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Plasma and Electrolyte Changes in Exercising Humans After Ingestion of Multiple Boluses of Pickle Juice

Michael A. McKenney, MS, ATC, NASM-CES*; Kevin C. Miller, PhD, AT, ATC†; James E. Deal, PhD‡; Julie A. Garden-Robinson, PhD, LRD§; Yeong S. Rhee, PhD, RD§

*Sports Performance, Northeastern University, Boston, MA; †School of Rehabilitation and Medical Sciences, Central Michigan University, Mount Pleasant; Departments of ‡Human Development and Family Science and §Health, Nutrition, and Exercise Sciences, North Dakota State University, Fargo

Context: Twenty-five percent of athletic trainers administer pickle juice (PJ) to treat cramping. Anecdotally, some clinicians provide multiple boluses of PJ during exercise but warn that repeated ingestion of PJ may cause hyperkalemia. To our knowledge, no researchers have examined the effect of ingesting multiple boluses of PJ on the same day or the effect of ingestion during exercise.

Objective: To determine the short-term effects of ingesting a single bolus or multiple boluses of PJ on plasma variables and to characterize changes in plasma variables when individuals ingest PJ and resume exercise.

Design: Crossover study.

Setting: Laboratory.

Patients or Other Participants: Nine euhydrated men (age = 23 ± 4 years, height = 180.9 ± 5.8 cm, mass = 80.7 ± 13.8 kg, urine specific gravity = 1.009 ± 0.005).

Intervention(s): On 3 days, participants rested for 30 minutes, and then a blood sample was collected. Participants ingested 0 or 1 bolus (1 mL·kg^{-1} body weight) of PJ, donned sweat suits, biked vigorously for 30 minutes (approximate temperature = 37°C, relative humidity = 18%), and had a blood sample collected. They either rested for 60 seconds (0- and 1-bolus conditions) or ingested a second 1 mL·kg^{-1} body weight bolus of PJ (2-bolus condition). They resumed exercise for another 35 minutes. A third blood sample was collected, and they exited the environmental chamber and rested for 60 minutes (approximate temperature = 21°C, relative humidity = 18%). Blood samples were collected at 30 and 60 minutes postexercise.

Main Outcome Measure(s): Plasma sodium concentration, plasma potassium concentration, plasma osmolality, and changes in plasma volume.

Results: The number of PJ boluses ingested did not affect plasma sodium concentration, plasma potassium concentration, plasma osmolality, or changes in plasma volume over time. The plasma sodium concentration, plasma potassium concentration, and plasma osmolality did not exceed 144.6 mEq·L^{-1} (144.6 mmol·L^{-1}), 4.98 mEq·L^{-1} (4.98 mmol·L^{-1}), and 289.5 mOsm·kg$^{-1}H_2O$, respectively, in any condition at any time.

Conclusions: Ingesting up to 2 boluses of PJ and resuming exercise caused negligible changes in blood variables. Ingesting up to 2 boluses of PJ did not increase plasma sodium concentration or cause hyperkalemia.

Key Words: hyperkalemia, hypernatremia, osmolality, potassium, sodium

Key Points

- Ingesting multiple small boluses of pickle juice did not result in changes in plasma sodium concentration, plasma potassium concentration, plasma volume, or plasma osmolality up to 125 minutes after ingestion.
- Hyperkalemia did not occur and plasma sodium concentration did not increase when up to 2 boluses of pickle juice were ingested during 1 exercise session.

Sodium (Na^+) is the primary electrolyte in sweat; normal sweat Na^+ concentrations can range from 0.5 to 2.3 g·L^{-1} (20 to 100 mmol·L^{-1}).[1] Sodium losses range widely; some authors[2,3] have observed that athletes lose 2.5 to 30 g of Na^+ in 1 day of training. Large Na^+ losses can put athletes at risk for developing hyponatremia, an injury marked by a plasma Na^+ concentration ($[Na^+]_p$) less than 135 mEq·L^{-1} (135 mmol·L^{-1}). Moreover, Na^+ losses are thought to increase the risk for developing exercise-associated muscle cramps (EAMC).[4–7]

