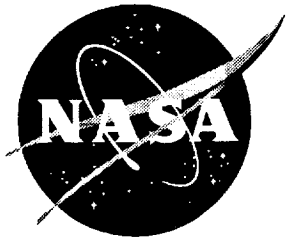
Technical Paper 3456

Fluid-Loading Solutions and Plasma Volume: Astro-Ade and Salt Tablets With Water

Suzanne M. Fortney, Ph.D.
Laura Steinmann
Joan A. Young
Cherylynn N. Hoskin
Linda H. Barrows

January 1994



Technical Paper 3456

Fluid-Loading Solutions and Plasma Volume: Astro-Ade and Salt Tablets With Water

Suzanne M. Fortney, Ph.D.
Lyndon B. Johnson Space Center
Houston, Texas

Laura Steinmann
Joan A. Young
Cherylynn N. Hoskin
Linda H. Barrows
KRUG Life Sciences
Houston, Texas

1994

National Aeronautics
and Space Administration

Contents

Tables

Figures

INTRODUCTION

Salt tablets and water (8 grams salt in 0.97 liters of water) is the current fluid-loading countermeasure used by Shuttle crewmembers to acutely restore plasma volume during the 1 to 2 hours before touchdown [2]. Presumably, increasing plasma volume will enhance cardiac filling and improve postflight orthostatic intolerance. Based on our experiences with ground-based studies, anecdotal reports from Shuttle crewmembers, and the Russian literature [9, 12], we know that some individuals experience unpleasant side effects including nausea, stomach cramping, diarrhea, and vomiting after taking this quantity of salt tablets and water. Our goal is to screen a variety of drinking solutions for their effectiveness in expanding plasma volume while inducing minimal side effects over a time profile similar to a Shuttle landing. In this report we compared responses to Astro-ade, a fluid-loading solution developed at the NASA Ames Research Center, with the current Shuttle fluid-loading countermeasure.

Based on previous studies [7, 8, 9, 10] it appears that isotonic (0.9%) or slightly hypertonic (1.07%) salt solutions are most effective in acutely expanding plasma volume for prolonged periods. The critical factor seems to be the isotonicity rather than composition; as an isotonic salt/sugar solution such as 0.74% saline and 1% glucose [7] or an isotonic bouillon drink [11] have very different compositions yet both successfully expand plasma volume for several hours. Hypertonic salt or salt/sugar solutions stimulate a brisk diuresis and are less effective in expanding plasma volume [8]. Similarly, hypotonic solutions (water, 0.45% saline, or 1% glucose) resulted in only small transient increases in plasma volume when given to hypovolemic [8] or normally hydrated [7] subjects.

Our specific aim was to compare the responses of a recently developed isotonic electrolyte solution, Astro-ade [8], to the current fluid-loading countermeasure (salt tablets with water), to determine if Astro-ade is equally effective in expanding plasma volume in normally hydrated individuals while inducing fewer side effects. The chemical characteristics of Astro-ade are shown in Table 1.

Table 1. *Astro-Ade chemical composition* [8]

Contents		Ionic Concentrations (mEq[%wt/vol])	
Sodium Chloride (gm)	9.00	Na^+	157 (0.360)
Sodium Citrate (gm)	15.44	K^+	0
Aspartame (gm)	0.72	Cl^-	76 (0.270)
Total Volume (mL)	2000	Mg^{++}	0
		Ca^{++}	0
		P^{+++}	0
		Total	233 (0.630)
Osmolality	270		

* Shaklee U.S., Inc. San Francisco, CA 94111

METHODS

Subjects

Eleven healthy men (Table 2) volunteered for this study and participated in one to three trials. The three trial conditions were: no fluid loading (control), orange-flavored Astro-ade ingestion (Astro-ade), and intake of salt tablets with water (tablets).

Table 2. *Subject characteristics*

Subject	Age (yr)	Height (cm)	Weight (kg)
		Astro-ade Trials	
1	30	167	64.5
2	29	182.5	78.2
3	36	191	99
4	32	175	100.2
5	31	182	92
6	34	188	74.5
		Salt Tablet Trials	
1	30	167	64.5
2	29	182.5	78.2
3	36	191	99
5	31	182	92
7	28	170.2	73.2
8	42	175.5	84.5
		Control Trials	
1	30	167	65.5
2	29	182.5	78.2
8	42	175.5	84.5
9	45	167	75.7
10	38	166.5	78
11	32	175	86

Overall Protocol

Each subject had a light, nonsalty breakfast and reported to the laboratory at approximately 7:30am. They were immediately given 5 mL/kg of water to drink so that they would be well-hydrated at the beginning of the test day. A catheter was inserted in an arm vein, and each subject rested quietly in a recliner chair for the remaining 4.5 hours of the study, except to urinate as needed. The subjects sat with the chairs fully reclined so that their feet were approximately at heart level. Immediately after each blood draw, subjects were given the opportunity to empty their bladder. In this way, subjects maintained the same reclining position for at least 30 minutes immediately prior to each blood draw.

