 mL of hypertonic saline, 83 ± 9 mL of pickle juice, and 83 ± 8 mL of DIW prior to *ad libitum* fluid consumption. Therefore, subjects ingested 0.77 ± 0.08 g, 0.75 ± 0.08 g, and 0 ± 0 g of Na^+ on the hypertonic saline, pickle juice, and DIW trials, respectively.

Ad Libitum Fluid Consumed

Subjects ingested different volumes of DIW *ad libitum* based on the treatment drink consumed each testing day ($F_{2,28} = 4.2$, $P = 0.03$, power = 0.7). Subjects consumed significantly more DIW *ad libitum* post-ingestion of hypertonic saline (708.03 ± 371.03 mL) than when DIW was the treatment drink (532.99 ± 337.14 mL, $P < 0.05$). Subjects consumed similar volumes of DIW *ad libitum* during the pickle juice (700.35 ± 366.15 mL) and hypertonic saline trials ($P > 0.05$). Moreover, there was no difference in *ad libitum* DIW ingestion between pickle juice and DIW ($P > 0.05$).

Plasma Variables

No interaction between time and treatment drink ($F_{10,140} = 1.7$, $P = 0.09$, power = 0.8, Figure 1.), or drink effect occurred for $[Na^+]_p$ ($F_{2,28} = 2.1$, $P = 0.14$, power = 0.4). However, $[Na^+]_p$ did change over time ($F_{5,70} = 30.4$, $P < 0.001$, power = 1.0). Pre-exercise $[Na^+]_p$ (-105

minutes) was lower than all other times ($P < 0.05$). Plasma [Na^+] was higher at -0.5 and 15 minutes than at 30, 45, and 60 minutes post-treatment drink ingestion ($P < 0.05$).

Plasma osmolality did not differ between treatment drinks over time ($F_{10,140} = 1.6$, $P = 0.18$, power = 0.5, Figure 1.), or vary by drink ($F_{2,28} = 1.8$, $P = 0.19$, power = 0.3). However, OSM_p changed over time ($F_{5,70} = 34.5$, $P < 0.001$, power = 1.0). Pre-exercise OSM_p (-105 minutes) was lower than all other times ($P < 0.05$). Plasma osmolality was higher at -0.5 and 15 minutes than at 30, 45, and 60 minutes post-treatment drink ingestion ($P < 0.05$).

Percent change in plasma volume did not differ between treatment dinks over time ($F_{10,140} = 0.7$, $P = 0.74$, power = 0.3, Figure 1.), or vary between treatment drinks ($F_{2,28} = 0.4$, $P = 0.65$, power = 0.1). However a change in plasma volume occurred over time ($F_{5,70} = 35.7$, $P < 0.001$, power = 1.0). Changes in plasma volume decreased following 65 minutes of exercise and never returned to pre-exercise levels ($P < 0.05$). Changes in plasma volume were also lower at -0.5 minutes than 30 and 45 minutes post-treatment drink ingestion ($P < 0.05$). Changes in plasma volume were higher at 30 and 45 minutes post-treatment drink ingestion than 60 minutes ($P < 0.05$).

Perceptual Indicators

Palatability differed between treatment drinks ($F_{2,28} = 64.1$, $P < 0.001$, power = 1.0). Deionized water was more palatable (73 ± 14 mm) than hypertonic saline (17 ± 13 mm) and pickle juice (26 ± 16 mm, $P < 0.05$). Palatability was similar between pickle juice and hypertonic saline ($P > 0.05$).

Thirst did not differ between treatment drinks over time ($F_{8,112} = 1.13$, $P = 0.35$, power = 0.3, Figure 2.) or vary between treatment drinks ($F_{2,28} = 0.69$, $P = 0.51$, power = 0.2). However, a change in thirst occurred over time ($F_{4,56} = 29.88$, $P < 0.001$, power = 0.9). Thirst was higher at

-0.5 minutes than all other times ($P < 0.05$). Thirst was also higher at 15 minutes than 45 and 60 minutes post-treatment drink ingestion ($P < 0.05$).

No interaction between treatment drinks and time ($F_{8,112} = 1.19$, $P = 0.32$, power = 0.3, Figure 2.) or drink effect occurred for nausea ($F_{2,28} = 1.78$, $P = 0.18$, power = 0.3). However, a change in nausea occurred over time ($F_{4,56} = 10.35$, $P = 0.001$, power = 0.9). Nausea was higher immediately prior to treatment drink ingestion (-0.5 min) than at all other times ($P < 0.05$).

Fullness did not differ between treatment drinks over time ($F_{8,112} = 0.45$, $P = 0.89$, power = 0.2, Figure 2.), between drinks ($F_{2,28} = 1.15$, $P = 0.33$, power = 0.2), or over time ($F_{4,56} = 3.39$, $P = 0.052$, power = 0.6).

DISCUSSION

Some clinicians advocate for the use of pickle juice drinking guidelines because of the high [Na^+] of pickle juice.[13] These clinicians[13] fear drinking pickle juice will increase $[Na^+]_p$ and OSM_p, thereby causing a rapid fluid shift into the intravascular space. This, according to the authors,[13] will decrease thirst and thus, the volume of fluid consumed. While following the pickle juice drinking guidelines[13] will likely result in rehydrating according to the NATA's[5] recommendations, the data from the current study suggest the rationale that led to the creation of pickle juice drinking guidelines is questionable.

Our data does not support the concern that drinking a high Na^+ drink, such as pickle juice, increases $[Na^+]_p$ or OSM_p.[13] We observed no differences in $[Na^+]_p$ or OSM_p between treatment drinks over 60 minutes post-ingestion. The fact that subjects drank more DIW *ad libitum* post-ingestion of pickle juice and hypertonic saline cannot explain the lack of differences in $[Na^+]_p$ or OSM_p. Other scientists have observed similar results when only pickle juice is ingested.[8] Miller et al[8] gave euhydrated subjects 1 $mL \cdot kg^{-1}$ body mass of pickle juice (~86 mL) and monitored $[Na^+]_p$ and OSM_p over 60 minutes. No changes in $[Na^+]_p$ or OSM_p occurred at any time post-ingestion despite subjects consuming 0.8 g of Na^+.[8] In a follow up study, subjects exercised in the heat for two hours and ingested ~79 mL of pickle juice. Despite ingesting twice as much Na^+ (1.5 g) as in the euhydrated study,[8] no changes in $[Na^+]_p$ or OSM_p occurred over 60 minutes (unpublished observations). These observations are not unique to pickle juice ingestion. Johannsen et al[6] had subjects ingest 1.4 g of Na^+ by drinking chicken noodle soup ($[Na^+]$ = 166 $mmol \cdot L^{-1}$) and also observed no changes in $[Na^+]_p$ or OSM_p within 45 minutes of ingestion. Thus, clinicians need not worry about increasing OSM_p or $[Na^+]_p$ if athletes drink small volumes of pickle juice.

The fear that plasma volume will increase post-pickle juice ingestion[13] is also unsupported. In the current study, drinking pickle juice did not cause a greater increase in plasma volume than DIW. In fact, the majority of studies examining changes in plasma volume following pickle juice ingestion indicate plasma volume decreases.[8,10] Miller et al[10] observed a 5% decrease in plasma volume when euhydrated subjects ingested a large bolus of pickle juice (550 mL), and only a mild plasma volume expansion (< 1.3%) when euhydrated subjects ingested a small volume (86 mL).[8] When subjects are 3% hypohydrated and ingest a small volume (79 mL) of pickle juice, changes in plasma volume decrease less than 1% over 60 minutes (unpublished observations). Johannsen et al[6] also observed a small (~2%) but insignificant, decrease in plasma volume in euhydrated subjects at 45-minutes post-ingestion of chicken noodle soup. Therefore, it appears changes in plasma volume depend on the volume of the high Na^+ drink consumed and the subject's hydration status. If small volumes of pickle juice are consumed, the effect on plasma volume is negligible.

Interestingly, a small (~2.5%) decrease in plasma volume was observed 60 minutes post-treatment drink ingestion. This decrease may be the result of isotonic fluid shifting from the extracellular fluid space to the intracellular fluid space.[24] Scientists have shown that unless potassium is the primary electrolyte in the rehydration beverage, the extracellular fluid compartment is preferentially restored over the intracellular fluid compartment.[3] In our study plasma volume changes gradually increased over the first 45 minutes of the rehydration period. The resulting decrease in OSM_p may have caused fluid to move into the intracellular fluid space,[24] thus decreasing plasma volume. Anecdotally, it appeared our subjects consumed more DIW at the onset of the *ad libitum* rehydration period. Similarly, Nose et al[3] witnessed 2% hypohydrated subjects rapidly consumed water *ad libitum* in the first 30 minutes of its

availability and slowed *ad libitum* consumption thereafter. Moreover, they[3] observed a small (< 1%) decrease in plasma volume between the 30 and 60 minute blood samples when subjects rehydrated *ad libitum* with water. Therefore, if more DIW was ingested at the beginning of the rehydration period the majority of the fluid would have emptied from the stomach within 30 minutes,[10] thereby allowing the fluid to move between the body fluid compartments. Since the small (~2.5%) decrease in plasma volume in our study was seen with all treatment drinks it is unlikely a consequence of the content of the treatment drink.

Our observations also indicate drinking pickle juice will not decrease thirst as speculated.[13] Perceived thirst did not differ between treatment drinks at any point during the 60-minute rehydration period. Scientists[25,26] have observed the act of drinking, not a decrease in OSM_p or $[Na^+]_p$, is responsible for the rapid satiety of thirst. Additionally, the Na^+ content of the fluid consumed appears to have a minimal impact on thirst.[27] Phillips et al[27] infused ~335 mL of a hypertonic (450 $mmol \cdot L^{-1}$) saline solution into subjects' stomachs and had them rate their perceived thirst. While an increase in thirst was observed immediately post-infusion, thirst had returned to pre-infusion levels within 5 minutes of *ad libitum* drinking. These changes occurred well before changes in OSM_p or $[Na^+]_p$.[27] Therefore, the volume of fluid ingested, rather than its content affects perceived thirst.

The most prominent concern by some clinicians, that *ad libitum* drinking would be inhibited after pickle juice ingestion,[13] was also not supported. We observed subjects consumed more, not less, DIW *ad libitum* post-ingestion of small volumes of hypertonic saline (and likely pickle juice) than DIW. While our subjects consumed more DIW *ad libitum* with the incorporation of these treatment drinks, they did not consume enough to meet the NATA's[5] guidelines for fluid replacement. The NATA[5] recommends replacing 150% of fluid losses and

adding 0.3 to 0.7 g of Na^+ to every liter of a rehydration beverage to offset Na^+ lost via exercise induced sweating. Our subjects lost 1600 mL of fluid; therefore, to comply with these recommendations, our subjects would have needed to consume between 1000 and 2500 mL of DIW *ad libitum*. Subjects ingested ~700 mL following pickle juice and hypertonic saline and 532 mL with DIW. As a result, subjects only replaced 43% of their losses when pickle juice and hypertonic saline were consumed and 33% when DIW was consumed. Thus, subjects were still ~1.3% hypohydrated at the end of the 60-minute rehydration period. This is not surprising as humans are poor at rehydrating voluntarily.[28,29] Even with access to fluids, Godek et al[28] observed professional football players only replaced 66% of their fluid losses during practice. Passe et al[29] observed runners replaced 30% of their sweat lost despite ample access to cool fluids. Therefore, regardless of whether pickle juice is ingested or not, clinicians need to focus on drinking schedules if they wish to fully rehydrate athletes within 60 minutes.

The greater volume of DIW consumed post-pickle juice and hypertonic saline ingestion is not due to an increase in thirst, $[Na^+]_p$, or OSM_p or changes in plasma volume as previously discussed. While Na^+ impacts *ad libitum* fluid ingestion,[3,6] the Na^+ content of the treatment drinks cannot fully explain why our subjects drank more DIW *ad libitum* with pickle juice and hypertonic saline than DIW. We propose subjects drank more DIW because the palatability of pickle juice and hypertonic saline was low. Some clinicians have expressed concern over the palatability of pickle juice,[13,17] and not surprisingly, subjects favored DIW over pickle juice and hypertonic saline. Thus, subjects may have ingested more DIW to remove the unpleasant taste from their mouths. Anecdotally, subjects appeared to drink more DIW immediately post-consumption of pickle juice and hypertonic saline rather than in the latter portions of the rehydration period. The effect of flavoring on *ad libitum* drinking is well established.[15,16]

Following exercise, humans have an increased preference for sweet[30] and salty[31] drinks, while their preference for bitter[30] tasting drinks remain unchanged. Despite humans having an increased preference for Na^+ after exercise,[31] the mild fluid (and likely Na^+) losses in the current study were likely not great enough to alter subjects perceived palatability of pickle juice. Moreover, the similar palatability ratings for pickle juice and hypertonic saline suggest it was the Na^+, rather than the ingredients in pickle juice (e.g., vinegar), that was responsible for its low palatability.

Some scientists have suggested pickle juice ingestion may cause nausea.[32] Subjects complained of mild nausea and fullness during the rehydration period, which was not exacerbated by any treatment drink. Miller et al[10] observed mild (4 mm on a 100 mm scale, 100 being extremely nauseous) nausea when euhydrated subjects ingested a large volume (~550 mL) of pickle juice. Moreover, Phillips et al[27] observed no differences in fullness after infusion of ~335 mL of hypertonic (450 $mmol \cdot L^{-1}$) and isotonic (150 $mmol \cdot L^{-1}$) saline into the stomach. Thus, drinking small volumes of pickle juice post-exercise does not cause significant feelings of nausea or fullness.

Finally, we acknowledge three limitations to our study. First, simulating "real life" drinking situations in a laboratory environment is difficult. To ensure valid measures of $[Na^+]_p$, OSM_p, and plasma volume, our subjects were seated in the same position for 60 minutes with unlimited access to water. In athletic settings the pace of play often dictates water breaks. Less fluid may be ingested in an athletic setting as athletes may have fewer opportunities to drink. Second, our rehydration period only lasted 60 minutes. Complete rehydration takes much longer (> 12 h) and should include food.[20] Finally, our subjects were given room temperature water to drink. Subjects prefer and drink more fluid *ad libitum* when cool fluids are provided post-

exercise.[33] Therefore, providing cool fluids following pickle juice ingestion may result in subjects consuming more fluid *ad libitum*. Future research may examine this assertion, the effect of pickle juice ingestion before exercise on *ad libitum* drinking during and post-exercise as well as the effects of pickle juice ingestion on rehydration for longer than 60 minutes.

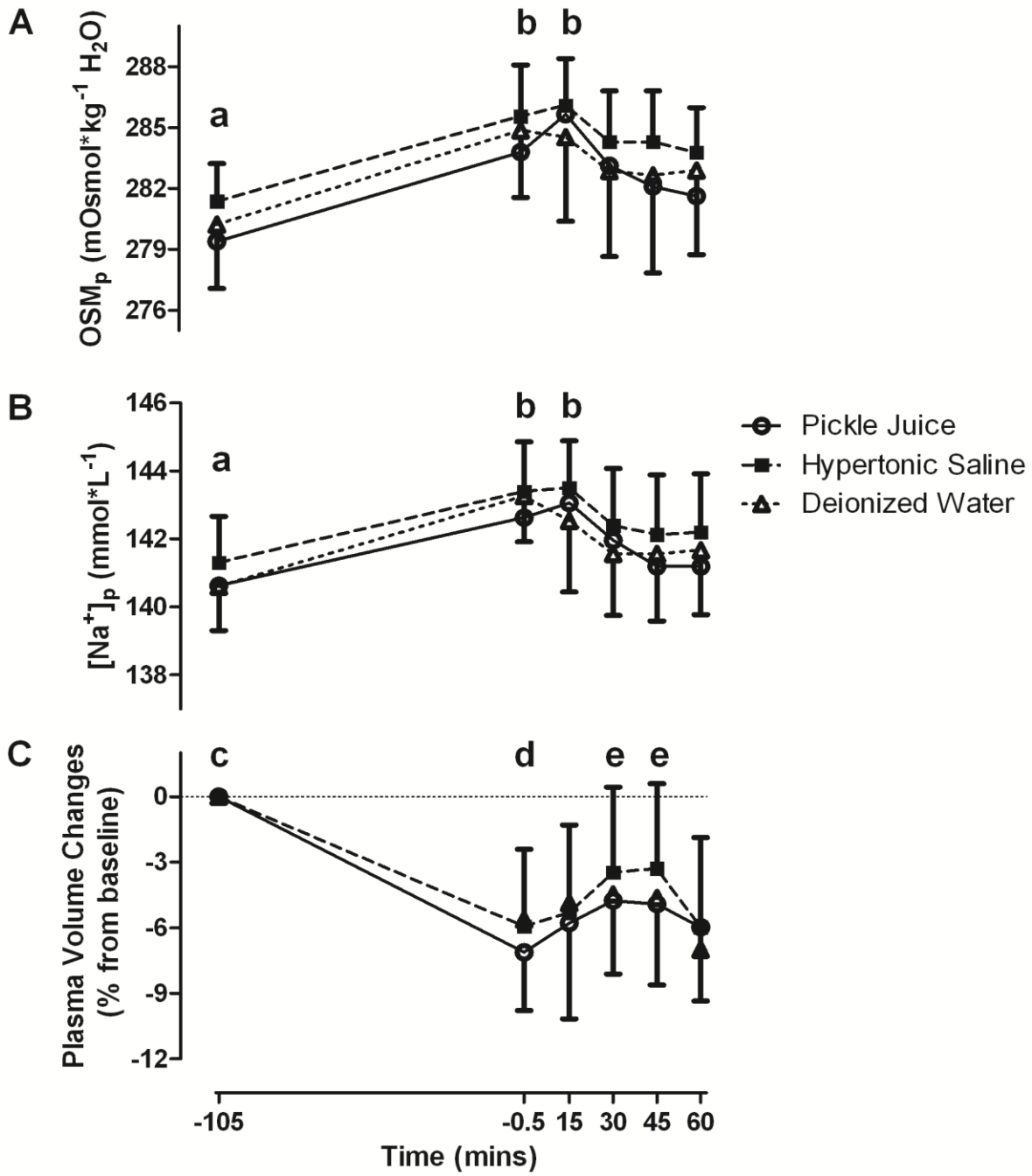
In conclusion, consuming small volumes of pickle juice did not decrease *ad libitum* DIW ingestion. The concern of some clinicians[13] that the high Na^+ content of pickle juice will cause a rapid increase in $[Na^+]_p$, OSM_p, and plasma volume and a subsequent decrease in thirst is also unsupported. Although less palatable than DIW, pickle juice did not exacerbate nausea or fullness. Pickle juice does not deter drinking; however, total body fluid replacement does not occur within 60 minutes post-exercise. While pickle juice drinking guidelines[13] are based on false assertions, the guidelines themselves[13] will likely ensure athletes rehydrate more completely. To ensure total rehydration, athletes should drink to a schedule regardless of whether pickle juice is consumed and follow the NATA's recommendations[5] for fluid replacement.