A number of authors[5–8] have made recommendations for Na^+ replacement for athletes. The National Athletic Trainers' Association[6] recommended adding 0.3 to 0.7 g of Na^+ to every liter of rehydration drink to offset Na^+ losses due to sweating. The American College of Sports Medicine[8] recommended adding 1.2 to 2.5 g of Na^+ to every liter of sports drink to treat EAMC. Bergeron[9] reported success treating EAMC by adding up to 6 g·L^{-1} of Na^+ to a sports drink. Other clinicians have experimented with different methods of replacing Na^+, including ingesting chicken noodle soup[10,11] or pickle juice (PJ).[12,13]

Of athletic trainers polled, 25% (92 of 370) used PJ to treat EAMC.[13] However, some authors[12,14] have cautioned against PJ ingestion. Fowkes-Godek et al[12] observed mild hyperkalemia, a plasma potassium concentration ($[K^+]_p$) greater than 5 mEq·L^{-1} (5 mmol·L^{-1}), when American

football players supplemented their meals with PJ. Hyperkalemia is a concern because it is associated with cardiac abnormalities[15] and may contribute to the onset of fatigue.[16] Another possible concern is that ingesting PJ may increase $[Na^+]_p$ and plasma osmolality (OSM_p), thereby rapidly expanding plasma volume, decreasing thirst, and impairing rehydration.[14] However, others have observed no changes in plasma electrolyte concentrations, OSM_p, or plasma volume when euhydrated[17] or mildly hypohydrated[18–20] individuals ingested small volumes (approximately 80 mL) of PJ. Furthermore, ingesting PJ did not alter perceived thirst or the volume of water ingested ad libitum postexercise.[19]

Previous examinations of the effect of PJ on the extracellular fluid space had 3 limitations.[17–21] First, the authors only provided 1 bolus of PJ at 1 time, either preexercise[17,21] or postexercise.[18–20] Anecdotally, some athletic trainers give athletes PJ multiple times over the course of an exercise session to treat or prevent EAMC (eg, before a game or at halftime). Second, participants did not exercise postingestion of PJ.[17–19,21] No researchers have examined the extracellular fluid space after individuals ingested PJ and then resumed exercise. Given that aldosterone increases during exercise, consuming a salty drink and resuming exercise may increase $[Na^+]_p$ or OSM_p because aldosterone increases Na^+ absorption in the kidney. Third, the effects of ingesting PJ on the extracellular fluid space have not been measured after 60 minutes postingestion. Therefore, the purpose of our study was 2-fold: (1) to investigate the short-term effects of ingesting a single bolus and multiple boluses of PJ on $[Na^+]_p$, $[K^+]_p$, changes in plasma volume, and OSM_p up to 125 minutes postingestion and (2) to determine what happens to these variables when participants ingest PJ and resume exercise. Based on previous research,[17–21] we hypothesized that ingesting multiple small boluses of PJ would not increase $[Na^+]_p$, $[K^+]_p$, or OSM_p or cause further changes in plasma volume and that these variables would not be altered with exercise.

METHODS

Experimental Design

A crossover 3 × 5 factorial with repeated measures on time design guided data collection. The independent variables were number of PJ boluses (1 $mL \cdot kg^{-1}$ body weight [BW]) ingested (0, 1, or 2) and time (–5, 30, 65, 95, and 125 minutes postingestion). The dependent variables were $[Na^+]_p$ ($mEq \cdot L^{-1}$ [$mmol \cdot L^{-1}$]), $[K^+]_p$ ($mEq \cdot L^{-1}$ [$mmol \cdot L^{-1}$]), OSM_p ($mOsmol \cdot kg^{-1}$ H_2O), and changes in plasma volume percentage change from preingestion. Sodium and potassium (K^+) content changes were estimated using hematocrit, hemoglobin, and plasma electrolyte data.[22] We measured urine specific gravity to ensure participants began testing euhydrated (urine specific gravity < 1.02).[23]