Body weights were obtained for each subject immediately before beginning fluid loading and 4.5 hours later. Fluid balance was calculated by measuring the difference between urine output and fluid intake between the start of fluid loading and 4.5 hours later. Heart rates and blood pressures were obtained immediately before each blood sampling.

In all trials, after initial 30 minutes of quiet rest, the baseline blood sample was obtained. During fluid-loading trials, each subject either slowly sipped the Astro-ade solution (15 mL/kg) or took salt tablets and water during the next 60 minutes (hydration period). The salt tablet mixture was adjusted so that the quantity of salt and water taken was in a ratio of approximately 1 salt tablet (1 gm) for each 110 mL of water. The total volume taken was adjusted to the nearest whole salt tablet. For example, a 70-kg man would have a target fluid requirement of 70x15 mL/kg = 1050mL. For this volume of fluid, 9.54 salt tablets would be required (1050 mL/110 mL• g^{-1} = 9.54 g, or 9.54 tablets). This subject would be administered 10 salt tablets and 1100 mL of fluid.

Postfluid-loading blood samples were obtained at 1 hour, 1.5, 2.5, 3.5, and 4.5 hours after the start of the hydration period. In a nominal Shuttle landing, fluid ingestion would begin approximately 2 hours prior to touchdown. In the event of a one-revolution wave-off, there would be a 90-minute delay before touchdown (or 3.5 hours after beginning fluid loading).

Subjects were given a questionnaire to complete describing the presence of certain symptoms three times during the study: during the baseline period, at the end of the hydration period, and just before release at the end of the study. Subjects were asked to circle "yes" or "no" whether they were experiencing symptoms of headache, nausea, vomiting, stomach cramping, diarrhea, or thirst.

Control subjects followed an identical protocol except they did not drink during the hydration period. During all three trials, no further fluid or food ingestion was allowed during or after the hydration period.

Measurements

From each blood sample, duplicate measurements were made of hematocrit and hemoglobin concentration (Coulter Counter), serum osmolality (freezing-point depression), serum sodium concentration (ion analyzer), and blood glucose using a modified enzymatic approach (Beckman Synchron CX5 System).

Data Analysis

Changes in plasma volume between the baseline sample and each succeeding blood sample were calculated from hematocrit and hemoglobin values using the formula described by Dill and Costill [4]. All dependent blood variables were compared for differences across time with a repeated measures ANOVA design, and among groups using a nonrepeated measures design (Clear Lake ANOVA Statistical Program). When a significant effect was found among groups or times, post hoc multiple comparisons were performed with a Duncan Multiple Range Test. Changes in body weight and fluid balance for the three groups were compared by using a nonpaired t test. For all comparisons, statistical significance was determined when $p \leq 0.05$ and data are presented as the mean ± standard error.

RESULTS

Hematocrits

The hematocrit responses did not differ significantly ($p<0.59$) among the three groups. However, there were significant differences across time ($p<0.002$) and a significant interaction between time and group. For the Astro-ade and salt tablet groups, hematocrit had decreased slightly from baseline approximately 2.5 hours after drinking and returned to baseline during the remainder of the trial. In contrast, hematocrit continuously increased across time in the control group.