Table 1. Composition of Treatment Drinks

	Pickle Juice	Hypertonic Saline	Deionized Water
OSM ($mOsm \cdot kg^{-1}$ H_2O)	853 ± 3	727 ± 2	0 ± 0
$[Na^+]$ ($mmol \cdot L^{-1}$)	395 ± 0	403 ± 4	0 ± 0
$[K^+]$ ($mmol \cdot L^{-1}$)	30 ± 0	0 ± 0	0 ± 0
$[Cl^-]$ ($mmol \cdot L^{-1}$)	305 ± 0	390 ± 0	0 ± 0
[Glucose] ($mmol \cdot L^{-1}$)	28.25 ± 0.35	0 ± 0	0 ± 0
pH	3.82 ± 0.01	5.89 ± 0.04	5.86 ± 0.11
Specific Gravity	1.02 ± 0.0	1.012 ± 0.0	1.00 ± 0.0

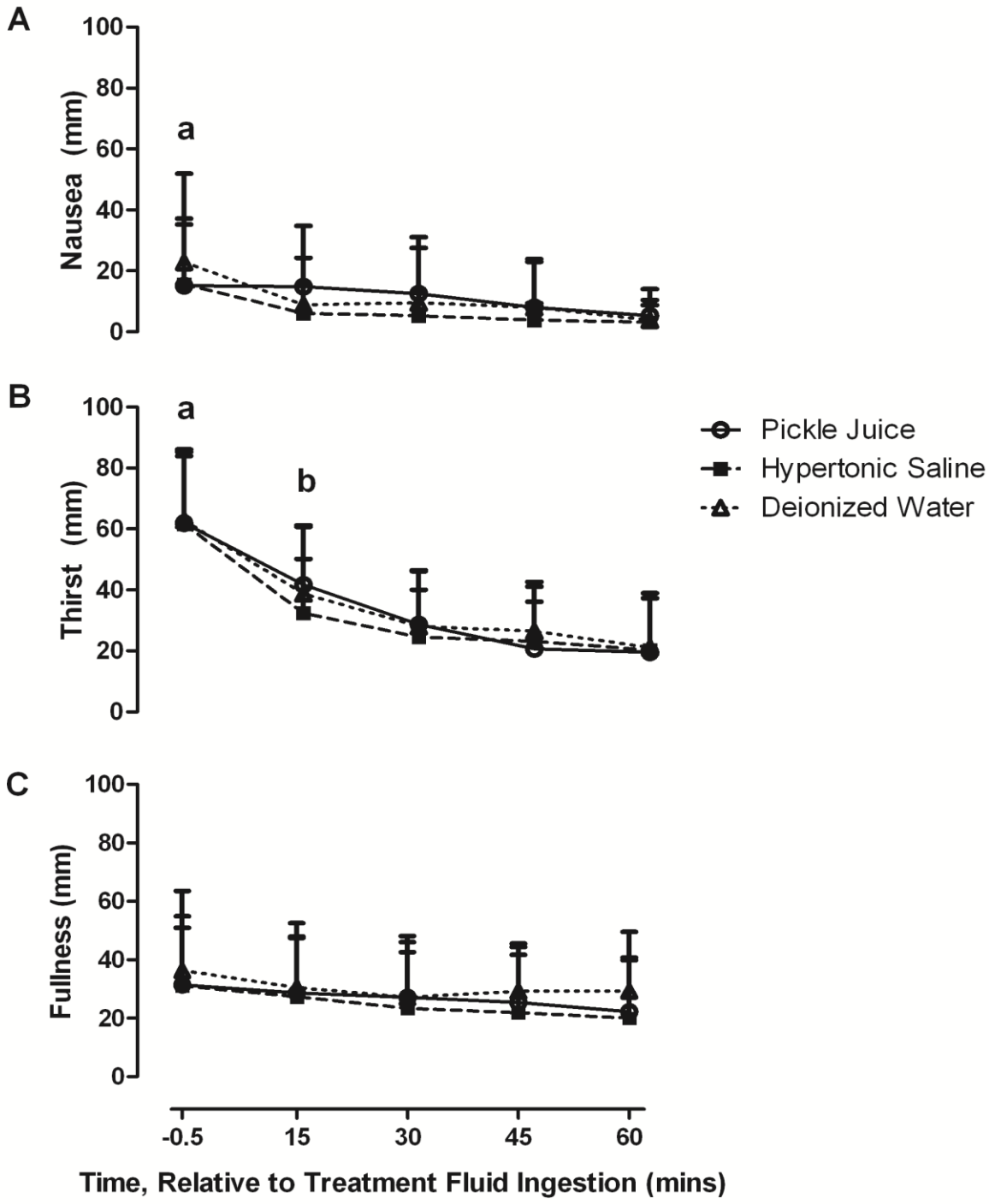
OSM = osmolality, $[Na^+]$ = sodium concentration, $[K^+]$ = potassium concentration, $[Cl^-]$ = chloride concentration, [Glucose] = glucose concentration. Analyses done in duplicate (means ± SD).

Figure 1. OSM_p, $[Na^+]_p$, and Plasma Volume.



Plasma osmolality (OSM_p, A), plasma sodium concentration ($[Na^+]_p$, B), and percent change in plasma volume (C) pre- and post-ingestion of pickle juice, hypertonic saline and deionized water (means ± SD). [a] = -105 min < all other times. [b] = -0.5 and 15 min > 30, 45, and 60 min. [c] = -105 min > all other times. [d] = -0.5 min < 30 and 45 min. [e] = 30 and 45 min > 60 min. Significance accepted when $P < 0.05$ (n = 15).

Figure 2. Nausea, Thirst, Fullness.



Nausea (A), thirst (B), and fullness (C) over pre- and post-ingestion of pickle juice, hypertonic saline and deionized water (means ± SD). [a] = -0.5 min > all other times. [b] = 15 min > 45 and 60 min. Significance accepted when $P < 0.05$ (n = 15).

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APPENDIX A. PROSPECTUS

INTRODUCTION

Voluntary dehydration, when an individual fails to adequately rehydrate despite favorable conditions, is a problem for physically active people. Decreased outdoor running speed,[1] diminished stationary biking performance,[2] and impaired resistance strength[3] have all been directly related to hypohydration. Furthermore, decreased plasma volume caused by hypohydration, results in elevated heart rate and oxygen consumption, and reduced cardiac output.[1,4,5] Hypohydration is also theorized to be a cause of exercise associated muscle cramps (EAMCs).[6,7]

Guidelines and research exist to prevent hypohydration and to ensure adequate rehydration.[8,9] The National Athletic Trainers' Association (NATA) recommends that dehydration be kept to less than 2% total body weight loss and suggests replacing 150% of total sweat losses.[8] Similarly, the American College of Sports Medicine (ACSM) recommends drinking 1.5 liters of fluid for each kilogram of body weight lost to sweat.[9] Additionally, rehydration can be enhanced by cooling and flavoring fluids.[10-12] Despite these recommendations, some disparity exists as to the best beverage and method for rehydration.[13]

Substantial research has emphasized the importance of sodium in rehydration.[14-17] When compared to tap water, consuming 0.45 grams of sodium chloride per 100 mL of water significantly increased *ad libitum* fluid intake in hypohydrated individuals.[15] Furthermore, drinks with a high sodium concentration (50 $mmol \cdot L^{-1}$ $[Na^+]$) restored plasma volume and sodium more effectively than a drink with a low sodium concentration (25 $mmol \cdot L^{-1}$ $[Na^+]$).[14] Atypical rehydration fluids have been examined in rehydration based on their high sodium concentrations. Three hundred fifty five milliliters of chicken noodle soup, with a sodium concentration of over 330 $mmol \cdot L^{-1}$, was more effective than the same volume of water or a

carbohydrate electrolyte drink at restoring plasma volume. This was attributed to improved fluid retention and decreased urine production.[16] *Ad libitum* drinking was higher when chicken noodle soup (1227 ± 602g) was ingested 45 minutes prior to exercise than a carbohydrate electrolyte beverage (1062 ± 675g) or water (852 ± 554g).[17]

Pickle juice, an acidic brine with a high sodium concentration (415.2±0.28 $mmol \cdot L^{-1}$),[18] has recently been advocated as a possible treatment for EAMCs.[19-21] Twenty-five percent (92/370) of athletic trainers (ATCs), use or have used pickle juice as a treatment for EAMCs. However, some clinicians have expressed concern about athletes ingesting pickle juice because of its high sodium content.[22] This has led to the creation of pickle juice drinking guidelines.[23] These guidelines are theoretical, and based on mathematical equations rather than scientific evidence. Moreover, these equations considered only the volume of pickle juice ingested, its sodium content, and the amount of hypotonic fluid needed to be ingested to meet current NATA guidelines for fluid replacement. These estimates must therefore be considered "target volumes" to be ingested. The amount of fluid ingested *ad libitum* following pickle juice consumption has yet to be examined. Additionally, scientists have only examined the changes in plasma volume, plasma osmolality (OSM_p), and plasma sodium concentration ($[Na^+]_p$) up to 5 minutes post pickle juice ingestion in hypohydrated individuals.[18] The plasma responses 5 minutes post-ingestion of pickle juice and other hypotonic fluids is unknown in hypohydrated individuals.

Research Questions

1. Does ingesting small volumes (1 $mL \cdot kg^{-1}$ body mass) of pickle juice (PJ), hypertonic saline (HS), or deionized water (DIW) influence volume of fluid ingested *ad libitum* in hypohydrated individuals?

2. Does ingesting small volumes (1 mL·kg^{-1} body mass) of PJ, HS, or DIW immediately prior to *ad libitum* fluid ingestion affect changes in plasma volume, $[Na^+]_p$, or OSM_p?
3. Does ingesting small volumes (1 mL·kg^{-1} body mass) of PJ, HS, or DIW immediately prior to *ad libitum* fluid ingestion affect perceptual indicators of hydration (i.e., thirst, fullness, and nausea).
4. Does the palatability of PJ, HS, or DIW differ between hypohydrated subjects prior to *ad libitum* drinking?

Research Hypotheses

1. *Ad libitum* fluid ingestion will be higher following the consumption of 1 mL·kg^{-1} body mass of PJ than HS. Similarly, *ad libitum* fluid ingestion will be higher following the consumption of 1 mL·kg^{-1} body mass of HS than DIW.
2. Changes in plasma volume, $[Na^+]_p$, and OSM_p, will be higher following consumption of PJ than HS. Similarly, changes in plasma volume, $[Na^+]_p$, and OSM_p will be higher following consumption of HS than DIW.
3. Perceptual indicators of hydration (i.e., thirst, fullness, and nausea) will be higher after consumption of PJ than HS or DIW.
4. Palatability of PJ and HS will be lower than DIW.

Assumptions

1. Alternating running and biking every 15 minutes for 60 minutes is sufficient to induce hypohydration.
2. Not having the subjects blinded will not impact *ad libitum* fluid ingestion.

3. The long duration of the rehydration period (60 minutes) will not affect *ad libitum* fluid ingestion.
4. Preexisting knowledge of body fluid balance will not influence subjects' *ad libitum* fluid ingestion

Limitations

1. Subjects will be able to taste the treatment fluids ingested each day.
2. Hormones associated with fluid balance (e.g., AVP, aldosterone) will not be measured.
3. Subject's rehydration behaviors will only be observed for 60 minutes post-ingestion.
4. Exercise will be terminated after 60 minutes, thus variability in hypohydration will occur between subjects.
5. Sodium losses will vary between subjects.

Delimitations

1. All subjects will be male between the ages of 18-35.
2. Subjects will not have a history of heart disease, asthma, diabetes, high blood pressure, or high cholesterol.
3. Subjects will not have a history of chest pain, dizziness, fainting, blackouts, or unreasonable breathlessness during exercise.
4. All subjects will be non-smokers.
5. Subjects will not have any history of food allergies.
6. Subjects will not have a history of heat related illnesses (e.g., heat syncope, heat exhaustion, heat stroke) in the six months preceding the study.
7. Subjects will be free of injuries or surgeries in the 12 months preceding the study.

8. Subjects will meet current ACSM guidelines for physical activity (moderate-intensity aerobic physical activity for a minimum of 30 minutes on five days each week, or vigorous-intensity aerobic activity for a minimum of 20 minutes on three days each week).[24]
9. Subjects will not be acclimated to exercise in heat in the six days preceding data collection.[25]
10. Hypertonic saline will have a similar [Na^+] as pickle juice.
11. Subjects will exercise for 60 minutes at a hard intensity of 80-90% age predicted maximal heart rate.[26]

Definition of Terms

Ad libitum: In accordance with ones wishes, without restraint or limit.

Dehydration: The process of losing body water.

Euhydration: A state of normal body water. A plasma osmolality < 290 mOsmols·kg H_20^{-1}, and a urine specific gravity of < 1.02 indicates euhydration.[9]

Fullness: Sensation of containing all that can be held. For this study, extreme fullness will be described to subjects as the feeling after eating a large meal. No fullness will be described as the feeling of being very hungry.

Hematocrit (Hct): The ratio of the volume of red blood cells to a given volume of blood. Used in conjunction with hemoglobin measurements to calculate changes in plasma volume.

Hemoglobin (Hb): The oxygen carrying molecule in red blood cells. Used in conjunction with hematocrit measurements to calculate changes in plasma volume.

Hyperhydration: Increased body water content. Expressed as a percentage of body weight.

Hypertonic: A solution with a comparatively higher concentration of solutes compared to another, having a higher osmotic pressure in a fluid compared to another fluid.

Hypohydration: Decreased body water content. Expressed as a percentage of body weight.

Hypotonic: A solution with a comparatively lower concentration of solutes compared to another, having a lesser osmotic pressure in a fluid compared to another fluid.

Involuntary dehydration: The delay in rehydration by spontaneous drinking after dehydration induced by exercise, fluid restriction, and environmental heat and cold.

Isotonic: A solution with the same concentration of solutes compared to another, having the same osmotic pressure in a fluid compared to another fluid.

Nausea: Feeling of sickness in the stomach. For this study extreme nausea will be described to subjects as the feeling of sickness in their stomach. No nausea will be described as the feeling of calmness in their stomach.

Osmolality: The concentration of osmoles of solute per kilogram of solvent.

Palatability: The acceptability of taste. For this study palatable will be defined as pleasant or acceptable tasting. Unpalatable will be not pleasant or unacceptable tasting.

Pickle Juice: A salty and acidic brine brought about through the process of pickling cucumbers. Strained from whole dill pickles.

Plasma: The fluid portion of blood in which cells are suspended.

Plasma Osmolality (OSM_p): A measure of the concentrations of substances in the blood. Expressed in mOsmols·kg H_20^{-1}.

Plasma Volume: The volume of blood that is plasma expressed as a percentage. Calculated by measuring hemoglobin and hematocrit

Rehydration: The process of gaining water from the hypohydrated state towards euhydration.

Hypertonic Saline: A solution containing common table salt. For this study hypertonic saline will be a solution of water and sodium chloride with a concentration similar to that of pickle juice.

Sodium (Na^+): An inorganic compound often found in the salt form added to foods as a preservative and for seasoning. Abundant in the body and has a major influence on body fluid balance.

Thirst: The desire to drink resulting from a deficit of water. For this study extreme thirst will be described to subjects as the feeling of dryness in their mouth or throat. No thirst will be the feeling of wetness in their mouth or throat.

Urine Specific Gravity (U_{sg}): The ratio of the density of substances in the urine to the density of water. Normal urine specific gravity for euhydrated persons is < 1.02[9].

Voluntary dehydration: When an individual doesn't adequately rehydrate even though drinking fluids are plentiful and readily available.

Abbreviations

ACSM: American College of Sports Medicine

ATC: Certified athletic trainer

$[Cl^-]_p$: Plasma chloride concentration

DIW: Deionized water

EAMC: Exercise associated muscle cramp

Hb: Hemoglobin

Hct: Hematocrit

$[K^+]_p$: Plasma potassium concentration

mmol: Millimole

mOsm: Milliosmole

$[Na^+]$: Sodium concentration

$[Na^+]_p$: Plasma sodium concentration

NATA: National Athletic Trainers' Association

NCAA: National Collegiate Athletic Association

OSM_p: Plasma osmolality

U_{sg}: Urine specific gravity

REVIEW OF LITERATURE

This literature review will discuss the important effects of hydration on exercise performance, physiological function, thirst, and drinking. Emphasis will be placed on the importance of sodium in rehydration. The literature review will be organized by the following topics:

Databases and Key Words Searched

Physiological Effects of Hypohydration

Effects of Hydration on Performance

    Exercise Associated Muscle Cramps

Voluntary Dehydration and Thirst

    Ad libitum Fluid Replacement

Recommendations for Rehydration

Sodium and Rehydration

Pickle Juice

    Gastric Emptying

Summary

Databases and Key Words Searched

The following databases were searched in writing this literature review: National Library of Medicine's Pubmed (Medline), EBSCO (Academic Search Premier) sport discus (SPORTDiscus), Thomson Reuters' Web of Knowledge (Web of Science), Elsevier's Science Direct (ScienceDirect), and CINAHL (CINAHL Plus). Journal articles written in English

between the years 1974 and 2010 were searched. Additional references were collected by careful analysis of the citations of others' research and textbooks.