Participants

A convenience sample of 12 non–heat-acclimated participants volunteered for this study. Three volunteers discontinued testing on the first day due to difficulties associated with venipuncture (eg, venous collapse and syncope). Nine physically active men (age = 23 ± 4 years, height = 180.9 ± 5.8 cm, mass = 80.7 ± 13.8 kg) with no self-reported history of heat illness (eg, heat stroke, heat exhaustion, or heat syncope) completed testing (Table 1). *Physically active* was defined as being involved in 20 to 60 minutes of vigorous activity on 3 or more days per week.[24] Exclusion criteria were self-reported blood or plasma donation 8 weeks before data collection; diabetes; anemia; food allergy to pickles; musculoskeletal, cardiovascular, bloodborne, or neurologic disease; or history of lower extremity injury within the 12 months preceding data collection. All volunteers provided written informed consent before data collection, and the study was approved by the North Dakota State University Institutional Review Board.

Table 1. Participant Demographics and Descriptive Data (Mean ± SD; N = 9)

Variable	Bolus(es), No.		
	0	1	2
Body weight measurement, kg			
1	80.7 ± 13.8	80.6 ± 13.3	80.6 ± 13.6
2	80.7 ± 13.8	80.6 ± 13.3	80.6 ± 13.6
3	79.5 ± 13.9	79.5 ± 13.5	79.5 ± 13.8
4	79.1 ± 13.9	79.1 ± 13.4	79.1 ± 13.6
Sweat volume, L[a]	1.2 ± 0.2	1.1 ± 0.3	1.1 ± 0.3
Hypohydration, %[b]	2.1 ± 0.5	2.0 ± 0.6	1.9 ± 0.6
Preexercise urine specific gravity	1.01 ± 0.004	1.009 ± 0.005	1.009 ± 0.006
Pickle-juice volume ingested, mL	0 ± 0	81 ± 13	162 ± 27
Sodium content ingested, g	0 ± 0	0.99 ± 0.16	1.97 ± 27.2
Potassium content ingested, g	0 ± 0	0.1 ± 0.02	0.2 ± 0.03
Heat chamber temperature, °C	37 ± 1	36 ± 2	37 ± 1
Heat chamber relative humidity, %	18 ± 2	18 ± 2	17 ± 2

[a] Calculated by subtracting body weight measurement (BW) 3 from BW 2.

[b] Calculated by subtracting BW 4 from BW 2, dividing by BW 2, and multiplying by 100.

Procedures

Participants reported for testing at approximately the same time of day on 3 days after fasting for 12 hours. They were instructed to refrain from strenuous activity for 48 hours before testing, maintain a similar diet throughout the experiment, and avoid caffeine and alcohol for 24 hours before testing.

They reported to a laboratory, voided their bladders completely, and had their urine measured for specific gravity with a refractometer (model SUR-Ne; Atago USA Inc, Bellevue, WA). If hypohydrated (urine specific gravity > 1.02),[23] participants were excused and rescheduled for another testing session at least 24 hours later. If euhydrated, they inserted a rectal thermistor (YSI; Advanced Instruments Inc, Norwood, MA) at least 10 cm past the anal sphincter and put on a heart-rate monitor (Polar Electro Inc, Lake Success, NY). The antecubital region of 1 forearm was cleaned with isopropyl alcohol, and a sterile, 20-gauge

Table 2. Pickle-Juice Composition[a]

Variable	Mean ± SD
Osmolality, mOsmol·kg^{-1} H_2O	915 ± 0
pH	3.56 ± 0.02
Specific gravity	1.018 ± 0
Sodium concentration, mmol·L^{-1}	530 ± 14
Potassium concentration, mmol·L^{-1}	28.8 ± 0
Chloride concentration, mmol·L^{-1}	344 ± 0
Glucose concentration, mmol·L^{-1}	24.4 ± 0

[a] Pickle juice was analyzed in duplicate.

venous catheter was inserted into a superficial vein. They were weighed (BW) nude to the nearest tenth of a kilogram on a scale (model DA-150; Denver Instrument, Bohemia, NY) and sat for 30 minutes to ensure equilibration of fluid compartments.[25] We used BW measurement 1 to calculate the ingested PJ volume (1 mL·kg^{-1} BW; Table 1).