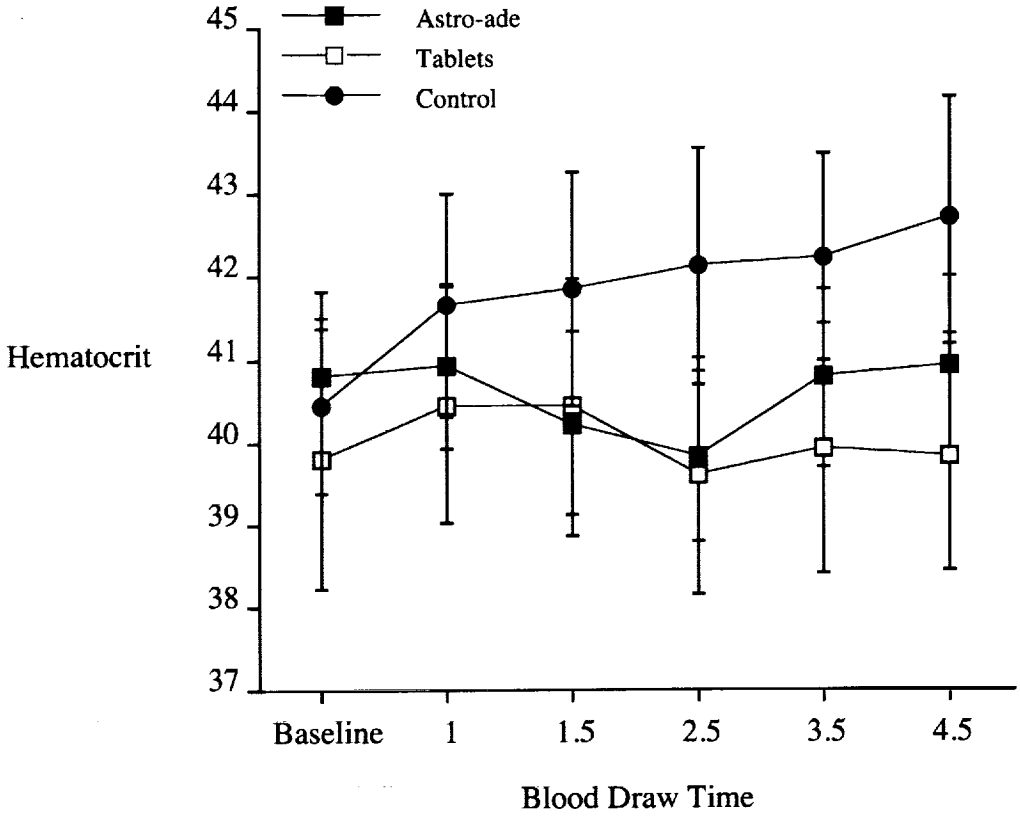


Figure 1. *Hematocrit values at baseline and at intervals (hours) after beginning of fluid loading. Results shown are the mean ±SE, n=6 in each group (group effect, p=0.59; time effect, p=0.01; interaction, p=0.01).*

Hemoglobin Concentration

There were no significant group differences, although hemoglobin concentration tended to decline after drinking in the fluid-loading groups while it continuously increased in the control group. The time effect and the group/time interaction were significant ($p<0.0001$).