The following keywords were used:

Acetic acid	Electrolytes
Ad libitum	Flavoring
Body water	Fluid
Cardiovascular function	Fluid spaces
Dehydration	Hydration
EAMC	Hypohydration
Involuntary dehydration	Rehydration
Na^+	Sodium
Osmolality	Sports drinks
Palatability	Thirst
Plasma volume	Temperature
Pickle juice	Voluntary dehydration

Physiological Effects of Hypohydration

Total body water accounts for 50-70% of lean body mass in humans. This is divided into intracellular fluid and extracellular fluid. Intracellular fluid sustains cell integrity and function and makes up approximately 45% of the body's mass. Extracellular fluid is responsible for the internal environment necessary for cell function. It is divided into plasma volume, also referred to as intravascular fluid (5% total body mass) and interstitial fluid (15% total body mass), which is found between cells and blood vessels.[27] Fluid exchange between the interstitium and the

intracellular fluid depends on osmotic gradients. That is, water will flow from areas of low solute concentration to areas of high solute concentrations. Water is able to freely pass between the membranes separating the intracellular and extracellular fluid compartments; however these membranes are only selectively permeable to solutes.[28]

During physical exertion, metabolism increases and leads to increased energy production. This increase in energy is released in large part as heat. In order to maintain homeostasis, excess heat needs to be dissipated and is done so primarily via evaporation of sweat. During exercise in heat, sweat rates have been measured between 0.3 to 2.5 liters per hour. Excessive sweating leads to body water loss from each fluid compartment. This causes a necessary response of fluid redistribution due to osmotic gradients.[27,29]

Since sweat is hypotonic compared to plasma, dehydration causes a decrease in plasma volume and an increase in plasma osmolality. This occurs because plasma is the main source of fluid for sweat. Decreased plasma volume, and the increase in plasma osmolality influences the movement of fluid out of the intracellular space and into the interstitium and plasma.[27,29] Mild dehydration cause fluid losses mainly from the extracellular fluid compartment.[28] As dehydration worsens, progressively more fluid is lost from the intracellular space as it is pulled into the plasma. This is done so by the osmotic drive from the increased plasma osmolality. This in effect defends central blood volume and pressure.[5,28]

Effects of Hydration on Performance

When examining the differences in rehydrating with glycerol and water, and plain water researchers found significant performance effects.[30] Subjects were dehydrated to 4% body weight loss, and then rehydrated with glycerol and water or plain water. They were then placed on a cycle ergometer and exercised until exhaustion criteria were met. The results showed

subjects reached exhaustion 19% faster in the water alone trial (27.1 ± 3.3min) compared to the water and glycerol trial (32.5 ± 3.8 min). Due to the lack of caloric influence from glycerol, the authors contribute this change in performance to better restoration on plasma volume.[30]

The effects of hypohydration on muscular strength, power and force have been further examined.[3] Three performance tests were examined at varying stages of hydration. Subjects were tested for muscular strength by doing six sets of parallel back squats at 80% of the subjects 1 repetition maximum. To test lower body power, subjects completed a set of three jump squats on a force plate. Lower body force was then tested by measuring ground forces on the force plate during an isometric back squat. A measure of the central activation ratio was also examined for each trial. To test this, examiners attached electrodes to the rectus femoris and vastus medials of each subject's dominant leg. Subjects then completed a maximal knee extension on a modified knee extension machine. The examiners then applied an electrical stimulation designed to sustain a maximum force production. The central activation ratio was calculated by taking the maximal voluntary torque and dividing it by the maximal voluntary force with the electrical stimulation. The experimental hydration levels were 2.5% and 5.0% body weight loss respectively.

The results showed no significant differences in the vertical jump height, jump squat power, isometric force squat, or central activation ratio for any of the hydration trials. This suggests that low repetition, and power producing force is not significantly affected by hypohydration. There was however, a significant change in the six set parallel back squat between hydration states. For sets two and three, both the -2.5% and -5.0% hydration levels showed significant decreases in work from the baseline euhydration level. The fourth and fifth sets showed a difference in work completion for the 5.0% hydration level and the baseline. This

suggests that repetitive, multiple set, isotonic exercise performance is affected by hypohydration, and that a 5.0% body weight loss to sweat is more detrimental than 2.5%.[3]

These results are furthered by an examination of race performance at varying levels of hydration.[1] Examiners recruited trained runners to complete a 12-kilometer outdoor trail run. Four trials were completed. Two trials were at a controlled intensity to standardize finishing time. During one of these sub maximal trials subjects were given 400 mL of water at the four kilometer mark and the eight kilometer mark. In the other trial no fluid was given during the run. The other two trials were at a race pace where subjects were encouraged to finish as fast as they could. During the hydration trial, 400 mL of water was given at the four and eight kilometer mark, and during the other trial no water was given.

Subjects recorded their body weight for 17 consecutive days and this weight served as a baseline. Subjects in the hypohydration trials were instructed to restrict water intake 22 hours before the start of the race. Those in the hydrated trials were allowed to drink fluid *ad libitum* until their race time. This was done to simulate a race situation.

The results showed significant differences in hydration levels between the trials. In the sub maximal trial prerace urine specific gravity was 1.008 and 1.026 for the hydrated and dehydrated groups. In the race trial urine specific gravity prerace was 1.009 and 1.027. These signified significant differences in hydration level. Finishing times for the race trial showed significantly faster time for the hydrated group (53.15 ± 6.05 min) compared to the dehydrated group (55.70 ± 7.45 min). The physiological changes in the sub maximal trial showed an increased heart rate by almost 15 beats per minute for the dehydrated group when compared to the hydrated group. The researchers reason this is due to a decrease in plasma volume. Therefore an elevated heart rate is required to sustain cardiac output. The added physiological

strain and decreased performance in a real life athletic setting emphasized the need for adequate hydration before and during exercise.[1]

Further research has examined the effects of hypohydration and cardiovascular strain during exercise.[4] Researchers recruited subjects to complete moderate intensity stationary cycling at graded levels of hydration. Subjects completed a familiarization trial in which the amount of fluid necessary to replace their sweat losses during exercise was determined. A common carbohydrate-electrolyte sports drink was used as a replacement beverage. Subjects arrived in a euhydrated state and were instructed to drink 5 mL of water per kilogram of body weight two hours before their trial. Fluid was administered at 15-minute intervals and was given as a bolus for the first two quantities to stimulate gastric emptying. Subsequent volumes were standardized for the remainder of the trial. Four trials were completed with subjects receiving no fluid, fluid to replace 20%, 48%, or 81% of their total sweat losses. Heart rate, O_2 consumption, and cardiac output were measured continually throughout the trial.

Results showed that cardiac output declined throughout the no fluid trial, and this decline was proportional to the amount of fluid consumed in the rehydration trials. This emphasizes the connection between decreased cardiac output and hypohydration. Similar results were found with stroke volume and heart rate. The best cardiac results were found with 81% fluid replacement. The authors suggest athletes consume at least 81% of their fluid losses due to sweat in order to maximize physiological function and enhance performance[4]. These researchers used a commercially available sports drink for fluid replacement and found similar results as previously reported.[1] Other organizations have suggested even higher fluid replacements for optimal performance.[8,9]

These findings were replicated in a similar study examining the independent effects of carbohydrate and fluid ingestion during exercise.[2] Subjects were recruited to ride a stationary bike for 50 minutes and receive one of four treatments. Treatments were a fluid-carbohydrate solution, fluid-electrolyte solution, carbohydrates, or a placebo. Fluid replaced in the first two trials was similar to the amount lost via sweat and was determined for each individual. Heart rate was monitored throughout the trial. Fluid was administered as a bolus to stimulate gastric emptying at the start of the trial, and equally throughout the remainder of the trial. Subjects arrived in a euhydrated state, completed the 50-minute exercise protocol where they received one of the four treatments. Following the 50-minute trial at constant work, subjects began a performance test in which they completed a set amount of work as fast as possible.

Results from the fluid trials (fluid-electrolyte and fluid-carbohydrate) showed a reduction of 0.5% body weight, while results from the non fluid trials showed a reduction of approximately 2.0% body weight. When a large amount of fluid was ingested compared to the no fluid ingestion there was a 6% performance increase (10.22 ± 0.27 vs. 10.93 ± 0.32 min). Comparatively there was a 6% performance increase when only carbohydrate was ingested compared to no carbohydrate ingestion (10.23 ± 0.28 vs. 10.92 ± 0.32 min). The increase in performance fluids and carbohydrates is individual, and appears to be additive, as there was a 12% increase in performance when a carbohydrate-electrolyte solution was ingested compared to a placebo (9.93 ± 0.28 vs. 11.34 ± 0.32 min). There were also significantly increased heart rates in the trials with no fluid replacement (6 beats$\cdot$min^{-1}) when compared to the fluid trials (2 beats$\cdot$min^{-1}) over the course of the test. No change in heart rate was seen with the carbohydrate ingestion. This further suggests the role of fluid replacement in physiological cardiac function.[2]

Exercise Associated Muscle Cramps. Exercise associated muscle cramps (EAMCs) are often attributed to hypohydration and electrolyte imbalances, particularly sodium deficits.[6,7,31] An evaluation of sodium content in sweat for selected tennis players revealed sodium losses averaging over 2700 milligrams per hour.[6] The author therefore argues sodium losses that high with sustained exercise make it extremely difficult to recoup the deficit. This is especially true during exercise where fluid and sodium replacement is nearly impossible. These substantial losses in fluid and electrolytes can lead to EAMCs.[7]

A case report examines EAMCs in a 17 year old tennis player.[6] This athlete suffered from widespread, recurrent EAMCs in the quadriceps, hamstrings, and calf muscles for over two years. He had no underlying medical conditions and noticed a higher incidence of EAMCs during sustained play in hot, humid weather. Resting blood serum electrolytes were normal. Sweat rates measured in this athlete were approximately 2.5 $L \cdot h^{-1}$ with a sodium concentration of 35.9 $mmol \cdot L^{-1}$. This calculated out to just over 2 g of sodium loss per hour of play. It was therefore concluded by the author that a sodium deficit was the leading cause of the EAMCs. A treatment recommendation was made to increase his daily sodium intake to 6000-8000 mg. Better hydration prior to completion was also recommended. This would theoretically ensure proper fluid balance prior to competition, and replace electrolytes lost in sweat. It was also recommended that the athlete carry a 0.5 tablespoon packet of salt to add to his sports drink if symptoms of EAMCs appeared. This successfully prevented any attacks of EAMCs for nine months.[6]

Voluntary Dehydration and Thirst

Thirst is primarily modulated by two factors, decreased central blood volume and an increased in extracellular osmolality.[32] Osmolality of extracellular fluid is determined primarily

by sodium, chloride, and bicarbonate.[27] Since cellular membranes are fully permeable to fluid, and only partially permeable to solute, increased osmolality is often seen in the extracellular space. Increased extracellular osmolality is the more powerful of the two mechanisms for thirst.[28] During exercise in heat, significant volumes of fluid as well as solute are lost. Despite an increase in plasma osmolality, an overall solute deficit will remain unless replaced.[33]

Thus, the use of water as the sole source of rehydration poses a problem. When volumes of water are used to rehydrate, central blood volume is partially restored with a corresponding decrease in plasma osmolality. This is turn depresses the thirst mechanism. Despite the return to normal osmolality, a solute deficit remains in the extracellular space. Therefore, volumes of water that restore osmolality and blood volume may still leave the individuals in a fluid deficit.[27,29,33]

Voluntary dehydration occurs when an individual loses body water, and despite access to rehydration fluids, they fail to fully rehydrate.[11,34] In addition to physiological factors, sociological factors influence voluntary drinking behaviors.[33] Research has examined voluntary dehydration in athletic competition.[34,35]

One study focused on voluntary dehydration in runners.[34] Highly trained runners were selected to participate in a 10-mile race. During this time, a lemon-flavored sports drink was offered to them every two miles. Subjects could drink as much as they liked and could take the fluid with them while they continued to run. This was designed to simulate a competitive atmosphere. Weight was taken to measure sweat losses at the beginning and end of the race. Following completion of the race, subjects estimated their sweat losses and fluid replacement.

The researchers found that subjects underestimate their sweat losses (perceived = 12.0 ± 7.4 $mL \cdot kg^{-1}h^{-1}$, actual = 21.6 ± 5.1 $mL \cdot kg^{-1}h^{-1}$). Runners were also found to only voluntarily

replace 30% of their fluid losses, leaving an average of almost 2% body weight loss at the end of the race. Interestingly though was the accuracy of their estimated fluid intakes. Runners underestimated their fluid consumption by only 9% (perceived = 5.2 ± 3.2 $mL \cdot kg^{-1}h^{-1}$, actual = 6.1 ± 3.4 $mL \cdot kg^{-1}h^{-1}$), however they vastly misjudged their sweat losses by 42%. This may give insight to the reason for voluntary dehydration. If runners are unable to estimate their fluid losses they would be assumed to be inaccurate at replacing those losses. Despite favorable conditions for drinking, and a flavored sports drink shown to be palatable, runners were incapable of fully replacing their sweat losses.[34]

Voluntary rehydration habits have also been examined in football players.[35] In an attempt to discourage voluntary dehydration, professional football players were assigned a hydration specialist that shadowed them during practice. Players were constantly offered either cold water or a cold sports drink every play they weren't actively engaged in practice. In contrast, NCAA Division II football players had access to fluid at four stations set up between two fields. They were allowed to drink *ad libitum* at regularly scheduled 10-15 minute intervals. They were only offered cold water. Sweat rates and fluid ingestion was measured after the morning practice, before the afternoon practice, and after the afternoon practice. Both professional football players with constant access to various fluids, and NCAA Division II football players, who were only offered fluid at breaks, replaced approximately 66% of their sweat losses. Moreover, both groups lost approximately 1.4% of their initial body weight. While the clinical importance of these numbers are questioned by the authors, this draws attention to voluntary dehydration. Despite unlimited access to fluids, professional football players still only replaced slightly over half of their fluid losses.[35]

Ad libitum Fluid Replacement. Several factors have been recognized as causes of thirst and influences on fluid intake including osmoreceptors and volume receptors in the body, as well as the temperature and palatability of the fluid.[27] Hormonal influences also play a role in thirst.[32] Thirst however, is a poor indicator of hydration and provides an insufficient stimulus to drinking. This is further emphasized during exercise in heat where humans rarely drink enough voluntarily,[36] often replacing 2/3 or less of their fluid losses.[33,35,37,38]

Researchers have examined several variables that influence *ad libitum* drinking. One of the factors examined was the influence of temperature and flavor on voluntary drinking.[36] Researchers subjected participants to six hours of hiking in desert like conditions (40°C) and gave them fluid at warm (40°C) or cool (15°C) temperatures. Three trials of each temperature were conducted with different flavoring. Plain tap water, tap water with iodine tablets, and tap water treated with iodine tablets and flavored with cherry beverage powder. Iodine was selected as it is routinely used in military settings as a water disinfectant. Additionally, the temperature was selected to simulate ambient temperature (40°C), which is how water is typically consumed in military settings.[36]

Their results showed significant increases in water consumption when flavoring was added and beverage temperature was cooled. An additional 600-1000 grams of fluid was consumed by subjects when it was cooled to 15°C compared to 40°C. Moreover, subjects consumed between 500-800 additional grams of fluid when cherry flavoring was added. This effect was summative as subjects drank over a liter and a half (1600 g) more fluid when cooled and flavored. Substantial differences in total body rehydration were seen. Using iodine flavored warm water; subjects only voluntarily rehydrated a mere 35%. Whereas cooled, cherry flavored water resulted in rehydration of over 80%. The authors reason this is due to the unpleasant taste

of iodine, which appears to deter drinking behavior more than the body's inherent drive to rehydrate.[36]

The influence of flavoring and temperature on *ad libitum* drinking becomes even more evident in subjects more reluctant to voluntarily rehydrate.[11] Researchers examined the drinking behaviors of men with four beverage choices. Water was served as either cool (15°C) or warm (40°C), and either raspberry flavored or iodine flavored. Similar to previous research,[36] iodine was used to simulate disinfecting field water during army combat. Each subject exercised in hot temperatures (40°C) for six hours. Following the cool iodine water trial, researchers classified those who lost more than 2% body weight to sweat as "reluctant drinkers" and those who maintained their weight loss to less than 2% as drinkers. These classifications were used to examine the changes in their drinking behaviors for subsequent trials.

Results showed a 37% decrease in fluid consumption in the drinkers group, and a 59% reduction in the reluctant drinkers group when the fluid temperature was raised. Surprisingly, the drinkers group showed little to no change in fluid consumption when flavoring was added. Cooling either the raspberry flavored, or iodine treated water proved to be the more influential factor in *ad libitum* fluid consumption in the drinkers group. In the reluctant drinkers group, flavoring of the warm beverage showed a significant increase of 79% fluid consumption compared to non-flavored, and increased consumption of the flavored cool beverage over the non-flavored cool beverage, but not significantly so. Again beverage temperature was shown to be the more significant factor in increasing *ad libitum* drinking, even in reluctant drinkers. This confirms other research that beverage temperature and flavor are important factors in *ad libitum* drinking behaviors.[11]

Additional research has focused on the effects of both sodium content and flavoring on *ad libitum* drinking behaviors. One such study examined *ad libitum* drinking in adolescent males.[12] Subjects were required to exercise in heat (35°C) while given access to one of three drinks; water, grape-flavored water, or grape-flavored water containing 6% carbohydrate and 18.0 $mmol \cdot L^{-1}$ sodium chloride. Subjects were given unlimited access to their beverage, and consumption was measured throughout the 180-minute exercise duration. Fluid intake increased 44.5% for the flavored water compared to plain water, and over 90% for the carbohydrate-sodium flavored water. This confirmed previous finding that flavoring increases fluid palatability and consumption. Body weight loss during the plain water and flavored water trials after rehydration were -0.65% and -0.32% respectively. Interestingly a finding of over hydration (0.47% body weight) was found in the carbohydrate sodium trial. These results reinforce the importance of sodium during rehydration, not only for body fluid replacement, but also its effect on *ad libitum* drinking behavior.[12] These results have been further confirmed by similar research.[39,40]

Additional research has examined the effect of carbohydrate content and osmolality on *ad libitum* fluid ingestion.[41] Three beverage compositions were examined with varying glucose content and osmolality. Glucose concentrations of 0%, 2%, and 10% were examined with corresponding osmolalities of 74 ± 1, 188 ± 3, and 654 ± 4 $mOsm \cdot kg^{-1} H_2O$. Electrolyte content, including sodium, was held constant for all trials, and flavoring was equalized between beverages. Subjects were dehydrated to approximately 2% body weight via exercise and heat and then given 120 minutes to rehydrate with one of the three beverages. Beverages were served at room temperature (37°C). Perceptive rating was taken for sweetness, pleasantness, and bitterness for each trial during the rehydration period.