After the 30-minute rest period, a 5-mL blood sample was collected (–5 minutes). Participants were weighed nude (BW measurement 2), put on a sweat suit (hooded sweatshirt and sweatpants), and had 60 seconds to ingest either 0 or 1 bolus of chilled (approximately 6°C) PJ (dill pickles; Gedney Foods Company, Chaska, MN; Table 2). On the 0-bolus days, participants rested for 60 seconds at all ingestion periods. After PJ ingestion, they biked on a semirecumbent cycle ergometer (model 846i-R; Precor Inc, Woodinville, MA) at 80% to 85% of their age-predicted maximal heart rates for 30 minutes in the heat (Table 1). After 30 minutes of exercise, a 5-mL blood sample was collected. On the 2-bolus days, participants ingested another 1 mL·kg^{-1} BW of chilled PJ. For the 0- or 1-bolus days, they rested for 60 seconds during this period. They resumed biking for another 30 minutes and then cooled down for 5 minutes at a self-selected lower intensity.

A third 5-mL blood sample was collected immediately after cool down. After the blood sample, participants stood and exited the heat chamber, towel dried, removed their sweat suits, were weighed nude (BW measurement 3), and voided their bladders completely. They removed the heart-rate monitor and rectal thermistor and were weighed nude again (BW measurement 4). Participants sat in a climate-controlled room (approximate temperature = 21°C, relative humidity = 18%) for an additional 60 minutes, during which blood samples were collected at 95 minutes postingestion (30 minutes postexercise) and 125 minutes postingestion (60 minutes postexercise).

We instructed participants to report for their other testing days at least 48 hours later. Trials differed only by the number of boluses ingested (0, 1, or 2). The order of the number of boluses ingested was randomized and counterbalanced a priori using half of the possible order combinations.

Blood and Plasma Analysis

Whole blood was used to determine hematocrit and hemoglobin concentrations. For the hematocrit, blood was drawn into heparinized, microcapillary tubes; centrifuged at 3000 revolutions per minute for 5 minutes; and read using a microcapillary reader (model IEC 2201; Damon/IEC, Needham Heights, MA). We estimated hemoglobin concentration using the cyanomethemoglobin technique.[17,21] Hematocrit and hemoglobin concentrations were measured in triplicate immediately after sampling and averaged for statistical calculations. Changes in plasma volume were estimated by inserting hematocrit and hemoglobin data into the Dill and Costill[26] equation. Changes in K^+ and Na^+ content were estimated using Greenleaf et al[22] equations.

The remaining whole blood was centrifuged at 3000 revolutions per minute for 15 minutes at 3°C. Plasma was removed from the packed red cells, and plasma electrolyte concentrations were analyzed using an ion-selective electrode system (NOVA Biomedical Corp, Waltham, MA). We determined OSM_p by freezing-point depression osmometry (model 3D3; Advanced Instruments Inc). Plasma electrolyte concentrations and OSM_p were measured in duplicate and averaged for statistical analysis.

Statistical Analysis

We calculated separate 3 × 5 repeated-measures analyses of variance to determine the effects of ingesting multiple boluses of PJ on plasma variables over time. Shapiro-Wilk tests were used to assess normality. We used the Mauchly test to confirm sphericity. When sphericity was violated, Greenhouse-Geisser corrections to degrees of freedom and P values were applied. We used Tukey-Kramer multiple-comparison tests to determine differences within each independent variable at each time point. Given the number of analyses of variance performed, a Bonferroni correction to the α level was applied a priori. We used NCSS 2007 software (version 07.1.18; NCSS, Kaysville, UT) to analyze the data. Findings were considered different when $P < .01$.

RESULTS

Participants reported compliance with all pretesting instructions before each testing session. They began testing in similarly euhydrated states, lost similar volumes of sweat, and were similarly hypohydrated postexercise (Table 1). They ingested 0, 1, or 2 bolus(es) of PJ, resulting in various quantities of Na^+ and K^+ being ingested (Table 1). The composition of the PJ is shown in Table 2.