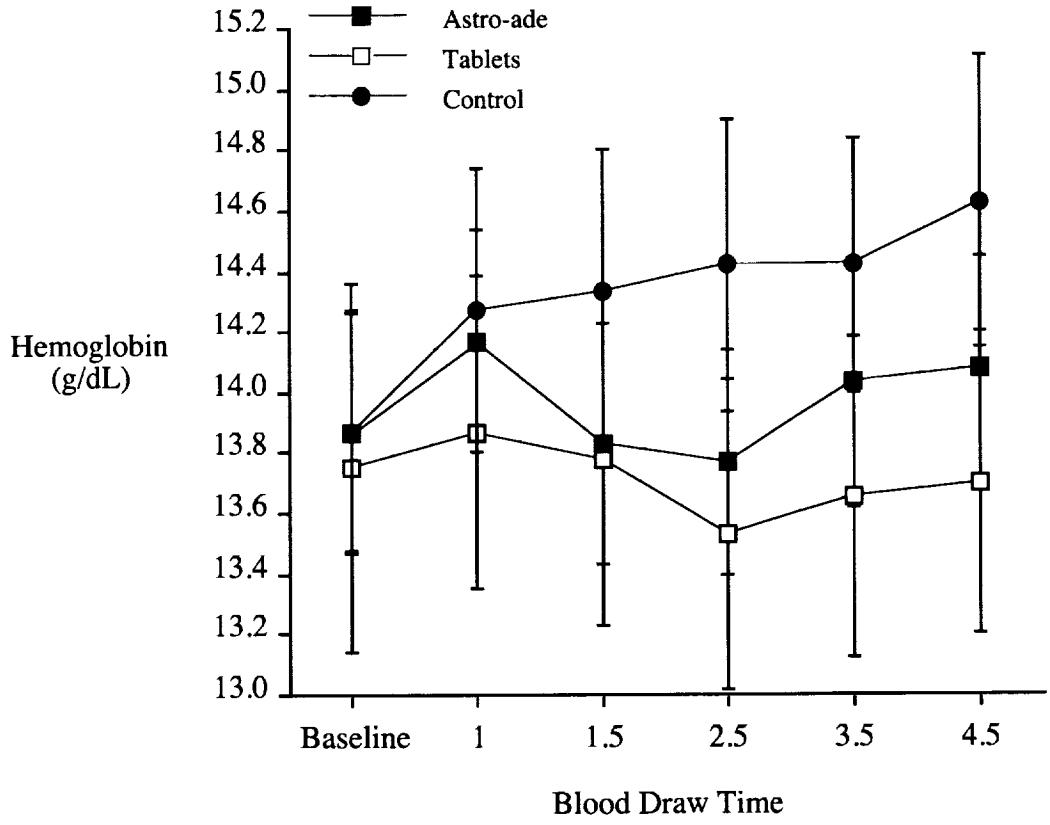


Figure 2. *Hemogobin concentration at baseline and at intervals (hours) after beginning of fluid loading. Results shown are the mean ±SE, n=6 in each group (group effect, p=0.65; time effect, p=0.01; interaction, p=0.01).*

Plasma Osmolality

The plasma osmolality responses did not differ (p=0.21) among groups or across time (p= 0.34). There was a borderline interaction effect, p<0.05.

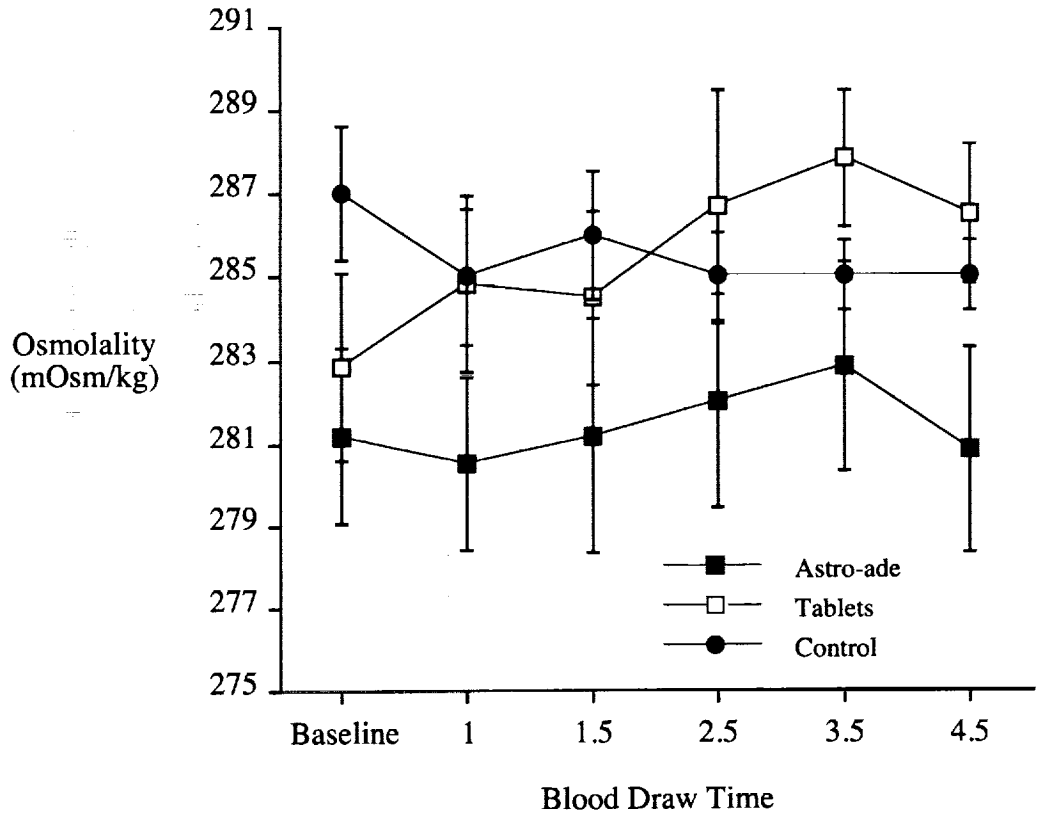


Figure 3. *Plasma osmolality at baseline and at intervals (hours) after beginning of fluid loading. Results shown are the mean ±SE, n=6 in each group (group effect, p=0.21; time effect, p=0.34; interaction, p=0.05).*

Serum Sodium Concentration

Serum sodium concentration also did not differ among groups (p=0.67) or across time (p=0.83). The interaction effect was not significant (p<0.37).