Results showed no significant differences in total fluid intake, total fluid retention, change in plasma volume, or net fluid balance. Perceived sweetness, bitterness, and pleasantness were the same for each trial as well. The authors concluded *ad libitum* drink behaviors are not influenced by osmolality and glucose content when flavoring and sodium content are held constant.[41] This adds to the body of evidence that palatability, sodium and electrolyte content, and temperature play a significant role in *ad libitum* fluid consumption.[12,36,39-41]

More recently, research has focused on the differences in voluntary fluid intake between water, diluted orange juice, a commercial sport beverage (orange flavored) and a homemade sport beverage (orange flavored).[10] This examination used 50 triathletes exercising for 75 minutes. To simulate a competitive athletic event, subjects were only given access to their beverage for 60 seconds at the 30 and 60 minute marks of the race. Total fluid intake was monitored. Also measured were the subjects' perceptions of liking or disliking the flavor, sweetness, tartness, saltiness, and overall acceptance of the drink. The commercially produced drink scored significantly higher than the rest on overall fluid intake, acceptance of drink, and liking of flavor. Despite the author's affiliation with the Gatorade Sports Science Institute, the results suggest the sports drink industry has done a good job of creating a palatable beverage for consumption.[10]

Recommendations for Rehydration

Several organizations have published rehydration guidelines. The National Athletic Trainers' Association (NATA) recommends fluid replacement to approximate sweat and urine losses during exercise.[8] At a minimum the NATA aims to maintain hydration losses to less than 2% body weight. Following exercise, an additional 50% of fluid lost should be replaced to account for urinary output. To positively influence drinking behaviors they suggest providing

cool beverages (10-15°C) that are easily accessible in clear water bottles marked in 100 mL increments. Additionally, benefit is suggested from providing a sports drink with a 6-8% carbohydrate concentration. Moreover, a fluid containing 0.3-0.7 $g \cdot L^{-1}$ sodium chloride is suggested to help offset electrolyte losses.[8]

The American College of Sports Medicine (ACSM) has published a similar position statement for fluid replacement.[9] They suggest prehydrating several hours before exercise to allow for fluid absorption and urine production. During exercise, *ad libitum* drinking may be appropriate as long as it prevents excessive dehydration (> 2% body weight loss). Drinks containing modest amounts of electrolytes (20-30 $meq \cdot L^{-1}$) and carbohydrates ($\leq$ 8%) are appropriate to help sustain fluid and electrolyte balances. Following exercise it is recommended that rehydration should match 1.5 liters for each kilogram of body weight lost. Snacks and fluid with sodium can help stimulate thirst during this time.[9]

These recommendations however, have come under recent scrutiny.[13] Arguments have been made that there is a lack of scientific evidence that only full rehydration provides optimal performance and prevention of heat related-illnesses. Moreover, some experts argue that untrained individuals may be at risk of overhydration and hyponatremia if drinking is overly promoted. Finally, the interests of the commercial sports drink industry in the research community cannot be denied.[13]

Sodium and Rehydration

The importance of sodium replacement following dehydration has been further examined.[42] Researchers dehydrated several volunteers, and over the course of six hours rehydrated them with varying volumes of either a high sodium content drink (61 $mmol \cdot L^{-1}$) or a low-sodium content drink (23 $mmol \cdot L^{-1}$). The results showed the volume of fluid was essential

in rehydration. Subjects replacing approximately 50% and 100% of their fluid losses were in a fluid deficit five hours post exercise. Those subjects that consumed 150% and 200% of their fluid losses, regardless of sodium content were in a positive net fluid balance. Interestingly the importance of sodium content becomes apparent six hours post exercise. Those subjects with the low sodium content fell into a fluid deficit due to substantial urine losses, while those in the high sodium content trial remained fully hydrated. This enforces the importance of sodium in retaining fluid and preventing excessive urine production.[42]

Another finding of this research was the effect of drinks with varying volumes and tonicity on plasma volume. Larger volumes of fluids were more effective at restoring replacing plasma volumes in both the high sodium and low sodium trial. However, the effect on plasma volume restoration was greater in the high sodium fluid.[42]

Further examination into the importance of sodium in rehydration beverages used chicken noodle soup and chicken broth compared to water and a carbohydrate electrolyte drink.[16] Sodium concentration was highest in the soup (333.8 $mmol \cdot L^{-1}$) compared to the broth (109.5 $mmol \cdot L^{-1}$) and carbohydrate electrolyte drink (16.0 $mmol \cdot L^{-1}$). Subjects were dehydrated to 2-3% body weight and then replaced 100% of their fluids lost during the two hour rehydration period with one of the selected beverages.

After rehydration, plasma volume was not significantly different from pre to post levels for either the soup (-1.4 ± 0.9%) or broth (-1.6 ± 1.1%). However, a significant deficit remained when rehydrating with either water (-5.6 ± 1.1%) or the carbohydrate electrolyte beverage (-4.2 ± 1.0%). These results confirm previous findings that sodium content is important in reaching complete rehydration. Even when 100% of fluid is replaced, a plasma volume deficit of 4-5% remained when either water or a carbohydrate electrolyte beverage was used. The low sodium

content of the carbohydrate electrolyte beverage made it as ineffective at restoring plasma volume as water alone.[16]

Chicken noodle soup has been further examined due to its high sodium concentration (≥ 330 mmol·L^{-1}).[17] Subjects were given one of three beverages for consumption 45 minutes before exercise. Chicken noodle soup, a carbohydrate electrolyte beverage, or water was provided to subjects before exercising for 90 minutes. Subjects were allowed to drink water *ad libitum* throughout the exercise duration, and total volume ingested was measured at the end. Blood draws were taken at 30-minute intervals throughout the study. Total fluid intake was significantly higher after ingesting chicken noodle soup (1227 ± 602 g) over a carbohydrate electrolyte drink (1062 ± 675 g) and water (852 ± 554 g). Moreover, total urine output was least in the soup trial (190 ± 183 mL) compared to water (233 ± 214 mL), and the carbohydrate electrolyte drink (216 ± 152 mL). This resulted in an overall fluid balance of -251 ± 418 g for soup and a fluid balance of -657 ± 593 g for water. This shows that sodium ingestion prior to exercise and *ad libitum* drinking improves plasma volume restoration and overall fluid balance.[17]

The importance of plasma volume restoration has been further emphasized by research using glycerol.[30] Glycerol was chosen as it has no caloric benefit to exercise, yet increases the tonicity of fluid consumed. Subjects were hypohydrated to a 4% body weight loss. Subjects were then given either no fluid, water, or glycerol and water. Results predictably showed decreased urine output and plasma volume, and increased plasma osmolality and sodium content in the no fluid trial. Small but important changes were found in the glycerol trial. Compared to the water trial, a decreased urine output and increased plasma osmolality was found in a glycerol trial. The authors concluded the increased osmotic drive, coupled with better retention of fluid

was responsible for the small but noticeable increase in plasma volume in the glycerol trial. Adding glycerol improved the water retention in a similar fashion to sodium.[30]

Pickle Juice

Pickle juice has received attention from ATCs as a treatment for EAMCs.[19,20] Currently, almost 25% of ATCs use or have used pickle juice to treat EAMCs.[21] Moreover, almost 19% of ATCs use or have used pickle juice in the prevention of EAMCs. Of the ATCs who advocate the use of pickle juice, 80% of them recommend it in conjunction with water replacement. For the majority of ATCs (64%), the perceived effectiveness of pickle juice is due to it replacing sodium and other electrolytes.[21] The perception that pickle juice is effective due to its high sodium content leads some to question its role as a rehydration beverage.[23]

Despite its wide usage by ATCs, some experts caution against drinking pickle juice due to the high sodium content.[22,31] The researchers argue that the high sodium content and distastefulness of pickle juice limit the amount that would be voluntarily consumed. They also argue small quantities of pickle juice that would be palatable would be ineffective at replacing sodium lost in sweat.[22]

The questions surrounding the palatability of pickle juice have been examined.[43] Subjects consumed 7 $mL \cdot kg^{-1}$ of either deionized water (DIW) or pickle juice (PJ). Subjects were asked to rate the pre-ingestion and post-ingestion nausea for each beverage. No significant differences in nausea were found between drinks, and neither resulted in substantial feelings of nausea (100 point scale: PJ = 4.1 ± 1.3, DIW = 1.2 ± 1.3). Palatability of deionized water (83.4 ± 6.2) was higher than pickle juice (34.0 ± 7.7) though. Important to note however, was nine out of ten subjects reported gastrointestinal distress later in the day after ingestion of pickle juice, while none of those who drank deionized water reported distress.[43] This is only partially

applicable, as 7 mL·kg^{-1} of pickle juice is a significantly higher volume than would often be administered by athletic trainers.[21]

Changes to plasma variables after pickle juice consumption have also been briefly examined.[18] Euhydrated subjects were given 1 mL·kg^{-1} of either pickle juice, tap water, or a carbohydrate electrolyte drink. Blood samples were then recorded for one hour post-ingestion. No significant changes were found in plasma volume over time for any of the drinks. Additionally, plasma osmolality and sodium concentrations were unchanged 60 minutes post-ingestion.[18] This discounts the claim that ingestion of pickle juice only will exacerbate dehydration and plasma hypertonicity.[23] While the importance of these findings cannot be discarded, the researchers tested only euhydrated subjects, leaving uncertainty as so the effects of pickle juice on hypohydrated subjects.

Guidelines have been published for pickle juice consumption.[23] Examining two varieties of pickle juice with differing sodium concentrations, theoretical values were calculated for consumption of pickle juice and water to meet current drinking guidelines set by the NATA.[8] For pickle juice containing 7.4 ± 0.1 grams of sodium per liter (220 mg per serving), 10 mL of water is required for every 1 mL pickle juice ingested to meet current guidelines. That is 1.5 liters of water for every 150 mL of pickle juice. The suggested guidelines for pickle juice containing 17.1 ± 0.1 grams per liter (390 mg per serving) are even higher. Athletes would need to drink almost 25 mL of water for each milliliter of pickle juice to meet these guidelines. For a 70 kg man given 1 mL·kg^{-1} pickle juice, he would be required to drink an additional 1.75 L of water. The high volume of fluid required to dilute the sodium content to the recommended guidelines causes the author to question the viability of pickle juice as a rehydration beverage. These numbers are based on purely theoretical values, and require confirmation and further

research. Moreover, the author suggests further research in the area of *ad libitum* fluid intake after pickle juice consumption, as well as the impact on plasma variables.[23]

Gastric Emptying. The viability of rehydration and electrolyte replacement initially depends on gastric emptying. Until absorbed into the bloodstream, fluid replacement is ineffective. Several factors influence gastric emptying rates.[43-45]

Volume ingested is the main determinate of gastric emptying.[44] Subjects were dehydrated with 90 minutes of exercise and then administered either 100% or 150% of their losses to sweat. Dosages were given at 30 minute intervals, with a priming dose of 30% total volume administered first, followed by subsequent dosages of 14% total volume. Gastric volume was measured hourly for the next three hours. Results showed significantly higher volumes emptied by the stomach in the 150% trial than then 100% trial. When corrected for volume, the hourly gastric emptying rates were also significantly faster in the 150% trial. This suggests the importance of volume and gastric distention in gastric emptying rates.[44]

The effect of pickle juice on gastric emptying also has been examined.[43] Euhydrated subjects were given the same volumes of either pickle juice or deionized water on separate occasions. Gastric emptying rates were then measured over 30 minutes. During the initial five minutes, similar volumes of pickle juice and deionized water rapidly left the stomach (pickle juice=219.2 ± 39.1 mL, deionized water=305.0 ± 40.5 mL). Subsequent gastric emptying ceased for pickle juice, while deionized water continued to empty from the stomach for the remainder of the trial. This suggests that volume caused initial gastric emptying for both deionized water and pickle juice. Once the volume stimulus was removed, the high osmolality inhibited further gastric emptying for pickle juice[43]. High osmolality and low pH have been shown to decrease gastric emptying in previous research.[46,47] This causes concern for the use of pickle juice as a

rehydration beverage. If the constituents of pickle juice limit its ability to leave the stomach, the effectiveness of it as a rehydration beverage is questionable.

Summary

Hypohydration of varying levels has been shown to cause detrimental effects on athletic performance.[1,3,4] Moreover, modest levels of hypohydration can lead to a variety of physiological changes, including changes in plasma osmolality and central blood volume.[5] These changes in turn trigger the thirst response in humans.[27] Several factors influence thirst and drinking behaviors including temperature, taste, and sodium content.[10-12,36] Despite often favorable conditions for rehydration, athletes continue to show voluntary dehydration and the inability to properly maintain their body fluid balance.[34] This has lead several organizations to publish drinking guidelines aimed to promote rehydration.[8,9] These recommendations, and further research emphasize the need for sodium consumption during rehydration.[6,7,14,16,42]

Pickle juice has previously gained notoriety as a treatment for EAMCs due to its high sodium concentration.[19-21] Despite its wide usage among ATCs,[21] several clinicians caution against its use for rehydration due to its high tonicity.[22] Guidelines have since been published for pickle juice consumption, however these remain theoretical and untested.[23] These guidelines are simply "target volumes" of hypotonic fluid to be ingested in conjunction with pickle juice to reach recommendations set by the NATA[8] for fluid replacement. Additionally, the *ad libitum* drinking behaviors of individuals after consuming pickle juice is unknown. Moreover, the impact of pickle juice on plasma volume restoration has only been briefly examined.[18] The lack of knowledge regarding pickle juice as a rehydration beverage and the drinking behaviors following its consumption highlight the need for further examination.

METHODS

Experimental Design

A 3x6 factorial crossover design with repeated measures will guide data collection. The independent variables will be drink (pickle juice strained from sliced dill pickles, [Vlasic Pickles, Pinnacle Foods Corp, Cherry Hill, NJ], hypertonic saline, or deionized water) and time (-105 minutes pre-ingestion, -0.5 minutes pre-ingestion, 15 minutes post-ingestion, 30 minutes post-ingestion, 45 minutes post-ingestion, and 60 minutes post-ingestion). The hypertonic saline solution will be a solution of sodium chloride with a $[Na^+]$ similar to pickle juice. The dependent variables will be amount of fluid consumed *ad libitum* (g), changes in plasma volume (percentage from baseline), OSM_p ($mOsm \cdot kg^{-1} H_2O$), and $[Na^+]_p$ ($mmol \cdot L^{-1}$). Perceptual indicators of hydration (i.e., thirst, fullness, and nausea) will be quantified using a 100 mm visual analog scales (e.g., 0 = no thirst, 100 = extreme thirst). Palatability of the treatment drink will be assessed using a single 100 mm visual analog scale (e.g., 0 = unpalatable, 100 = palatable). Urine specific gravity and body mass will characterize hydration status and hypohydration level prior to and post-exercise respectively.

Subjects

Sample size was estimated *a priori* based on previous findings[17] (Appendix B); a convenience sample of 15 healthy male volunteers will be recruited to participate in this study to detect a difference with 80% power at an alpha level of 0.05.

Subjects will be excluded if they: (1) are female, (2) have a history of heat related illnesses (e.g., heat exhaustion, heat stroke, heat syncope) in the six months prior to data collection, (3) had an injury or surgery in the 12 months prior to data collection, (4) self-report a history of heart disease, asthma, diabetes, high blood pressure, or high cholesterol, (5) self-report

a history of chest pain, dizziness, fainting, blackouts, or unreasonable breathlessness during exercise, (6) have any food allergies, (7) smoke, (8) are not between the ages of 18-35, (9) do not meet current ACSM guidelines for physical activity,[24] or (10) have been acclimated to heat in the preceding 6 days.[25] All subjects will provide informed written consent, and the study's procedures will be approved by our university's institutional review board prior to data collection.

Procedures

Twenty-four hours prior to each testing session subjects will be instructed to drink water consistently, avoid alcohol and caffeine, and refrain from strenuous exercise. Twelve hours prior to testing, subjects will be instructed to fast, during which time they will only be allowed to drink water. Subjects will self-report compliance prior to testing each day. If subjects are noncompliant, they will be excused and rescheduled for a different day at least 48 hours later.

Subjects will arrive at the Athletic Training Research Center (BBFH 14) and provide a urine sample to ensure they are euhydrated. Subjects with a urine specific gravity less than 1.020 will be considered euhydrated.[9] If hypohydrated ($U_{sg} > 1.020$), subjects will consume 3 $mL \cdot kg^{-1}$ body weight of deionized water and rest 30 minutes to allow for water absorption. Urine specific gravity will be reassessed to ensure subjects are euhydrated.