We observed no interaction between the number of boluses ingested and time for $[Na^+]_p$ ($F_{8,64} = 2.2$, $P = .04$) or $[Na^+]_p$ ($F_{2,16} = 4.2$, $P = .04$). However, $[Na^+]_p$ did change over time ($F_{2,15} = 43.2$, $P < .001$, mean effect size = 2.3; Figure 1). Similarly, we noted an interaction between the number of boluses ingested and time for percentage change in plasma Na^+ content ($F_{8,64} = 3.2$, $P = .004$; Figure 1).

No interaction between the number of boluses ingested and time ($F_{5,25} = 0.7$, $P = .54$) or main effect of bolus for $[K^+]_p$ ($F_{2,16} = 1.8$, $P = .21$) was demonstrated. However, $[K^+]_p$ changed over time ($F_{4,32} = 0.4$, $P < .001$, mean effect size = 1.3; Figure 2). Estimated percentage changes in K^+ content did not differ between bolus and time ($F_{8,64} = 2.4$, $P = .03$) or between boluses only ($F_{2,16} = 0.8$, $P = .47$) or time only ($F_{4,32} = 3.4$, $P = .02$).

We observed no interaction between number of boluses ingested and time ($F_{8,64} = 1.2$, $P = .32$) or main effect of bolus for changes in plasma volume ($F_{2,16} = 0.02$, $P = .98$). However, changes in plasma volume occurred over time ($F_{4,32} = 61.4$, $P < .001$, mean effect size = 2.2; Figures 1 and 2).