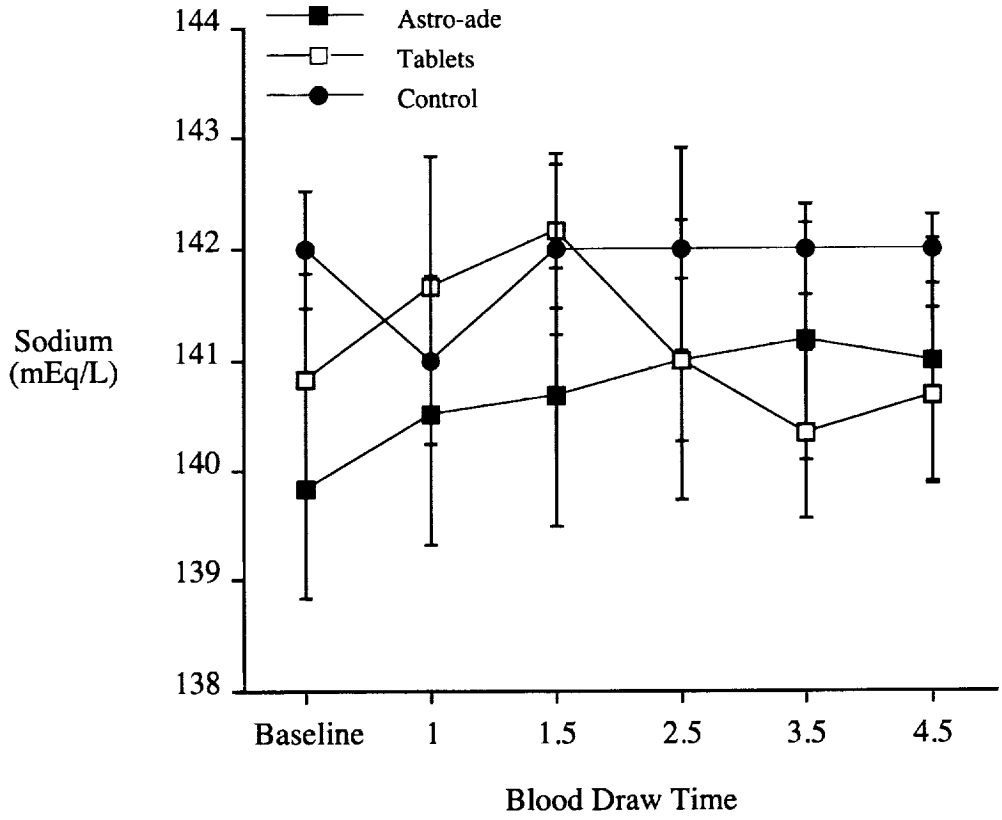


Figure 4. *Plasma sodium concentration at baseline and at intervals (hours) after beginning of fluid loading. Results shown are the mean ±SE, n=6 in each group (group effect, p=0.67; time effect, p=0.83; interaction, p=0.37).*

Blood Glucose

Blood glucose concentration decreased significantly as a function of time ($p<0.0001$), becoming significantly lower than baseline within one hour. A similar response occurred in all three groups.