Subjects will then insert a rectal thermometer (YSI; Advanced Instruments Inc., Norwood, MA) and don a heart rate monitor (Polar Electric Inc., Lake Success, NY). Next, a venous catheter will be inserted into a superficial vein in the subjects forearm. Subjects will then be weighed nude using electronic scale accurate to the nearest tenth kilogram. Subjects will then change into a sweat suit (i.e., sweatshirt & sweatpants) that they will wear during exercise to

maximize fluid losses. Next, subjects will be seated and asked to minimize movement as much as possible for 30 minutes to allow for body compartment equilibration.[48]

After equilibration, a 5.0 mL blood sample will be collected (-105 minutes pre-ingestion). Subjects will then begin the first bout of exercise in an environmental chamber (38-39°C, RH: 20%-40%) at a hard intensity,[26] between 80-90% of their age predicted maximal heart rate (maximum heart rate = 220-age). Subjects will alternate between running and cycling every 15 minutes for 60 minutes. Exercise will be terminated early if rectal temperature exceeds 39.0°C, subjects shown signs and symptoms of heat illness (e.g., dizziness, nausea, confusion), or request to stop. No fluid will be administered during exercise. Following the 60 minutes of exercise, subjects will cool down at a self selected pace for 5 minutes. After the 5 minute cool down subjects will towel dry, provide a second urine sample, and be weighed nude. Subjects will change into dry clothing , be seated, and instructed to minimize movement as much as possible for 30 minutes to allow for body compartment equilibration.[48]

Following the 30 minute equilibration period, a second blood sample will be collected (-0.5 minutes pre-ingestion). Subjects will rate their perceived thirst, nausea, and fullness by making a mark on a 100 mm visual analog scale (Appendix C). Subjects will then have 30 seconds to consume 1 $mL \cdot kg^{-1}$ body mass of either chilled pickle juice (6°C), chilled hypertonic saline (6°C), or chilled deionized water (6°C). Immediately following the 30 second ingestion period, subjects will rate the palatability of the treatment drink by placing a mark on a 100 mm visual analog scale (Appendix D). Subjects will then be given a pre-weighed volume of room temperature (≈25°C) deionized water in opaque water bottles and allowed to drink *ad libitum* for 60 minutes. Subjects will be told to drink as much or as little deionized water as they want over the 60 minute rehydration period. The volume of water consumed *ad libitum* will be determined

by weighing the water bottles at the end of the 60 minute period and subtracting mass post-ingestion from the mass pre-ingestion.

At 15, 30, 45, and 60 minutes post treatment drink ingestion, 5.0 mL blood samples will be collected and subjects will rate their perceived thirst, fullness, and nausea (Appendices E-H). Following the last blood sample, subjects will be weighed nude, and the venous catheter, rectal thermometer, and heart rate monitor will be removed. Subjects will then be excused. Subsequent testing days will follow the same procedures as described above except that subjects will undergo a different treatment condition. Subjects will be randomly assigned a treatment drink on the first day of testing. Treatment drink order will be randomized and counterbalanced with a balanced latin square. Testing days will be separated by at least 72 hours and occur at approximately the same time of day.

To minimize bias, subjects will be told that the purpose of the study is to determine the effect of the treatment drinks on core temperature, heart rate, and blood variables following exercise in heat, and the 60 minute rehydration period is to ensure their safety and return to normal cardiac function.

Blood Analysis. Subject's antecubital region will be cleaned with alcohol prior to venipuncture. A single use, sterile, 20-gauge venous catheter (BD, Sandy, UT) will be inserted into a superficial forearm vein. The catheter will then be attached to a 3-way stopcock (Tyco Healthcare Group LP, Mansfield, MA) via small extension tubing (B. Braun Medical Inc., Bethlehm, PA). For each 5.0 mL blood sample, 1.0 mL will be used to measure hematcrit and hemoglobin (0.5 mL for each). The remaining 4.0 mL of blood will be sealed in a 6.0 mL lithium heparin vacutainer (BD, Franklin Lakes, NJ) and placed in an ice bath until the final blood sample is drawn. Blood samples take approximately 10 seconds to obtain.

To determine hematcrit, blood will be drawn into heperanized microcapillary tubes and centrifuged at 3000 rpm for 5 minutes (IEC Micro-MB; IEC, Needham Heights, MA) and be read using a microcapillary reader (IEC 2201; Damon/IEC, Needham Heights, MA). Hemoglobin will be measured by mixing 20 μL of whole blood with 5 mL cyanmethemoglobin reagent. The sample will be read using a standard spectrophotometer at 540 nm (iMark; Biorad, Hercules, CA) and a standard curve. Hemoglobin concentration and hematcrit will be performed in triplicate immediately after sampling. Change in plasma volume will be calculated from hemoglobin and hematcrit measurements using the Dill and Costill equation.[49]

The remaining blood will be centrifuged at 3000 rpm for 15 minutes at 3°C (5804; Eppendorf North America Inc., New York, NY) and plasma will be drawn off the red blood cells. Plasma osmolality will be determined in duplicate using freezing point depression osmometry (3D3; Advanced Instruments Inc., Norwood, MA). Plasma sodium concentration will be measured in duplicate by using an ion-sensitive electrode system (16; NOVA Biomedical, Waltham, MA).

Urine Analysis. Urine specific gravity will be measured using a handheld refractometer (SUR-Ne; Atago USA Inc., Bellevue, WA). A urine specific gravity of <1.020 will indicate euhydration.[9]

Drink Analysis. Pickle juice, hypertonic saline, and deionized water will be analyzed for electrolyte concentration, pH, glucose concentration, and osmolality. Drink pH will be measured with a pH meter (AB 15; Fischer Scientific, Pittsburg, PA.). Electrolyte and glucose concentration will be measured in duplicate with an ion selective electrode analyzer (16; NOVA

Biomedical, Waltham, MA). Osmolality will be measured in duplicate by freezing point depression osmometry (3D3; Advanced Instruments Inc., Norwood, MA).

Statistical Design

Means and standard deviations for all dependent variables will be calculated and used for statistical analysis. A MANOVA will be used to determine the influence of the plasma dependent variables on *ad libitum* fluid ingestion (SPSS v19; IBM, Armonk, NY). If a significant F-value is observed, individual repeated measures ANOVAs will be used for each dependent variable. Upon significant F-values of the repeated measures ANOVA, Tukey-Kramer post hoc tests will be used to identify differences between drinks. Significance will be accepted when $P < 0.05$.

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APPENDIX B. ADDITIONAL METHODS

Table 2. Sample Size Estimate

Equation[50]: $n=\frac{2(SD)^2 * (Z\alpha+Z\beta)^2}{\Delta^2}$

n=Sample size needed
SD=Standard deviation of conditions assuming equal variance
$Z\alpha$= Z statistic for α
$Z\beta$= Z statistic for β
Δ=Minimum difference between pickle juice and deionized water conditions

Assumptions:
1. SD= 350 mL
2. $Z\alpha$=1.96
3. $Z\beta$=0.84
4. Δ= 360 mL

Calculations: $n=\frac{2(350)^2 * (1.96+0.84)^2}{360^2}$

n=14.82

Table 3. Subject Drink Order and Demographics

Subject	Experimental Day 1 Drink	Experimental Day 2 Drink	Experimental Day 3 Drink	Age (yr)	Height (cm)
1	Pickle Juice	Hypertonic Saline	Deionized Water	21	177.8
2	Deionized Water	Pickle Juice	Hypertonic Saline	23	185.4
3	Hypertonic Saline	Deionized Water	Pickle Juice	22	180.3
4	Pickle Juice	Hypertonic Saline	Deionized Water	27	190.5
5	Deionized Water	Pickle Juice	Hypertonic Saline	20	172.7
6	Hypertonic Saline	Deionized Water	Pickle Juice	22	172.7
7	Pickle Juice	Hypertonic Saline	Deionized Water	20	182.9
8	Deionized Water	Pickle Juice	Hypertonic Saline	23	180.3
9	Hypertonic Saline	Deionized Water	Pickle Juice	19	185.4
10	Pickle Juice	Hypertonic Saline	Deionized Water	23	167.6
11	Deionized Water	Pickle Juice	Hypertonic Saline	20	177.8
12	Hypertonic Saline	Deionized Water	Pickle Juice	22	175.3
13	Pickle Juice	Hypertonic Saline	Deionized Water	18	172.7
14	Deionized Water	Pickle Juice	Hypertonic Saline	22	172.7
15	Hypertonic Saline	Deionized Water	Pickle Juice	24	182.9

Table 4. Data Collection Sheet

Name_____ Height_____ Age_____

Date_____ Day in Study: 1 2 3 Subject #_____ RH%_____

Room Temperature_____°C Drink Condition: Pickle Juice Hypertonic Saline DIW

Pre-Test Questionnaire:	**Answer**		**Decision**
1. Have you fasted for the last 12 hours?	Yes	No	Reschedule if no
2. Have you drank water consistently over the last 24 hours?	Yes	No	Reschedule if no
3. Have you exercised in the past 24 hours?	Yes	No	Reschedule if yes
4. Have you had alcohol or caffeine in the past 24 hours?	Yes	No	Reschedule if yes
5. Have you experienced any heat illnesses such as heat stroke, heat fainting, or heat exhaustion in the last 6 months?	Yes	No	Disqualify if yes
6. Do you have a history of heart disease, diabetes, high blood pressure, high cholesterol, or asthma?	Yes	No	Disqualify if yes
7. Do you smoke?	Yes	No	Disqualify if yes
8. Have you had a lower extremity injury or surgery in the past 12 months?	Yes	No	Disqualify if yes
9. Are you currently sick?	Yes	No	Reschedule if yes
10. Do you have an aversion to needles?	Yes	No	Disqualify if yes
11. Have you exercised in heat in the past six days?	Yes	No	Reschedule if yes
12. Are you on any medications, such as diuretics, or heart medications ?	Yes	No	Disqualify if yes
13. Do you have a history of blackouts, chest pain, dizziness, fainting, or unreasonable breathlessness during exercise	Yes	No	Disqualify if yes
14. Do you have any food allergies?	Yes	No	Disqualify if yes
15. Do you get at least 30 minutes of moderate aerobic activity on 5 days each week?	Yes	No	Skip 16 if yes
16. Do you get at least 20 minutes of vigorous aerobic activity on 3 days each week	Yes	No	Disqualify if no

Table 4. Continued

Sign informed consent
Urine sample #1

Urine Specific Gravity: _____ (Must be <1.020)

Insert rectal thermometer
Attach heart rate monitor
Insert venous catheter

Body Weight 1 (Nude): _____kg

Change into sweat suit
30 minute equilibration period

Blood Sample #1 (-105 minutes pre-ingestion):

	1	**2**	**Ave**		**1**	**2**	**3**	**Ave**
$[Na^+]_p$	____	____	_____	[Hb]	____	____	____	_____
OSM_p	____	____	_____	Hct	____	____	____	_____

Bottom Target HR (HRmax=0.8x(220-age)): _____bpm

Top Target HR (HRmax=0.9x(220-age)): _____bpm

Enter heat chamber
15 minutes jogging @ 80-90% HR

Heat Illness S/S?

Rectal Temperature 1 (15 minutes into exercise):_____°C _____

15 minutes cycling @ 80-90% HR

Rectal Temperature 2 (30 minutes into exercise):_____°C _____

15 minutes jogging @ 80-90% HR

Rectal Temperature 3 (45 minutes into exercise):_____°C _____

15 minutes cycling @ 80-90% HR

Rectal Temperature 4 (60 minutes into exercise):_____°C _____

5 minute cool down (cycling)
End of exercise

Table 4. Continued

Towel dry subject
Urine sample #2

Body Weight #2 (Nude): _____kg

Change into dry clothing
30 minute equilibration period

Blood Sample #2 (-0.5 minutes pre-ingestion):

	1	**2**	**Ave**		**1**	**2**	**3**	**Ave**
$[Na^+]_p$	____	____	_____	[Hb]	____	____	____	_____
OSM_p	____	____	_____	Hct	____	____	____	_____

VAS #1:
Thirst: _____mm Nausea: _____mm Fullness: _____mm

Volume of Treatment Fluid (1 mL·kg^{-1} body weight): _____mL

Subject has 30 seconds to drink treatment fluid

Palatability VAS: _____mm

Pre-weight of Water Bottles: _____g _____g _____g _____g

Post-weight of Water Bottles: _____g _____g _____g _____g

Total Amount Drank: _____g

Treatment Drink Temperature: _____°C

Ad libitum fluid drinking for 15 minutes

Blood Sample #3 (15 minutes post-ingestion):

	1	**2**	**Ave**		**1**	**2**	**3**	**Ave**
$[Na^+]_p$	____	____	_____	[Hb]	____	____	____	_____
OSM_p	____	____	_____	Hct	____	____	____	_____

VAS #2:
Thirst: _____mm Nausea: _____mm Fullness: _____mm

Ad libitum fluid drinking for 15 minutes

Table 4. Continued

Blood Sample #4 (30 minutes post-ingestion):

	1	**2**	**Ave**		**1**	**2**	**3**	**Ave**
$[Na^+]_p$	____	____	_____	[Hb]	____	____	____	_____
OSM_p	____	____	_____	Hct	____	____	____	_____

VAS #3:

Thirst: _____mm Nausea: _____mm Fullness: _____mm

Ad libitum fluid drinking for 15 minutes

Blood Sample #5 (45 minutes post-ingestion):

	1	**2**	**Ave**		**1**	**2**	**3**	**Ave**
$[Na^+]_p$	____	____	_____	[Hb]	____	____	____	_____
OSM_p	____	____	_____	Hct	____	____	____	_____

VAS #4:

Thirst: _____mm Nausea: _____mm Fullness: _____mm

Ad libitum fluid drinking for 15 minutes

Blood Sample #6 (60 minutes post-ingestion):

	1	**2**	**Ave**		**1**	**2**	**3**	**Ave**
$[Na^+]_p$	____	____	_____	[Hb]	____	____	____	_____
OSM_p	____	____	_____	Hct	____	____	____	_____

VAS #5:

Thirst: _____mm Nausea: _____mm Fullness: _____mm

End of rehydration

Body Weight #3 (Nude): _____kg

Remove venous catheter
Remove rectal thermometer
Remove heart rate monitor
Excuse Subject

Table 5. Experimental Timeline

Procedure	Post-Ingestion Time (min)	Overall Time (min)
Subject Arrives		0
Questionnaire & Informed Consent		3
US #1		6
Insert RT, & Attach HRM		9
Insert VC		13
BW #1		18
Seated Equilibration Period		20
BS #1 (Baseline)	-105	50
Begin Exercise		51
End Exercise		111
Cool Down		116
US #2		120
BW #2		124
Seated Equilibration Period		125
BS #2, VAS #1	-0.5	154.5
Treatment Fluid	0	155
Palatability VAS	.5	155.5
Ad Libitum Drinking	.5	155.5
BS #3, VAS#2	15	170.5
BS #4, VAS #3	30	185.5
BS #5, VAS #4	45	200.5
BS #6, VAS #5	60	215.5
BW #3	62	218
Remove VC, RT, HRM	65	221
Subject Excused	75	225

BS: Blood Sample BW: Body Weight HRM: Heart Rate Monitor
RT: Rectal Thermometer US: Urine Sample VAS: Visual Analog Scale
VC: Venous Catheter

Table 6. Statistical Analysis

1. Does pickle juice, hypertonic saline, or deionized water affect ad libitum fluid ingestion?

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subjects	14	4410007	315000.4			
B: drink	2	293516.8	146758.4	4.17	0.026007*	0.686505
AB	28	985618.3	35200.65			
S	0					
Total (Adjusted)	44	5689142				
Total	45					

* 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: subjects	14					
B: drink	2	4.17	0.026007*	0.060476	0.038910*	0.034343*
AB	28					
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: subjects	14					
B: drink	2	4.17	0.686505	0.476683	0.597644	0.627165
AB	28					
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	0.761325	0.835103	0.686500	4.9	2.0	0.086729	Okay

Table 6. Continued

Tukey-Kramer Multiple-Comparison Test

Response: Fluid Ingested (mL)
Term B: drink

Alpha=0.050 Error Term=AB DF=28 MSE=35200.65 Critical Value=3.4993

Group	Count	Mean	Different From Groups
DIW	15	532.994	HS
PJ	15	700.3506	
Saline	15	708.026	DIW

2. Does pickle juice, hypertonic saline, or deionized water affect $[Na^+]_p$?

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subjects	14	420.0185	30.00132			
B: drink	2	26.75741	13.3787	2.11	0.139599	0.396857
AB	28	177.187	6.328108			
C: time	5	172.438	34.48759	30.35	0.000000*	1.000000
AC	70	79.54815	1.136402			
BC	10	9.342592	0.9342592	1.70	0.086001	0.791272
ABC	140	76.87963	0.5491402			
S	0					
Total (Adjusted)	269	962.1713				
Total	270					

* 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: subjects	14					
B: drink	2	2.11	0.139599	0.167991	0.150592	0.145108
AB	28					
C: time	5	30.35	0.000000*	0.000077*	0.000000*	0.000000*
AC	70					
BC	10	1.70	0.086001	0.213153	0.149609	0.111319
ABC	140					
S	0					

Table 6. 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: subjects	14					
B: drink	2	2.11	0.396857	0.273125	0.353424	0.375293
AB	28					
C: time	5	30.35	1.000000	0.999161	0.999999	1.000000
AC	70					
BC	10	1.70	0.791272	0.229187	0.540697	0.693368
ABC	140					
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	0.814185	0.906330	0.771778	3.4	2.0	0.185653	Okay
AC	0.200000	0.370869	0.425094	0.012655	52.9	14.0	0.000002	Violated
ABC	0.100000	0.475824	0.750654	0.001368	69.0	54.0	0.081847	Okay

Tukey-Kramer Multiple-Comparison Test

Response: $[Na^+]_p$
Term C: time

Alpha=0.050 Error Term=AC DF=70 MSE=1.136402 Critical Value=4.1438

Group	Count	Mean	Different From Groups
-105	45	140.8445	45post, 60post, 30post, 15post, 0post
45post	45	141.6333	-105, 15post, 0post
60post	45	141.6889	-105, 15post, 0post
30post	45	141.9778	-105, 15post, 0post
15post	45	143.0333	-105, 45post, 60post, 30post
0post	45	143.1	-105, 45post, 60post, 30post

3. Does pickle juice, hypertonic saline, or deionized water affect OSM_p?

Table 6. Continued

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subjects	14	1412.967	100.9262			
B: drink	2	127.2222	63.61111	1.75	0.192421	0.335194
AB	28	1018.361	36.37004			
C: time	5	711.7778	142.3556	34.45	0.000000*	1.000000
AC	70	289.2222	4.131746			
BC	10	36.5	3.65	1.58	0.119185	0.752727
ABC	140	323.9167	2.31369			
S	0					
Total (Adjusted)	269	3919.967				
Total	270					