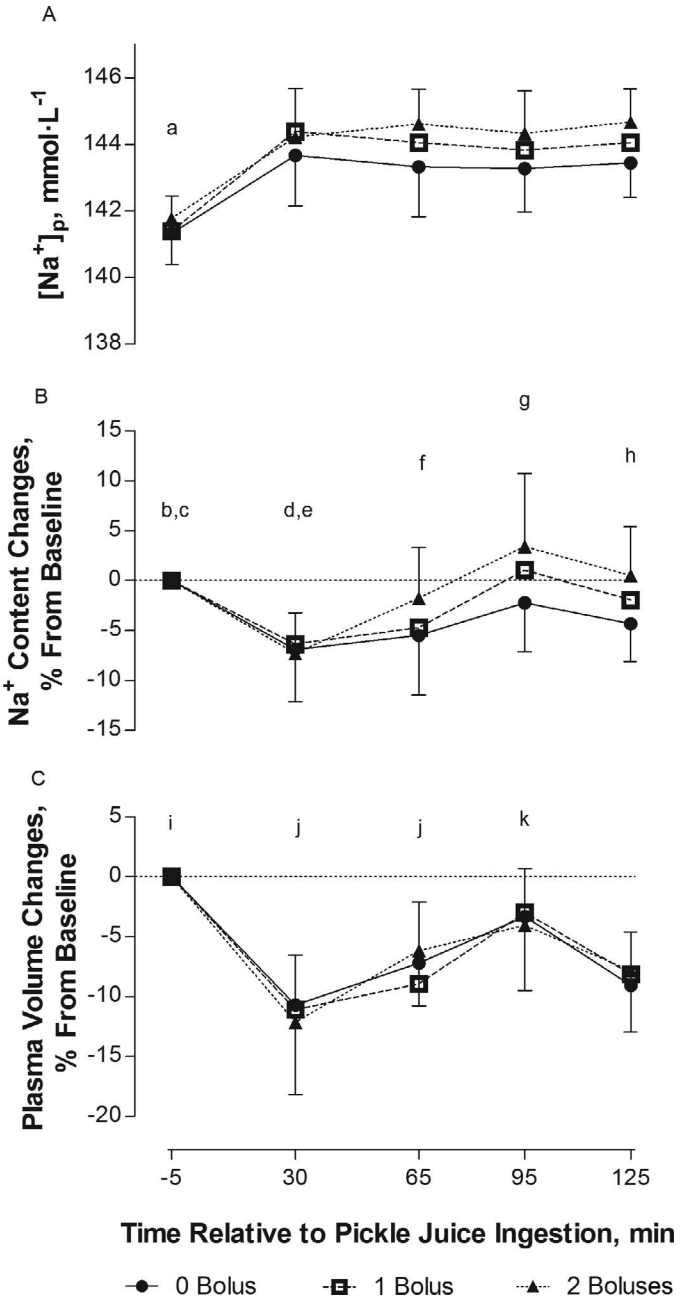

Figure 1. A, Plasma sodium concentration ($[Na^+]_p$), B, plasma sodium content changes, and C, changes in plasma volume after ingestion of varying boluses of pickle juice (mean ± SD). [a] Indicates –5 < all other times. [b] Indicates within 0 and 1 bolus: –5 minutes > 30 and 65 minutes. [c] Indicates within 2 boluses: –5 minutes > 30 minutes. [d] Indicates within 0 and 1 bolus: 30 minutes < 95 minutes. [e] Indicates within 2 boluses: 30 minutes < 65, 95, and 125 minutes postingestion. [f] Indicates within 1 and 2 boluses: 65 minutes < 95 minutes. [g] Indicates 0 bolus 95 minutes < 2 boluses 95 minutes. [h] Indicates 0 bolus 125 minutes < 2 boluses 125 minutes. [i] Indicates –5 minutes > 30, 65, and 125 minutes. [j] Indicates 30 and 65 minutes < –5 and 95 minutes. [k] Indicates 95 minutes > 125 minutes. Findings were considered different when $P < .01$ (N = 9).

No interaction between bolus and time ($F_{8,64} = 2.1$, $P = .05$) or main effect of bolus for OSM_p ($F_{2,16} = 2.5$, $P = .12$) were shown. Plasma osmolality did change over time ($F_{4,32} = 61.4$, $P < .001$, mean effect size = 1.5; Figure 3).

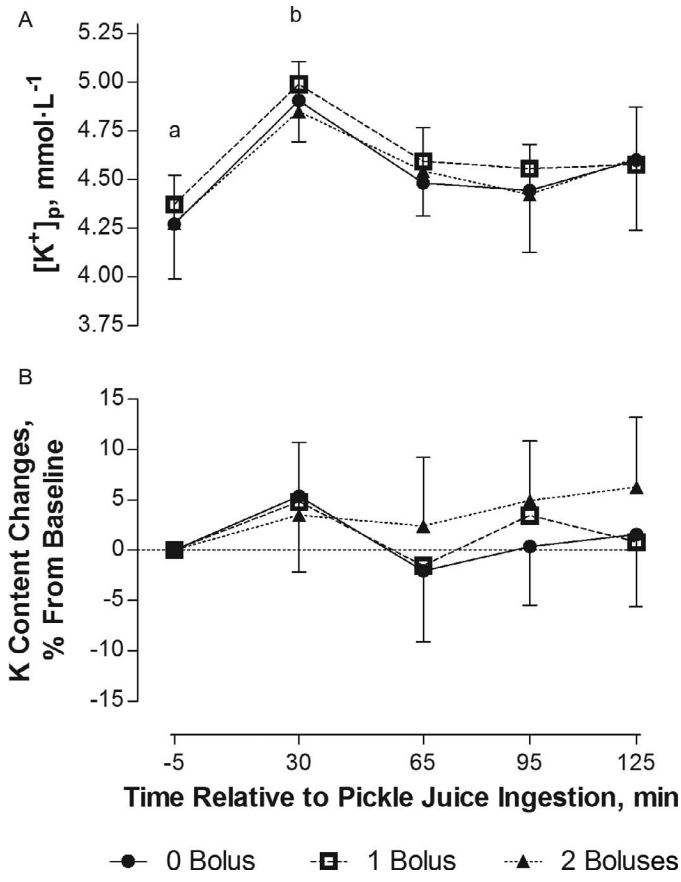

Figure 2. A, Plasma potassium concentration ($[K^+]_p$) and B, plasma potassium content changes after ingestion of varying boluses of pickle juice (mean ± SD). [a] Indicates –5 minutes < 30 and 125 minutes. [b] Indicates 30 minutes > all other times. Findings were considered different when $P < .01$ (N = 9).