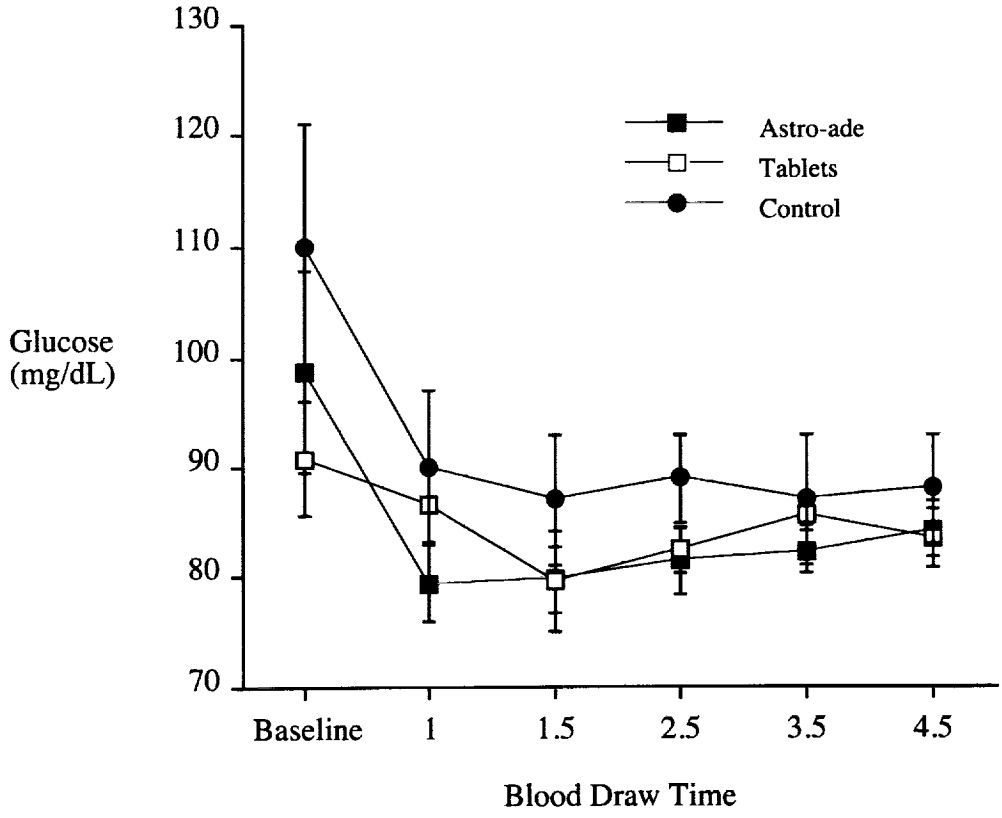


Figure 5. *Blood glucose concentration at baseline and at intervals (hours) after beginning of fluid loading. Results shown are the mean ±SE, n=6 in each group (group effect, p=0.29; time effect, p=0.01, interaction, p=0.64).*

Percent Change in Plasma Volume after Drinking

The plasma volume responses were similar after drinking each of the fluid-loading solutions. Plasma volume decreased significantly during the first hour after drinking. Then, plasma volume increased above baseline with a peak at approximately 2.5 hours after the start of fluid ingestion. Thereafter, it decreased to baseline levels during the last two hours of the study. During the control studies, plasma volume decreased progressively during the course of the study. This control response differed significantly ($p<0.01$) from the drink responses.