* 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: subjects	14					
B: drink	2	1.75	0.192421	0.207201	0.193207	0.192421
AB	28					
C: time	5	34.45	0.000000*	0.000041*	0.000000*	0.000000*
AC	70					
BC	10	1.58	0.119185	0.229668	0.181990	0.146279
ABC	140					
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: subjects	14					
B: drink	2	1.75	0.335194	0.234285	0.331541	0.335194
AB	28					
C: time	5	34.45	1.000000	0.999743	1.000000	1.000000
AC	70					
BC	10	1.58	0.752727	0.215937	0.502244	0.648152
ABC	140					
S	0					

Table 6. 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	0.980528	1.000000	0.980141	0.3	2.0	0.877760	Okay
AC	0.200000	0.421750	0.498370	0.033173	41.2	14.0	0.000165	Violated
ABC	0.100000	0.471251	0.739572	0.000909	73.3	54.0	0.041303	Violated

Tukey-Kramer Multiple-Comparison Test

Response: OSM_p
Term C: time

Alpha=0.050 Error Term=AC DF=70 MSE=4.131746 Critical Value=4.1438

Group	Count	Mean	Different From Groups
-105	45	280.3333	60post, 45post, 30post, 0post, 15post
60post	45	282.7667	-105, 0post, 15post
45post	45	283.0222	-105, 0post, 15post
30post	45	283.4333	-105, 0post, 15post
0post	45	284.7444	-105, 60post, 45post, 30post
15post	45	285.4333	-105, 60post, 45post, 30post

4. Does pickle juice, hypertonic or deionized water affect changes in plasma volume?

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subjects	14	475.7127	33.97948			
B: drink	2	26.16303	13.08151	0.43	0.651678	0.113576
AB	28	842.3755	30.08484			
C: time	5	1227.317	245.4634	35.74	0.000000*	1.000000
AC	70	480.8082	6.868689			
BC	10	45.7267	4.57267	0.68	0.739559	0.345364
ABC	140	938.3392	6.702423			
S	0					
Total (Adjusted)	269	4036.442				
Total	270					

* Term significant at alpha = 0.05

Table 6. 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: subjects	14					
B: drink	2	0.43	0.651678	0.520333	0.630735	0.651678
AB	28					
C: time	5	35.74	0.000000*	0.000034*	0.000000*	0.000000*
AC	70					
BC	10	0.68	0.739559	0.422669	0.655010	0.736875
ABC	140					
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: subjects	14					
B: drink	2	0.43	0.113576	0.094369	0.109972	0.113576
AB	28					
C: time	5	35.74	1.000000	0.999823	1.000000	1.000000
AC	70					
BC	10	0.68	0.345364	0.120296	0.248031	0.341659
ABC	140					
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	0.896553	1.000000	0.884617	1.6	2.0	0.450722	Okay
AC	0.200000	0.610719	0.800335	0.170245	21.4	14.0	0.091267	Okay
ABC	0.100000	0.562050	0.982247	0.005871	53.8	54.0	0.483037	Okay

Table 6. Continued

Tukey-Kramer Multiple-Comparison Test

Response: Change in Plasma Volume
Term C: time

Alpha=0.050 Error Term=AC DF=70 MSE=6.868689 Critical Value=4.1438

Group	Count	Mean	Different From Groups
60post	45	-6.322596	45post, 30post, -105
0post	45	-6.223381	45post, 30post, -105
15post	45	-5.322966	-105
45post	45	-4.279653	60post, 0post, -105
30post	45	-4.23784	60post, 0post, -105
-105	45	8.881784E-16	60post, 0post, 15post, 45post, 30post

5. Does ingesting pickle juice, hypertonic or deionized water prior to ad libitum fluid ingestion affect perceptions of thirst?

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subject	14	34825.13	2487.509			
B: drink	2	369.6622	184.8311	0.69	0.508532	0.154931
AB	28	7469.805	266.7787			
C: time	4	51828.02	12957	29.88	0.000000*	1.000000
AC	56	24280.25	433.5759			
BC	8	742.5156	92.81445	1.13	0.351249	0.500870
ABC	112	9230.018	82.41087			
S	0					
Total (Adjusted)	224	128745.4				
Total	225					

* Term significant at alpha = 0.05

Table 6. 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	14					
B: drink	2	0.69	0.508532	0.419178	0.476931	0.489680
AB	28					
C: time	4	29.88	0.000000*	0.000083*	0.000005*	0.000002*
AC	56					
BC	8	1.13	0.351249	0.306544	0.351043	0.354218
ABC	112					
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	14					
B: drink	2	0.69	0.154931	0.121413	0.141243	0.146484
AB	28					
C: time	4	29.88	1.000000	0.999043	0.999961	0.999984
AC	56					
BC	8	1.13	0.500870	0.167546	0.296794	0.351934
ABC	112					
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	0.783267	0.864522	0.723296	4.2	2.0	0.121774	Okay
AC	0.250000	0.353988	0.382215	0.009054	58.4	9.0	0.000000	Violated
ABC	0.125000	0.412544	0.554987	0.002677	65.9	35.0	0.001210	Violated

Table 6. Continued

Tukey-Kramer Multiple-Comparison Test

Response: Thirst
Term C: time

Alpha=0.050 Error Term=AC DF=56 MSE=433.5759 Critical Value=3.9862

Group	Count	Mean	Different From Groups
60	45	20.28889	15, -0.5
45	45	23.4	15, -0.5
30	45	27.04445	-0.5
15	45	37.57778	60, 45, -0.5
-0.5	45	62.11111	60, 45, 30, 15

6. Does ingesting pickle juice, hypertonic or deionized water prior to ad libitum fluid ingestion affect perceptions of fullness?

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subject	14	53234.91	3802.494			
B: drink	2	1258.462	629.2311	1.15	0.332670	0.231157
AB	28	15387	549.5359			
C: time	4	2317.627	579.4067	3.39	0.014998*	0.818503
AC	56	9583.84	171.14			
BC	8	314.2933	39.28667	0.45	0.887143	0.202519
ABC	112	9740.24	86.96643			
S	0					
Total (Adjusted)	224	91836.38				
Total	225					

* Term significant at alpha = 0.05

Table 6. 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	14					
B: drink	2	1.15	0.332670	0.302696	0.332232	0.332670
AB	28					
C: time	4	3.39	0.014998*	0.087065	0.051818	0.043830*
AC	56					
BC	8	0.45	0.887143	0.512448	0.809704	0.887143
ABC	112					
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	14					
B: drink	2	1.15	0.231157	0.169557	0.229548	0.231157
AB	28					
C: time	4	3.39	0.818503	0.402940	0.570319	0.614698
AC	56					
BC	8	0.45	0.202519	0.096130	0.162320	0.202519
ABC	112					
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	0.985976	1.000000	0.985776	0.2	2.0	0.911086	Okay
AC	0.250000	0.469727	0.540043	0.097707	28.9	9.0	0.000679	Violated
ABC	0.125000	0.621678	1.000000	0.012876	48.4	35.0	0.065157	Okay

7. Does ingesting pickle juice, hypertonic or deionized water prior to ad libitum fluid ingestion affect perceptions of nausea?

Table 6. Continued

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subject	14	29300.2	2092.871			
B: drink	2	858.3022	429.1511	1.78	0.187379	0.340303
AB	28	6754.898	241.2464			
C: time	4	4844.596	1211.149	10.35	0.000002*	0.999689
AC	56	6556.071	117.0727			
BC	8	916.8978	114.6122	1.19	0.310883	0.528231
ABC	112	10779.24	96.24317			
S	0					
Total (Adjusted)	224	60010.2				
Total	225					

* 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	14					
B: drink	2	1.78	0.187379	0.203579	0.190713	0.187379
AB	28					
C: time	4	10.35	0.000002*	0.006214*	0.001328*	0.000855*
AC	56					
BC	8	1.19	0.310883	0.293581	0.324325	0.325275
ABC	112					
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	14					
B: drink	2	1.78	0.340303	0.237479	0.325012	0.340303
AB	28					
C: time	4	10.35	0.999689	0.848384	0.948604	0.962851
AC	56					
BC	8	1.19	0.528231	0.174467	0.285888	0.328014
ABC	112					
S	0					

Table 6. 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	0.920588	1.000000	0.913738	1.2	2.0	0.556340	Okay
AC	0.250000	0.394009	0.435459	0.027581	44.6	9.0	0.000001	Violated
ABC	0.125000	0.351338	0.448649	0.000034	114.6	35.0	0.000000	Violated

Tukey-Kramer Multiple-Comparison Test

Response: Nausea
Term C: time

Alpha=0.050 Error Term=AC DF=56 MSE=117.0727 Critical Value=3.9862

Group	Count	Mean	Different From Groups
60	45	4.088889	-0.5
45	45	6.6	-0.5
30	45	9.111111	-0.5
15	45	9.933333	-0.5
-0.5	45	17.84444	60, 45, 30, 15

8. Does the palatability of pickle juice, hypertonic or deionized water differ between hypohydrated subjects prior to ad libitum drinking?

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: subjects	14	2965.778	211.8413			
B: drink	2	26712.84	13356.42	64.11	0.000000*	1.000000
AB	28	5833.822	208.3508			
S	0					
Total (Adjusted)	44	35512.45				
Total	45					

* Term significant at alpha = 0.05

Table 6. 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: subjects	14					
B: drink	2	64.11	0.000000*	0.000001*	0.000000*	0.000000*
AB	28					
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: subjects	14					
B: drink	2	64.11	1.000000	1.000000	1.000000	1.000000
AB	28					
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	0.983388	1.000000	0.983107	0.2	2.0	0.895171	Okay

Tukey-Kramer Multiple-Comparison Test

Response: Palatability
Term B: drink

Alpha=0.050 Error Term=AB DF=28 MSE=208.3508 Critical Value=3.4993

Group	Count	Mean	Different From Groups
Saline	15	17.26667	DIW
PJ	15	26.46667	DIW
DIW	15	72.93333	HS, PJ

Figure 3. Palatability Visual Analog Scale

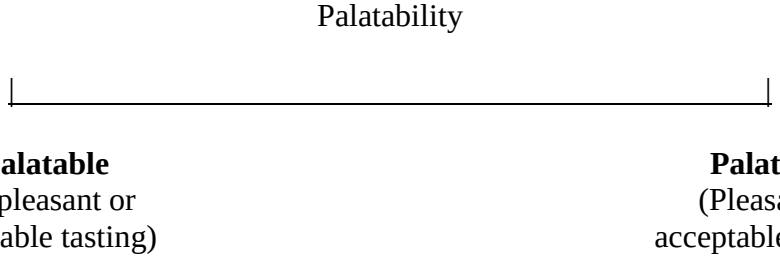

Figure 4. Perceptions of Thirst, Fullness, and Nausea Visual Analog Scale

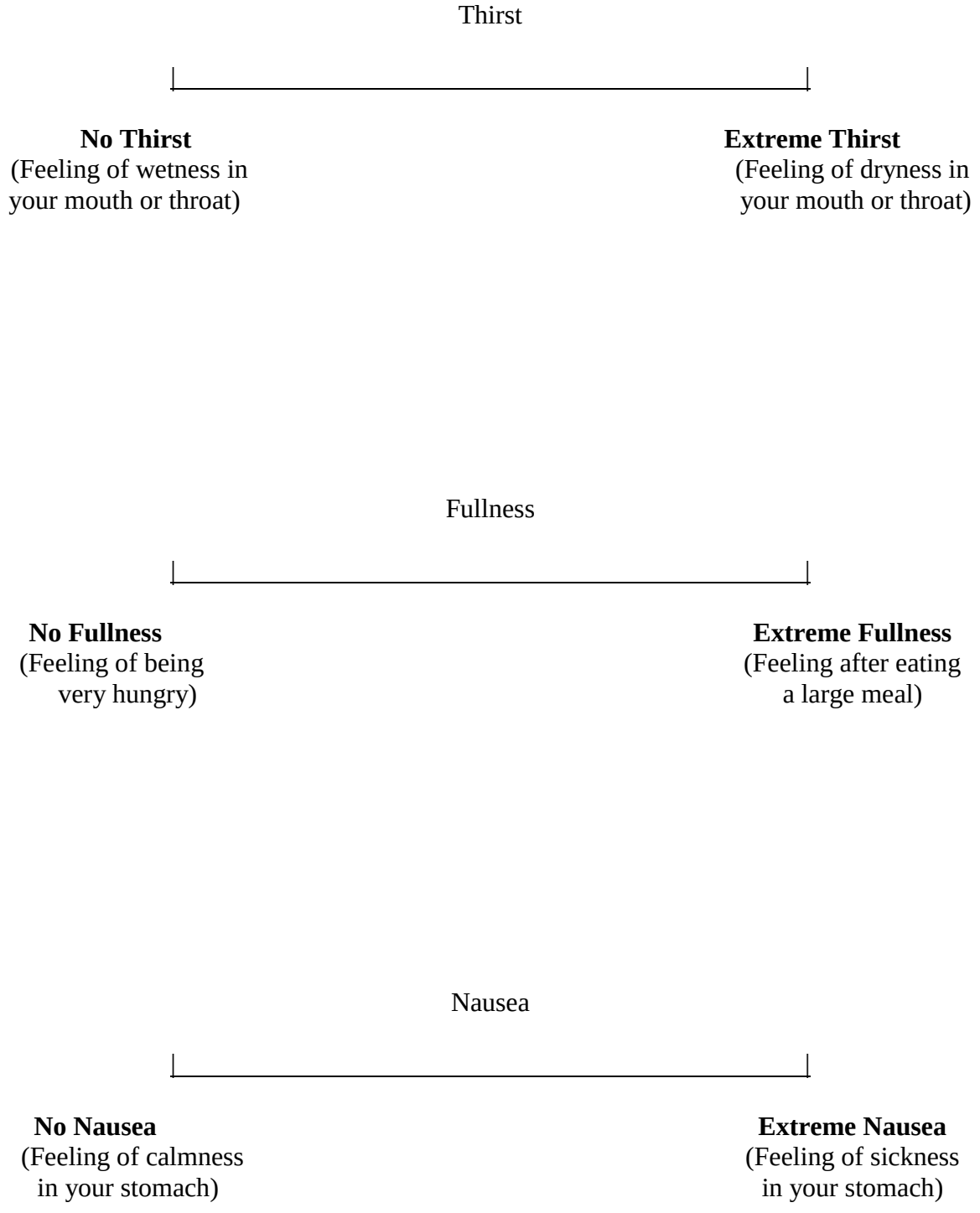

Figure 5. Institutional Review Board Approval Letter

NDSU NORTH DAKOTA STATE UNIVERSITY

Institutional Review Board
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

701.231.8995
Fax 701.231.8098
Federalwide Assurance #FWA00002439

November 9, 2011

Kevin C. Miller
Department of Health, Nutrition & Exercise Science

IRB Approval of Protocol **#HE12073**, **"Ad Libitum Fluid Intake and Plasma Response Following Pickle Juice and Hypertonic Saline Ingestion"**
Co-investigator(s) and research team: **Scott Allen, Beth Blodgett Salafia, Julie Garden-Robinson, Jay Albrecht**

Approval period: 11/9/2011 to 11/8/2012 **Continuing Review Report Due: 10/1/2012**

Research site(s): **NDSU** Funding agency: **n/a**
Review Type: ☐ Expedited category # ☒ Full Board
IRB approval is based on original submission, with revised: protocol, consent waiver request and consent form (received 11/8/2011).

Additional approval is required:

- prior to implementation of any proposed changes to the protocol (*Protocol Amendment Request Form*).
- 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:

- 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*).
- any significant new findings that may affect risks to participants.
- 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,
Kristy Shirley
Kristy Shirley, CIP
Research Compliance Administrator

Last printed 11/9/2011 3:27:00 PM

Figure 6. 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: Core Temperature, Heart Rate and Plasma Changes after Exercise in Heat

This study is being conducted by: Kevin C. Miller, PhD, ATC, CSCS, Scott Allen, BS, ATC, Elizabeth Blodgett Salafia, PhD, Julie Garden-Robinson, PhD, LRD, Jay Albrecht, PhD, ATC, LAT

Why am I being asked to take part in this research study? You are being asked to participate in this study because you are a non-smoking male between the ages of 18-35 with no: (1) food allergies, (2) history of heat related illnesses (e.g., heat exhaustion, heat stroke, or heat syncope) in the past six months, (3) injury or surgery in the past 12 months, (4) history of heart disease, asthma, diabetes, high blood pressure, or high cholesterol, (5) history of chest pain, dizziness, fainting, blackouts, or unreasonable breathlessness during exercise, (6) heat acclimation from exercising in the heat in the previous six days, OR (7) current medications, such as diruetics or heart medications. You are eligible because you exercise (1) at a moderate intensity for a minimum of 30 minutes on five days each week, or (2) at a vigorous intensity for a minimum of 20 minutes on three days each week.

What is the reason for doing the study? The purpose of this study is to examine the effect of various treatment drinks on core temperature, heart rate, and plasma variables after exercise in heat. This study will help people who exercise in the heat.

What will I be asked to do? You will report to the Athletic Training Research Center (Bentson Bunker Fieldhouse Room 14, NDSU Main Campus) on three occasions, separated by at least 72 hours. Twenty-four hours prior to each testing day you will need to drink water consistently and avoid exercise, alcohol, and caffeine. Twelve hours before testing you will need to fast. During your 12 hour fast, we ask that you continue to drink water and only water.

During the first day of testing you will read an informed consent document and be asked a series of questions to ensure you qualify for this study. You will then provide a urine sample to ensure you are hydrated. Next, you will be instructed in the use of a rectal thermometer, and in the privacy of a rest room or locker room you will insert the flexible probe into your rectum. This is necessary to monitor your core body temperature. The probes are flexible, cause little to no discomfort, and allow you to be fully functional. You will also attach a heart rate monitor across your chest.

Figure 6. Continued

Next, a trained phlebotomist (person experienced in taking blood samples) will clean your arm with alcohol twice to remove any dirt or contaminants. This makes the risk of infection very small. We will use universal precautions (e.g., wear gloves, use alcohol to sterilize 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 (less than $\frac{1}{32}$ inch diameter) 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 while only having to stick you with a needle once. You will then be weighed nude. The laboratory is entirely private, and only males will be present during data collection.