DISCUSSION

Authors have cautioned against ingesting PJ because they fear it will increase $[Na^+]_p$ and OSM_p, rapidly expand plasma volume, decrease thirst, and impair rehydration.[14] We observed no alterations in $[Na^+]_p$, OSM_p, or changes in plasma volume after participants ingested 0, 1, or 2 bolus(es) of PJ and exercised in the heat. These results are consistent with and extend the results of other scientists who provided PJ either before or after exercise.[17–21] Researchers[18–20] examining hypohydrated participants have found that ingesting 1 mL·kg^{-1} BW of PJ did not alter $[Na^+]_p$, OSM_p, or changes in plasma volume up to 1 hour postexercise. Although we observed a decrease in change in plasma volume, ingesting PJ did not exacerbate plasma shifts, as we found no differences among conditions over time. Thus, the initial decrease in plasma volume was likely due to exercise-induced shifts in fluid between compartments. Given that participants drank only up to 162 mL of fluid for the entire testing session and lost approximately 1 L of sweat, the gradual increase in plasma volume in all conditions occurring between 30 and 95 minutes postingestion was likely due to an increase in OSM_p. This would then cause water to shift into the extracellular fluid space. The decrease in plasma-volume change occurring in all conditions between 95 and 125 minutes postingestion was likely due to urine production.[17]

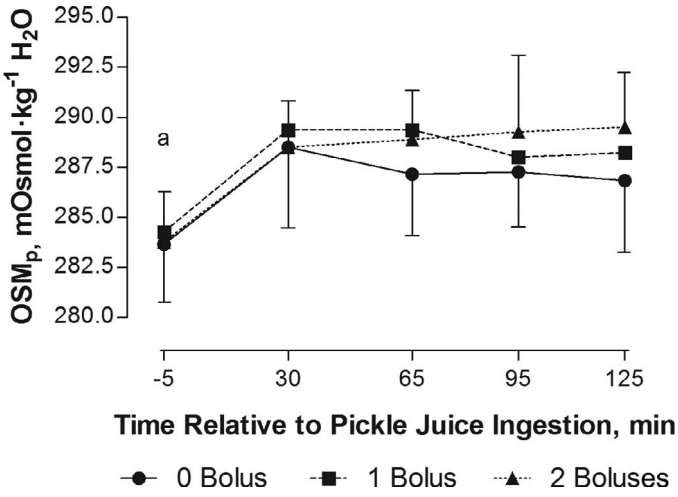

Figure 3. Plasma osmolality (OSM_p) after ingestion of varying boluses of pickle juice (mean ± SD). [a] Indicates –5 minutes < all other times. Findings were considered different when $P < .01$ (N = 9).

Unlike the results for $[Na^+]_p$ and OSM_p, we noted a change in plasma Na^+ content when different amounts of PJ were ingested. This observation is clinically important because it provides evidence regarding how many small boluses of PJ must be ingested to return Na^+ content to baseline levels after a bout of exercise in the heat. Our participants lost 1.1 L of sweat during exercise. Assuming an average sweat Na^+ concentration of 50 mmol·L^{-1}, our participants would have lost 55 mmol (1.3 g) of Na^+.[1,7] The decrease in plasma Na^+ content observed in the first 65 minutes postingestion was likely due to Na^+ loss via exercise-induced sweating. We observed an increase in plasma Na^+ content change from 30 to 65 minutes in the 2-bolus condition that was not observed in the 0- or 1-bolus condition. The delayed increase in plasma Na^+ content in the 0- and 1-bolus conditions was likely due to a smaller volume of fluid in the stomach. Gastric emptying is delayed by small stomach volumes,[27,28] vigorous exercise,[29,30] high osmolality,[31] and low pH of ingested beverages.[32] In our study, the gastric-emptying rates were likely low for all conditions due to the small volumes ingested and vigorous exercise. Miller et al[21] observed a gastric-emptying rate of approximately 2 mL per minute when rested, euhydrated participants ingested 1 bolus of PJ that was approximately 150 mL. In our study, plasma Na^+ content increased only in the 2-bolus condition from 30 to 65 minutes. Thus, the second bolus could have increased gastric distension more than the 1-bolus condition, thereby accounting for the earlier increase in plasma Na^+ content change. This hypothesis is supported by the observation that returning plasma Na^+ content to baseline in the 1-bolus condition took, on average, 95 minutes. Plasma Na^+ content returns to baseline faster when 2 boluses are ingested than when 1 bolus is ingested. Therefore, if cramping is due to Na^+ loss[5,7] and if athletes have average sweat Na^+ concentration and intend to replace Na^+ by ingesting PJ,[13] they must consume more than 1 mL·kg^{-1} BW of PJ. However, the prolonged delay in the increased Na^+ content suggests that ingesting PJ to increase Na^+ content to treat an acute cramp would be an ineffective strategy.