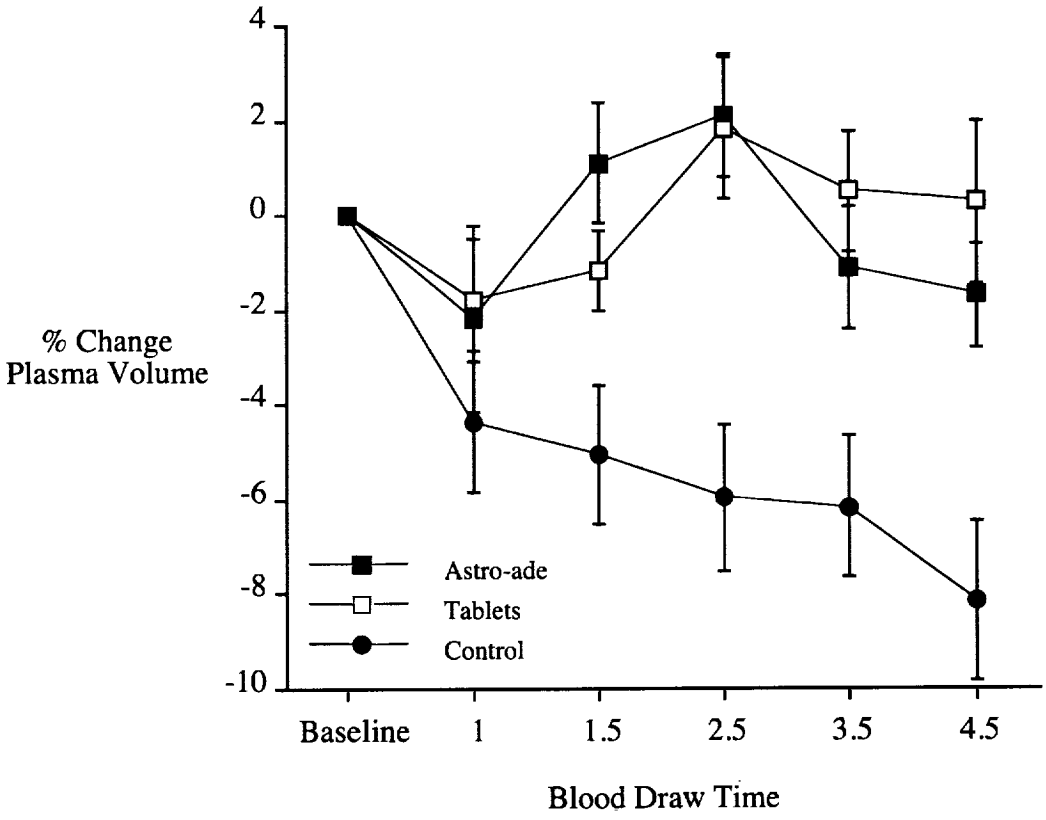


Figure 6. *Percent change in plasma volume between baseline and at intervals (hours) after fluid loading. Results shown are the mean ±SE, n=6 in each group (group effect, p=0.01; time effect, p=0.01; interaction, p=0.01).*

Individual and mean blood results are presented in Appendix B.

Symptoms

Both the salt tablet/water and Astro-ade drinks caused gastrointestinal distress in some subjects. Symptoms of stomach cramps, diarrhea, and indigestion were reported after both drinks. Nausea or vomiting were each seen in one subject after ingestion of salt tablets and water. The only symptom measured that appeared in the control group was thirst.

Table 3. *Symptoms (numbers correspond to subject identification in Table 2)*

Symptom	Baseline	1 Hour	4.5 Hours
		Astro-ade Trials	
Headache		6	6
Nausea			
Vomiting			
Thirst	2		2, 3, 4
Cramping		5	
Diarrhea		5	
Indigestion			2
		Salt Tablet Trials	
Headache			
Nausea		3	
Vomiting		7	
Thirst			2, 3
Cramping		3	
Diarrhea		3	
Indigestion			2
		Control Trials	
Headache			
Nausea			
Vomiting			
Thirst	2, 11	2, 8	8, 11
Cramping			
Diarrhea			
Indigestion			

Heart Rates and Blood Pressures (Appendix C)

There were no significant differences among groups for heart rate, systolic or diastolic blood pressure. Blood pressures did not change significantly across time in this study, however, heart rates did change significantly ($p<0.0001$) across time. From a simple effect analysis, heart rate decreased significantly between baseline and all other sampling times in the salt tablet and in the

control group. Heart rate had decreased an average of 8 beats per minute between baseline and the end of fluid loading for each of these groups. For the Astro-ade group, the average heart rate decreased by 2 beats per minute during this interval.

Fluid Balance and Body Weights (Appendix C)

There was no significant group effect for the change in body weight during the study ($p<0.12$). Between baseline and the end of the study, the Astro-ade group lost 0.25 ±0.25 kg, the salt tablet group lost 0.34 ±0.12 kg, and the control group lost 1.00 ±0.36 kg.

Fluid balance (urine output—fluid intake) differed significantly among groups, $p< 0.01$. The control group ended the study in a negative fluid balance (-867 ±300 mL), the Astro-ade group was in positive fluid balance (291 ±155 mL), and the salt tablet group maintained fluid balance (0.8 mL ±182 mL). (These differences are not corrected for insensible water loss which would be expected to average approximately 100 mL/hour or a total of about 450 mL.) Thus, all three groups lost some weight during the study.

DISCUSSION

Fluid-Loading Hydrated Subjects

Both Astro-ade and salt tablets and water significantly expanded plasma volume between 2 to 3 hours after ingestion, the time of a nominal Shuttle landing. Although the plasma volume expansion compared to baseline averaged only 2%, the control group had a 6.0% decrease in plasma volume, probably due to the prolonged hypokinesia and lack of fluid intake. Thus, both drink solutions increased plasma volume compared to control by an amount which should improve cardiac filling during an orthostatic stress.

The expansion of plasma volume seen in these subjects (2%) is somewhat smaller than that previously noted by Frey and coworkers [7] (5%) in five hydrated men after ingestion of a similar volume of 0.9% saline solution. However, such a small difference would be within the experimental error of our measurement procedures.