You will then sit in a chair and rest for 30 minutes. You will be asked to move as little as possible during this time. We will record your core temperature and heart rate at 15 minute intervals. Following this 30 minute period we will collect a 5 milliliter (less than ¼ ounce) blood sample. Blood collection is painless and you will not likely feel any differently.

You will then be asked to change into a sweat suit (sweat shirt and sweat pants) and enter a heat chamber. You will then alternate 15 minute sessions of jogging and cycling at a hard intensity. This intensity is safe for someone of your physical activity level. We will record your core temperature every 15 minutes and observe you for any signs of heat distress. At the end of the one hour excise period you will bike at a pace you are comfortable with for 10 minutes to cool down.

You will then exit the heat chamber, towel dry, provide a second urine sample, be weighed nude, and change into dry clothes. You will then sit for another 30 minutes. We will continue to record your core temperature and heart rate. As with before, you will be asked to remain as motionless as possible during this time. After this 30 minutes, we will collect another 5 milliliter blood sample and you will record your feelings of thirst, fullness, and nausea. To do this you will be given a sheet with three lines on it. Each line will be for a different feeling (i.e., thirst, fullness, nausea). At one end of the line will be a 0, indicating no thirst, nausea, or fullness, and at the other end will be a 100, indicating extreme thirst, nausea, or fullness. You will then place a mark on each line indicating how you feel at that point.

Immediately after that you will have 30 seconds to drink a small volume (about 3 ounces) of one of three treatment drinks. The treatment beverages are safe and are most likely a part of your regular diet. Immediately after you finish the treatment drink you will rate on another 100 millimeter line how palatable (tasty) the drink is. You will be given water and allowed to drink as much or as little as you want.

At 15 minute intervals (15, 30, 45, & 60 minutes) we will record your heart rate and core temperature, collect a 5 milliliter blood sample, and have you complete another scale indicating your level of thirst, fullness, and nausea. This period will last one hour. During this time you must sit still. You will be allowed to drink water during this time. After one hour you will be

weighed nude one last time and we will remove the catheter from your arm. We will cover your arm with sterile dressings and explain to you signs and symptoms of infection. You will then be allowed to remove the rectal thermometer and heart rate monitor in private. You will then be excused and asked to return 72 hours later for your next testing session.

The total volume of blood collected for the entire experiment is very small (90 milliliters or 3 ounces or 18 teaspoons worth of blood). We do not anticipate you having any negative consequences in your everyday activities as a result of you donating this volume of blood.

Where is the study going to take place, and how long will it take? The study takes place in the Athletic Training Research Center located in the basement of Bentson Bunker Fieldhouse in Room 14 on NDSU's Main Campus. Each session will take about 3.5 hours. You will be asked to participate in all 3 trial days resulting in a total time of about 11 hours.

What are the risks and discomforts? The main risk is that you could develop an infection as a result of blood collection. However, this risk is 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 you will 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).

There is a small risk of you developing a heat related illness such as heat fainting or heat exhaustion. We minimize this risk by monitoring your rectal temperature. Should your rectal temperature become elevated to a dangerous temperature (104°F) the trial will be immediately stopped. We also will monitor you for signs and symptoms of heat illnesses as both investigators are certified athletic trainers and are trained in the recognition and treatment of such conditions. This would include removing you from the heat chamber and giving you cool liquids and ice packs to lower your temperature.

There is also a very small risk from the rectal thermometer. There is a risk of puncturing the rectum; however, this risk is very small as the rectal thermometers are small flexible tubes. There is a risk of disease transmission from the rectal probes. However, this risk is also near zero since the rectal thermometers have been immersed in a sterilizing solution for 24 hours. This solution is a high level disinfectant and a medical grade sterilizer when used for at least 10 hours. Finally, there is a risk of rectum irritation if the thermometers have small amounts of the solution remaining on them. This risk has been minimized by washing the thermometers in water at least three times as indicated by the manufacturer's guidelines.

The hard intensity of exercise poses a small risk of an exercise related cardiac event (you having a heart problem from exercise). This risk is minimal as your current level of physical activity places you in the lowest possible risk category, and approves you for exercise at and above this intensity with no supervision.

Figure 6. Continued

If you are known to have a sensitivity to any food or food ingredient, or have had violent allergic reactions to drugs, chemicals, or food ingredients, you should not take part in this study. **What are the benefits to me?** You are not expected to get any benefit from being in this research study. However, if you are a student or interested in medical and scientific research you may gain valuable experience into the experimental process.

What are the benefits to other people? Exercise in the heat is very common among athletes and recreationally active people alike. If we can find new drinks that help with exercise, we may be able to improve the exercise experience.

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 for participating in this research. It will require about 11 hours of your time over the course of 3 days.

What are the alternatives to being in this research study? Instead of being in this research study, you can choose not to participate.

Who will see the information that I give? All information we record about you will be kept private. When we write about the study, we will write about the combined information that we have gathered. This research may be presented for publication, all information about you and your name will be kept private. We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. 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? You may decide to drop out at any point. Withdrawing from the study at any point will not affect your relationship with NDSU or the investigators. If you fail to show up to all sessions you may be removed from the study.

Will I receive any compensation for taking part in this study? Two raffles for $25 gift cards to Best Buy, and one raffle for a $50 gift card to Best Buy will be held following the completion of data collection. If for any reason you decide to drop out early, you will be eligible for the drawings based on the number of days you participated in the study. For example if you participate in two days of data collection you will be entered into the two drawings for the $25 gift cards. If you participate in all three days you are eligible for all three drawings. To be eligible for the $50 gift card you must participate in all three days of data collection. You may only win once.

Figure 6. Continued

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 Professor Margaret 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, Dr. Kevin C. Miller at (701) 231-5686 or Kevin.C.Miller@ndsu.edu, or Scott Allen, ATC at (507) 382-9373 or Scott.Allen@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 .

Figure 6. Continued

Documentation of Informed Consent:

You are freely making a decision whether to be in this research study. Signing this form means that

1. you have read and understood this consent form
2. you have had your questions answered, and
3. 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

_____ _____

Signature of researcher explaining study Date

_____

Printed name of researcher explaining study

Figure 7. Institutional Biosafety Committee Approval Letter

NDSU NORTH DAKOTA STATE UNIVERSITY

701.231.8114
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Institutional Biosafety Committee
Office of the Vice President for Research, Creative Activities and Technology Transfer
NDSU Dept. 4000
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Research 1, P.O. Box 6050
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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 7. Fluid Ingested Data

Subject	Drink	Volume Drank *Ad Libitum*	Percent Replaced *Ad Libitum*	Percent Hypohydration After Rehydration
1	PJ	655.08	44.56%	-1.34%
1	HS	936.43	51.73%	-1.39%
1	DIW	510.37	28.51%	-1.92%
2	PJ	991.92	63.18%	-0.81%
2	HS	991.21	72.88%	-0.54%
2	DIW	468.62	34.71%	-1.16%
3	PJ	221.24	14.75%	-1.52%
3	HS	278.69	21.44%	-1.21%
3	DIW	195.29	26.39%	-0.73%
4	PJ	1011.23	62.81%	-0.76%
4	HS	1188.07	79.20%	-0.48%
4	DIW	679.44	50.71%	-1.04%
5	PJ	263.25	15.86%	-1.57%
5	HS	555.93	28.36%	-1.61%
5	DIW	91.55	5.14%	-2.04%
6	PJ	1052.54	50.85%	-1.37%
6	HS	737.33	37.43%	-1.54%
6	DIW	817.6	50.78%	-1.12%
7	PJ	937.25	54.81%	-1.13%
7	HS	850.76	65.95%	-0.86%
7	DIW	152.08	12.99%	-1.42%
8	PJ	1019.33	68.87%	-0.70%
8	HS	718.2	50.22%	-0.84%
8	DIW	848.91	71.94%	-0.51%
9	PJ	132.79	5.25%	-2.49%
9	HS	125.27	7.46%	-1.67%
9	DIW	58.91	2.42%	-2.48%
10	PJ	244.45	15.47%	-1.86%
10	HS	165.92	8.05%	-2.63%
10	DIW	530.36	41.76%	-1.09%
11	PJ	1147.45	110.33%	+0.09%
11	HS	1238.22	98.27%	-0.44%
11	DIW	970.57	95.15%	-0.69%
12	PJ	1044.09	60.01%	-1.06%
12	HS	946.9	47.35%	-1.54%
12	DIW	1190.68	57.52%	-1.26%
13	PJ	329.09	24.93%	-1.41%
13	HS	293.07	24.83%	-1.26%
13	DIW	267.08	17.46%	-1.72%
14	PJ	768.85	30.87%	-2.53%
14	HS	1093.87	45.58%	-2.00%
14	DIW	608.54	31.05%	-1.93%

Table 7. Continued

Subject	Drink	Volume Drank *Ad Libitum*	Percent Replaced *Ad Libitum*	Percent Hypohydration After Rehydration
15	PJ	686.7	62.42%	-0.68%
15	HS	500.52	27.35%	-1.84%
15	DIW	604.91	42.59%	-1.22%

PJ = pickle juice, HS = hypertonic saline, DIW = deionized water

Table 8. Plasma Data

Subject	Drink	Blood Sample	$[Na^+]_p$	OSM_p	Percent Change in Plasma Volume
1	PJ	-105	141	284	0
1	PJ	-0.5	143.5	287.5	-6.504
1	PJ	15	143.5	288	-7.505
1	PJ	30	143	288	0.5975
1	PJ	45	141	282	-5.7880
1	PJ	60	141.5	283	-5.7880
1	DIW	-105	139	279	0
1	DIW	-0.5	142	283	-4.9071
1	DIW	15	141	282.5	-1.8987
1	DIW	30	141	284	-5.6234
1	DIW	45	140	279.5	-2.9740
1	DIW	60	142.5	286	-9.1590
1	HS	-105	141.5	280.5	0
1	HS	-0.5	145	287.5	-9.7103
1	HS	15	144	286.5	-2.1322
1	HS	30	142	283	-4.6553
1	HS	45	142	283.5	-2.8709
1	HS	60	142	283	-9.46642
2	PJ	-105	142	276.5	0
2	PJ	-0.5	142	281.5	-4.0175
2	PJ	15	142	281.5	-3.4593
2	PJ	30	140.5	278	-0.4535
2	PJ	45	140	277.5	-1.5014
2	PJ	60	139.5	275.5	-2.5668
2	DIW	-105	140	277	0
2	DIW	-0.5	142	281.5	-7.6376
2	DIW	15	141	281	-7.8686
2	DIW	30	140.5	279	-4.0292
2	DIW	45	141	280.5	-8.1710
2	DIW	60	141	279.5	-11.734
2	HS	-105	141	281	0
2	HS	-0.5	144	285	-10.330
2	HS	15	144	288	-10.761
2	HS	30	141	281	-8.9953
2	HS	45	141	282	-5.1491
2	HS	60	141	281	-11.698
3	PJ	-105	140	276.5	0
3	PJ	-0.5	143	283.5	-8.8688
3	PJ	15	144	287	-5.7700
3	PJ	30	143	283	-4.6171
3	PJ	45	143	282.5	-7.2157
3	PJ	60	143	282.5	-8.6158

Table 8. Continued

Subject	Drink	Blood Sample	$[Na^+]_p$	OSM_p	Percent Change in Plasma Volume
3	DIW	-105	141	278.5	0
3	DIW	-0.5	143.5	282	-7.3743
3	DIW	15	142	282	-3.9915
3	DIW	30	142	280.5	-5.9825
3	DIW	45	142	280	-5.1149
3	DIW	60	142.5	282.5	-9.4027
3	HS	-105	143	283	0
3	HS	-0.5	143	283.5	-7.4950
3	HS	15	143	286	-4.4281
3	HS	30	143	284.5	4.0425
3	HS	45	143	285.5	-0.9713
3	HS	60	143	285	-3.8078
4	PJ	-105	140	276.5	0
4	PJ	-0.5	141	278	-11.731
4	PJ	15	141	279.5	-8.4853
4	PJ	30	139.5	277	-7.2422
4	PJ	45	140	278.5	-7.9457
4	PJ	60	139	276	-2.7366
4	DIW	-105	140	278	0
4	DIW	-0.5	142	281	-2.4235
4	DIW	15	140	278	-5.7718
4	DIW	30	140	278	-6.4185
4	DIW	45	139	275.5	-2.8491
4	DIW	60	138.5	275.5	-8.6943
4	HS	-105	142	283	0
4	HS	-0.5	143	286	0.2722
4	HS	15	144	287	-0.7341
4	HS	30	143	286	1.0339
4	HS	45	143	285	2.5013
4	HS	60	143	284.5	-1.4021
5	PJ	-105	140.5	279	0
5	PJ	-0.5	143	283	-7.3140
5	PJ	15	143.5	284	-4.2350
5	PJ	30	143.5	282	-8.9248
5	PJ	45	143	283	-5.5885
5	PJ	60	143	283	-9.0654
5	DIW	-105	143	285	0
5	DIW	-0.5	146	289	-7.3032
5	DIW	15	149	295.5	-12.036
5	DIW	30	147	294	-10.823
5	DIW	45	146	294.5	-9.8909
5	DIW	60	146	292.5	-9.1564

Table 8. Continued

Subject	Drink	Blood Sample	$[Na^+]_p$	OSM_p	Percent Change in Plasma Volume
5	HS	-105	144	282.5	0
5	HS	-0.5	146	288	-5.4603
5	HS	15	146	287	-9.4694
5	HS	30	146	287.5	-5.3423
5	HS	45	146	288	-8.4886
5	HS	60	146	287	-7.4319
6	PJ	-105	138	276	0
6	PJ	-0.5	142	284	-10.816
6	PJ	15	142	284.5	-13.945
6	PJ	30	140.5	281	-8.3037
6	PJ	45	137	279	-9.6644
6	PJ	60	139	278	-12.262
6	DIW	-105	139	275.5	0
6	DIW	-0.5	142	281.5	-4.1447
6	DIW	15	141	281	-2.5693
6	DIW	30	140	278.5	-0.3733
6	DIW	45	139	279	0.9551
6	DIW	60	140	280	-1.9946
6	HS	-105	141	280.5	0
6	HS	-0.5	142	289	-3.3782
6	HS	15	143	286	-5.1276
6	HS	30	142	284.5	-5.9525
6	HS	45	143	285.5	-3.6873
6	HS	60	142	284	-5.4069
7	PJ	-105	141	280.5	0
7	PJ	-0.5	142	282.5	-6.5154
7	PJ	15	143	286	-4.2100
7	PJ	30	141	281	-4.0269
7	PJ	45	141	281	-9.2501
7	PJ	60	139	278	-5.9397
7	DIW	-105	140.5	284	0
7	DIW	-0.5	142.5	287	-5.0254
7	DIW	15	142	288	-7.4493
7	DIW	30	141	284	-5.4648
7	DIW	45	142	286	-9.2059
7	DIW	60	141	285	-11.645
7	HS	-105	141	285.5	0
7	HS	-0.5	144	287.5	-6.3747
7	HS	15	144	289	-11.774
7	HS	30	142	287	-6.9477
7	HS	45	142	287.5	-10.031
7	HS	60	141	286	-13.954

Table 8. Continued

Subject	Drink	Blood Sample	$[Na^+]_p$	OSM_p	Percent Change in Plasma Volume
8	PJ	-105	139	277	0
8	PJ	-0.5	141	280.5	-8.3817
8	PJ	15	142.5	287.5	-9.3215
8	PJ	30	140	282	-0.3096
8	PJ	45	139	279	-0.3856
8	PJ	60	139	279	-2.6454
8	DIW	-105	141.5	285.5	0
8	DIW	-0.5	144	291	-13.339
8	DIW	15	141.5	284.5	-2.4294
8	DIW	30	140.5	286	-7.5105
8	DIW	45	141	283	-8.3063
8	DIW	60	140.5	283.5	-8.7089
8	HS	-105	141.5	281	0
8	HS	-0.5	143	284	-5.3367
8	HS	15	143	284.5	-6.5338
8	HS	30	143	283	-4.4548
8	HS	45	142	284	-3.1454
8	HS	60	141.5	282.5	-5.0591
9	PJ	-105	139.5	277.5	0
9	PJ	-0.5	142	283.5	-10.916
9	PJ	15	142	283.5	-8.2420
9	PJ	30	143	285.5	-9.7337
9	PJ	45	143.5	287	-7.5475
9	PJ	60	144	288	-6.2761
9	DIW	-105	138	276	0
9	DIW	-0.5	142	283.5	1.3825
9	DIW	15	143	286.5	0.6974
9	DIW	30	142	284	-5.7585
9	DIW	45	142	285	-2.5954
9	DIW	60	142	283.5	-5.4618
9	HS	-105	138.5	278	0
9	HS	-0.5	140.5	280	-3.0107
9	HS	15	140.5	280.5	-0.2054
9	HS	30	140	281	-7.1077
9	HS	45	140.5	282	-2.2926
9	HS	60	141	281.5	-4.4222
10	PJ	-105	141	278.5	0
10	PJ	-0.5	142	281	-5.3675
10	PJ	15	142.5	282	0.9518
10	PJ	30	142	281	-5.8961
10	PJ	45	142	281.5	-2.4283
10	PJ	60	142	283	-5.9988