Another concern about ingesting PJ during exercise is the possible development of hyperkalemia,[12] presumably because of the K^+ content in the PJ. In preliminary work, Fowkes-Godek et al[12] observed an increase in $[K^+]_p$ when American football players supplemented their diets with PJ over 9 consecutive days. Before supplementation, $[K^+]_p$ was 4.7 ± 0.3 mEq·L^{-1} (4.7 ± 0.3 mmol·L^{-1}). Plasma K^+ concentration was higher after 5 days of PJ supplementation (5.2 ± 0.1 mEq·L^{-1} [5.2 ± 0.1 mmol·L^{-1}]).[12] Interestingly, after 9 days of supplementation, $[K^+]_p$ decreased to 4.9 ± 0.3 mEq·L^{-1} (4.9 ± 0.3 mmol·L^{-1}; S. Fowkes-Godek, written communication, March 2013). Hyperkalemia is associated with cardiac abnormalities, but $[K^+]_p$ must be elevated to 6 to 7 mEq·L^{-1} (6 to 7 mmol·L^{-1}) for abnormalities to occur.[15] We observed a $[K^+]_p$ increase in our study that was not exacerbated by ingesting any volume of PJ. Thus, the increase in $[K^+]_p$ was likely due to the release of K^+ into the bloodstream from the exercising muscles.[33,34] Zavorsky et al[33] showed that $[K^+]_p$ increased in their participants from approximately 4 to 5.3 mEq·L^{-1} (4 to 5.3 mmol·L^{-1}) after 5 minutes of vigorous cycling but returned to baseline values after 5 minutes of rest. Therefore, hyperkalemia is not a concern if athletes ingest multiple boluses of PJ during exercise on 1 day. The lack of a control group in the study by Fowkes-Godek et al[12] prevents us from determining the effect of ingesting PJ on $[K^+]_p$ over 9 consecutive days. The hyperkalemia that they observed may have been due to physical contact or exercise-induced muscle damage from preseason conditioning drills.[12] Additional research is needed to determine the effects of PJ supplementation on $[K^+]_p$ over consecutive days of training.

We acknowledge the limited external validity of our study. However, we tried to emulate certain conditions athletes experience when they participate in competitive athletics (eg, a break during exercise and resumption of activity). Furthermore, we emulated the dosage and timing of PJ ingestion that athletic trainers use.[13] Athletes normally have longer breaks, eat additional foods or consume fluids in addition to PJ, have various degrees of hydration, and exercise at various intensities. Given that these factors would have confounded our results, we chose to control them to answer our research questions.

CONCLUSIONS

When participants ingested multiple, small boluses of PJ, no changes occurred in $[Na^+]_p$, $[K^+]_p$, or OSM_p up to 125 minutes postingestion. Furthermore, the addition of exercise did not alter plasma variables. However, ingesting 2 boluses returned plasma Na^+ content to normal faster than ingesting 1 bolus. Additionally, hyperkalemia is not a concern when 1 or 2 bolus(es) of PJ are ingested during 1 exercise session. However, clinicians should continue to be cautious when athletes ingest PJ over consecutive days until researchers can address this concern in controlled experimental studies.

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Address correspondence to Kevin C. Miller, PhD, AT, ATC, School of Rehabilitation and Medical Sciences, Central Michigan University, 1217 Health Professions Building, Mount Pleasant, MI 48859. Address e-mail to mille5k@cmich.edu.