Table 8. Continued

Subject	Drink	Blood Sample	$[Na^+]_p$	OSM_p	Percent Change in Plasma Volume
10	DIW	-105	141	279.5	0
10	DIW	-0.5	142	281.5	-6.8991
10	DIW	15	142	281.5	-7.9190
10	DIW	30	140	279.5	-1.3588
10	DIW	45	140.5	280	-4.2231
10	DIW	60	140.5	280	-4.2613
10	HS	-105	140	280.5	0
10	HS	-0.5	141	282.5	-0.0958
10	HS	15	142	285	-1.3312
10	HS	30	141	283.5	3.4860
10	HS	45	141	284	3.3492
10	HS	60	141	284	-1.8838
11	PJ	-105	142.5	282.5	0
11	PJ	-0.5	144	286	-4.0293
11	PJ	15	144	288	-8.7277
11	PJ	30	143	286.5	-4.0635
11	PJ	45	141	284	-7.8196
11	PJ	60	140.5	283	-8.8499
11	DIW	-105	141	279.5	0
11	DIW	-0.5	143	284.5	-9.9448
11	DIW	15	143	283.5	-1.1855
11	DIW	30	140.5	280.5	-1.0700
11	DIW	45	140	279	-1.9667
11	DIW	60	140.5	280	-7.8793
11	HS	-105	141	283	0
11	HS	-0.5	144	287.5	-11.655
11	HS	15	142.5	285	-7.7422
11	HS	30	140	280.5	-0.2830
11	HS	45	139	280	0.3309
11	HS	60	139.5	279.5	-2.6657
12	PJ	-105	141	282.5	0
12	PJ	-0.5	143	286.5	-2.7680
12	PJ	15	144	288	-7.7291
12	PJ	30	142	283	-6.2064
12	PJ	45	141	282.5	-4.6248
12	PJ	60	142	282.5	-5.0672
12	DIW	-105	140	280	0
12	DIW	-0.5	144	285.5	-3.8146
12	DIW	15	143.5	286	-2.8137
12	DIW	30	142	282.5	-5.0359
12	DIW	45	141.5	281	-3.4816
12	DIW	60	141	281	-7.0704

Table 8. Continued

Subject	Drink	Blood Sample	$[Na^+]_p$	OSM_p	Percent Change in Plasma Volume
12	HS	-105	140	279	0
12	HS	-0.5	143.5	285.5	-3.6769
12	HS	15	143	285	-9.6593
12	HS	30	142	284	-3.6889
12	HS	45	142	283	-8.4584
12	HS	60	141.5	282	-10.172
13	PJ	-105	143	279.5	0
13	PJ	-0.5	144	282.5	-5.1943
13	PJ	15	145	287.5	-0.1810
13	PJ	30	144.5	287	-3.7269
13	PJ	45	144	285	-1.1509
13	PJ	60	143.5	284	-2.1284
13	DIW	-105	142	283	0
13	DIW	-0.5	145	287	-2.2833
13	DIW	15	144	286.5	-3.5419
13	DIW	30	143	283.5	-0.8991
13	DIW	45	144.5	286	-0.9201
13	DIW	60	144	284	1.8724
13	HS	-105	143	282	0
13	HS	-0.5	145	287.5	-8.7852
13	HS	15	145.5	288	-3.8654
13	HS	30	145	286.5	-3.4431
13	HS	45	144.5	285	-0.7300
13	HS	60	145.5	285	-2.5557
14	PJ	-105	137	276.5	0
14	PJ	-0.5	140	281.5	-7.0315
14	PJ	15	140	282	2.4791
14	PJ	30	140	281	-0.8421
14	PJ	45	138	278	3.1365
14	PJ	60	139	279.5	-1.1387
14	DIW	-105	141.5	280.5	0
14	DIW	-0.5	144	285	-2.1318
14	DIW	15	142	284	-8.8542
14	DIW	30	141	281	-3.7833
14	DIW	45	141	281.5	-7.1945
14	DIW	60	141	281.5	-7.7733
14	HS	-105	140.5	280	0
14	HS	-0.5	143	283	-7.4822
14	HS	15	143	284	0.4717
14	HS	30	142	283.5	-3.1175
14	HS	45	140	281	-5.2279
14	HS	60	142	284	-0.5874

Table 8. Continued

Subject	Drink	Blood Sample	$[Na^+]_p$	OSM_p	Percent Change in Plasma Volume
15	PJ	-105	144	288	0
15	PJ	-0.5	147	295.5	-7.2770
15	PJ	15	147	296	-8.3472
15	PJ	30	144	291	-7.6762
15	PJ	45	144.5	291	-6.0450
15	PJ	60	144	289.5	-10.658
15	DIW	-105	141.5	282.5	0
15	DIW	-0.5	145	290	-8.4302
15	DIW	15	143	287.5	-5.3336
15	DIW	30	143	288	-3.0758
15	DIW	45	144	289.5	-3.4713
15	DIW	60	144	289	-3.9786
15	HS	-105	141.5	281	0
15	HS	-0.5	144	287	-6.5219
15	HS	15	145	290	-6.5438
15	HS	30	144	289	-6.6432
15	HS	45	143	288.5	-4.4826
15	HS	60	143	287.5	-9.2157

PJ = pickle juice, HS = hypertonic saline, DIW = deionized water, $[Na^+]_p$ = plasma sodium concentration ($mmol \cdot L^{-1}$), OSM_p = plasma osmolality ($mOsm \cdot kg^{-1} H_2O$)

Table 9. Perceptions of Thirst, Nausea, Fullness, and Palatabilty Data

Subject	Drink	Blood Sample	Thirst	Nausea	Fullness	Palatability
1	PJ	-0.5	58	11	37	15
1	PJ	15	63	3	33	
1	PJ	30	50	24	26	
1	PJ	45	50	14	21	
1	PJ	60	53	19	25	
1	HS	-0.5	90	9	5	9
1	HS	15	63	6	12	
1	HS	30	59	0	20	
1	HS	45	60	0	21	
1	HS	60	58	0	21	
1	DIW	-0.5	90	0	10	79
1	DIW	15	76	0	16	
1	DIW	30	63	0	16	
1	DIW	45	61	0	18	
1	DIW	60	61	0	19	
2	PJ	-0.5	100	15	0	18
2	PJ	15	11	5	3	
2	PJ	30	0	4	8	
2	PJ	45	0	0	12	
2	PJ	60	0	0	11	
2	HS	-0.5	100	14	0	0
2	HS	15	0	0	7	
2	HS	30	0	0	6	
2	HS	45	0	0	0	
2	HS	60	0	0	0	
2	DIW	-0.5	77	21	4	91
2	DIW	15	19	6	8	
2	DIW	30	0	0	0	
2	DIW	45	0	0	26	
2	DIW	60	0	0	26	
3	PJ	-0.5	82	11	7	12
3	PJ	15	64	38	57	
3	PJ	30	10	43	12	
3	PJ	45	5	7	21	
3	PJ	60	12	28	4	
3	HS	-0.5	86	51	24	16
3	HS	15	15	27	17	
3	HS	30	8	25	12	
3	HS	45	2	8	21	
3	HS	60	2	1	18	
3	DIW	-0.5	91	70	5	76

Table 9. Continued

Subject	Drink	Blood Sample	Thirst	Nausea	Fullness	Palatability
3	DIW	15	1	1	4	
3	DIW	30	1	3	10	
3	DIW	45	3	26	9	
3	DIW	60	2	14	8	
4	PJ	-0.5	71	70	55	24
4	PJ	15	44	43	65	
4	PJ	30	29	43	72	
4	PJ	45	23	55	60	
4	PJ	60	23	15	55	
4	HS	-0.5	79	71	30	11
4	HS	15	36	29	50	
4	HS	30	17	10	17	
4	HS	45	13	14	32	
4	HS	60	8	21	29	
4	DIW	-0.5	87	62	49	94
4	DIW	15	58	52	38	
4	DIW	30	45	66	48	
4	DIW	45	39	54	49	
4	DIW	60	36	21	36	
5	PJ	-0.5	49	0	66	46
5	PJ	15	34	0	16	
5	PJ	30	40	0	3	
5	PJ	45	12	0	0	
5	PJ	60	2	0	0	
5	HS	-0.5	45	0	37	0
5	HS	15	24	0	11	
5	HS	30	22	0	3	
5	HS	45	16	0	0	
5	HS	60	0	0	0	
5	DIW	-0.5	53	86	82	59
5	DIW	15	19	10	18	
5	DIW	30	16	14	15	
5	DIW	45	23	3	20	
5	DIW	60	27	1	66	
6	PJ	-0.5	62	3	35	28
6	PJ	15	33	0	35	
6	PJ	30	25	0	31	
6	PJ	45	24	0	25	
6	PJ	60	33	0	26	
6	HS	-0.5	57	0	39	23
6	HS	15	39	0	46	

Table 9. Continued

Subject	Drink	Blood Sample	Thirst	Nausea	Fullness	Palatability
6	HS	30	26	0	44	
6	HS	45	40	0	35	
6	HS	60	34	0	31	
6	DIW	-0.5	50	0	31	82
6	DIW	15	34	0	27	
6	DIW	30	16	0	21	
6	DIW	45	29	0	17	
6	DIW	60	16	0	29	
7	PJ	-0.5	46	20	18	40
7	PJ	15	12	9	24	
7	PJ	30	19	4	22	
7	PJ	45	4	1	4	
7	PJ	60	1	3	0	
7	HS	-0.5	25	38	0	
7	HS	15	11	6	0	0
7	HS	30	10	12	0	
7	HS	45	19	11	0	
7	HS	60	19	3	0	
7	DIW	-0.5	18	0	35	56
7	DIW	15	16	0	35	
7	DIW	30	19	0	19	
7	DIW	45	21	0	39	
7	DIW	60	15	0	11	
8	PJ	-0.5	65	50	33	2
8	PJ	15	79	63	33	
8	PJ	30	60	51	29	
8	PJ	45	42	34	30	
8	PJ	60	36	10	30	
8	HS	-0.5	67	24	36	38
8	HS	15	31	7	33	
8	HS	30	11	17	33	
8	HS	45	14	16	11	
8	HS	60	6	10	13	
8	DIW	-0.5	80	41	76	50
8	DIW	15	24	25	67	
8	DIW	30	16	10	68	
8	DIW	45	15	8	49	
8	DIW	60	8	2	30	
9	PJ	-0.5	29	0	32	11
9	PJ	15	21	0	22	
9	PJ	30	8	0	44	

Table 9. Continued

Subject	Drink	Blood Sample	Thirst	Nausea	Fullness	Palatability
9	PJ	45	5	0	53	
9	PJ	60	7	0	36	
9	HS	-0.5	16	0	74	28
9	HS	15	39	0	73	
9	HS	30	26	0	71	
9	HS	45	39	0	76	
9	HS	60	32	2	78	
9	DIW	-0.5	30	0	73	62
9	DIW	15	57	0	72	
9	DIW	30	19	0	66	
9	DIW	45	20	0	32	
9	DIW	60	15	0	70	
10	PJ	-0.5	33	2	34	39
10	PJ	15	32	0	32	
10	PJ	30	27	0	38	
10	PJ	45	31	0	36	
10	PJ	60	31	0	38	
10	HS	-0.5	41	0	35	14
10	HS	15	29	0	37	
10	HS	30	28	0	40	
10	HS	45	21	0	35	
10	HS	60	33	0	32	
10	DIW	-0.5	60	0	44	74
10	DIW	15	48	0	42	
10	DIW	30	33	0	48	
10	DIW	45	35	0	41	
10	DIW	60	34	0	39	
11	PJ	-0.5	93	17	8	37
11	PJ	15	50	23	6	
11	PJ	30	29	15	5	
11	PJ	45	10	6	4	
11	PJ	60	6	3	4	
11	HS	-0.5	80	6	4	22
11	HS	15	48	3	4	
11	HS	30	35	6	3	
11	HS	45	17	3	3	
11	HS	60	12	1	2	
11	DIW	-0.5	82	27	3	57
11	DIW	15	59	32	5	
11	DIW	30	41	32	8	
11	DIW	45	25	20	10	

Table 9. Continued

Subject	Drink	Blood Sample	Thirst	Nausea	Fullness	Palatability
11	DIW	60	12	13	6	
12	PJ	-0.5	69	1	22	26
12	PJ	15	49	30	2	
12	PJ	30	45	0	21	
12	PJ	45	37	0	22	
12	PJ	60	40	0	22	
12	HS	-0.5	44	5	50	39
12	HS	15	37	5	34	
12	HS	30	34	5	33	
12	HS	45	50	3	29	
12	HS	60	51	4	24	
12	DIW	-0.5	62	3	21	95
12	DIW	15	41	1	20	
12	DIW	30	41	1	26	
12	DIW	45	33	1	28	
12	DIW	60	37	0	20	
13	PJ	-0.5	40	22	63	32
13	PJ	15	45	2	49	
13	PJ	30	11	0	55	
13	PJ	45	19	0	57	
13	PJ	60	7	0	56	
13	HS	-0.5	61	13	75	19
13	HS	15	37	4	46	
13	HS	30	31	0	33	
13	HS	45	19	0	33	
13	HS	60	11	2	28	
13	DIW	-0.5	49	24	64	75
13	DIW	15	35	3	61	
13	DIW	30	46	15	30	
13	DIW	45	41	4	61	
13	DIW	60	18	3	52	
14	PJ	-0.5	88	3	38	9
14	PJ	15	57	3	36	
14	PJ	30	52	3	22	
14	PJ	45	35	3	23	
14	PJ	60	40	2	21	
14	HS	-0.5	80	3	40	7
14	HS	15	62	3	20	
14	HS	30	47	4	14	
14	HS	45	35	2	18	
14	HS	60	32	3	11	

Table 9. Continued

Subject	Drink	Blood Sample	Thirst	Nausea	Fullness	Palatability
14	DIW	-0.5	72	6	26	63
14	DIW	15	70	3	30	
14	DIW	30	44	2	22	
14	DIW	45	42	4	33	
14	DIW	60	28	3	19	
15	PJ	-0.5	44	2	24	58
15	PJ	15	31	4	17	
15	PJ	30	25	1	19	
15	PJ	45	13	0	13	
15	PJ	60	3	0	6	
15	HS	-0.5	53	0	17	33
15	HS	15	14	1	21	
15	HS	30	13	0	21	
15	HS	45	2	0	14	
15	HS	60	5	0	14	
15	DIW	-0.5	41	2	22	81
15	DIW	15	24	0	15	
15	DIW	30	20	0	10	
15	DIW	45	9	0	6	
15	DIW	60	7	0	8	

PJ = pickle juice, HS = hypertonic saline, DIW = deionized water

Table 10. Dehydration and Environmental Data

Subject	Drink	U_{sg}	ΔBW	Percent Hypohydration	Average Temperature	Relative Humidity
1	PJ	1.006	1.47	-1.93	34.5	17.5
1	HS	1.003	1.81	-2.41	39	16
1	DIW	1.007	1.79	-2.32	36	17.5
2	PJ	1.010	1.57	-1.88	36.5	16
2	HS	1.010	1.36	-1.63	37	18.5
2	DIW	1.003	1.35	-1.61	39	16
3	PJ	1.011	1.50	-1.68	35	16
3	HS	1.012	1.30	-1.47	39.5	16
3	DIW	1.016	0.74	-0.84	37	16
4	PJ	1.006	1.61	-1.61	38	16
4	HS	1.003	1.50	-1.49	37.5	16
4	DIW	1.006	1.34	-1.35	38	16
5	PJ	1.004	1.66	-1.81	34.5	16
5	HS	1.004	1.96	-2.15	35	16
5	DIW	1.013	1.78	-1.96	36.5	16
6	PJ	1.005	2.07	-2.44	36	16
6	HS	1.002	1.97	-2.33	37	16
6	DIW	1.013	1.61	-1.91	37.5	17.5
7	PJ	1.002	1.71	-2.19	36.5	16
7	HS	1.003	1.29	-1.63	34	16
7	DIW	1.009	1.17	-1.46	35	16
8	PJ	1.004	1.48	-1.64	37	16
8	HS	1.011	1.43	-1.61	33	16
8	DIW	1.008	1.18	-1.31	37	16
9	PJ	1.009	2.53	-2.59	35.5	19
9	HS	1.012	1.68	-1.73	34	17.5
9	DIW	1.013	2.43	-2.49	34.5	16
10	PJ	1.007	1.58	-2.05	35.5	16
10	HS	1.007	2.06	-2.64	34.5	18.5
10	DIW	1.014	1.27	-1.66	32.5	16
11	PJ	1.007	1.04	-1.44	33	16
11	HS	1.010	1.26	-1.74	35	18.5
11	DIW	1.017	1.02	-1.41	34	17.5
12	PJ	1.009	1.74	-2.21	35.5	16
12	HS	1.010	2.00	-2.51	34.5	19
12	DIW	1.012	2.07	-2.66	34.5	16
13	PJ	1.015	1.32	-1.68	35.5	16
13	HS	1.009	1.18	-1.51	35.5	16
13	DIW	1.010	1.53	-1.93	34.5	16
14	PJ	1.008	2.49	-3.25	37.5	16
14	HS	1.004	2.40	-3.14	36.5	16
14	DIW	1.006	1.96	-2.58	37.5	16

Table 10. Continued

Subject	Drink	U_{sg}	ΔBW	Percent Hypohydration	Average Temperature	Relative Humidity
15	PJ	1.014	1.10	-1.51	33.5	16
15	HS	1.005	1.83	-2.48	33.5	16
15	DIW	1.003	1.42	-1.92	35.5	16

PJ = pickle juice, HS = hypertonic saline, DIW = deionized water, U_{sg} = urine specific gravity, ΔBW = change in body weight (%), Average Temperature (°C), Relative Humidity (%)

APPENDIX D. RECCOMENDATIONS FOR FUTURE RESEARCH

Table 11. Recommendations for Future Research.

1. Determine if pickle juice ingestion prior to exercise affects *ad libitum* drinking, plasma variables, and perceptions of thirst, fullness and nausea during and after exercise.
2. Determine pickle juice's effect on *ad libitum* drinking, plasma variables, and perceptions of thirst, fullness and nausea longer than 60 minutes.
3. Determine the effect of pickle juice ingestion on *ad libitum* drinking, plasma variables, and perceptions of thirst, fullness and nausea in rested, euhydrated individuals.
4. Determine the *ad libitum* drinking behaviors post-pickle juice ingestion during athletic practice outdoors in the heat.
5. Determine the effect of repeated doses of pickle juice on *ad libitum* drinking, plasma variables, and perceptions of thirst, fullness and nausea.
6. Determine if rehydrating with cold deionized water affects *ad libitum* rehydration post-pickle juice ingestion.
7. Determine the effect of rehydrating with other fluids (e.g., commercial carbohydrate-electrolyte beverages) on *ad libitum* drinking, plasma variables, and perceptions of thirst, fullness and nausea post-pickle juice ingestion.
8. Determine the effect on *ad libitum* drinking, plasma variables, and perceptions of thirst, fullness and nausea after ingestion of vinegar.