Fluid-Loading Hypohydrated Subjects

The effectiveness of a hydration solution may be influenced by the hydration status of the subject, where hypovolemic subjects retain more of a fluid load and have a greater expansion in plasma volume. As an example, the increase in plasma volume after drinking in these initially hydrated subjects is considerably smaller than the increases we found previously in subjects who had been given a short-acting diuretic (Lasix®) 2 hours prior to fluid loading (Figure 7). In our earlier study, both an isotonic saline solution and the salt tablet and water treatment increased plasma volume an average of 10% at 2 hours after beginning fluid ingestion. Similarly, Greenleaf and coworkers [8] reported a relatively large increase in plasma volume (8%) 70 minutes after seven hypovolemic subjects drank 12 mL/kg of Astro-ade. In Greenleaf's study, the subjects had been made hypovolemic by restricting fluid intake and eating dry food for 24 hours prior to testing.

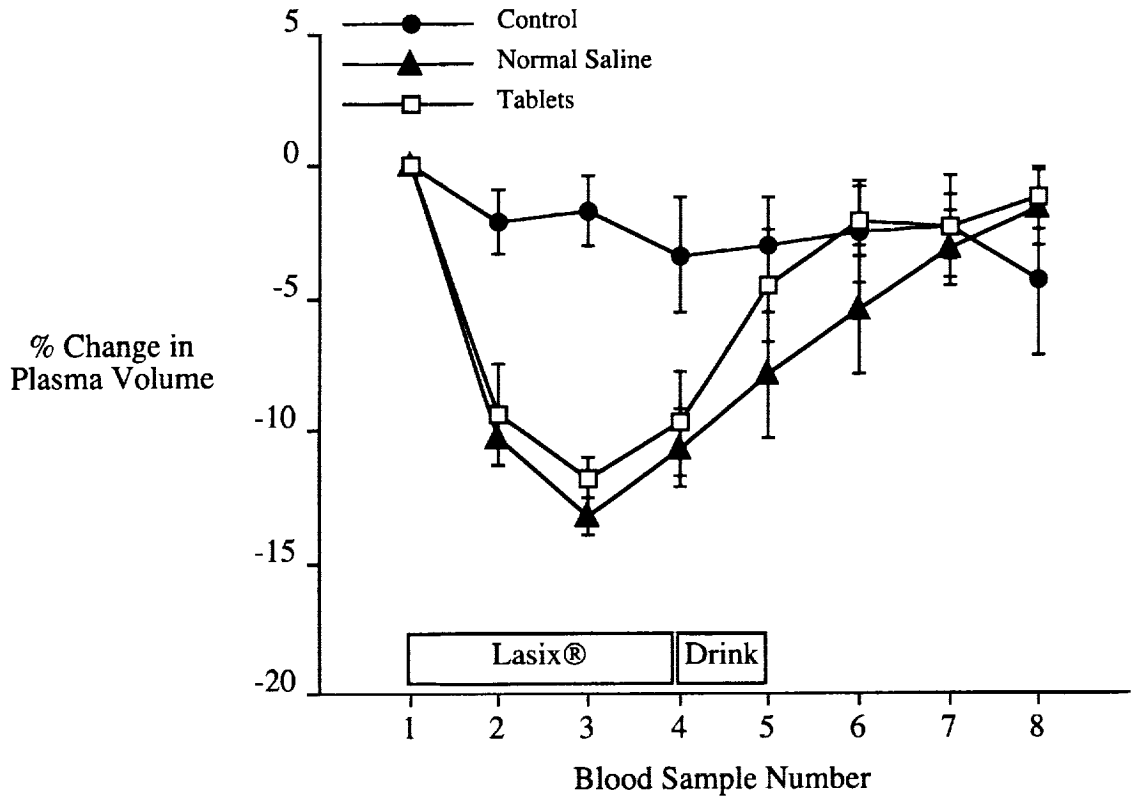


Figure 7. *Percent changes in plasma volume compared to baseline from a previous study comparing euhydrated subjects (n=6), subjects dehydrated with Lasix®, then rehydrated with an isotonic saline solution (n=6), and subjects dehydrated with Lasix®, then rehydrated with salt tablets with water (n=6). Sample 1 - baseline; sample 2 - 30 minutes after Lasix® administration; sample 3 - 1 hour after Lasix® administration; sample 4 - 2 hours after Lasix® administration, prerehydration; sample 5 - 1 hour after rehydration; sample 6 - 2 hours after rehydration; sample 7 - 3 hours after rehydration; and sample 8 - 4 hours after rehydration.*

Fluid Loading During a Shuttle Mission

When Shuttle crewmembers begin fluid loading, we suspect that in most cases, they are in a normally hydrated state with respect to their microgravity environment. After several days of spaceflight, crewmembers should have attained some degree of adaptation to microgravity and therefore fluid loading would represent an overhydration, stimulating the hormonal and renal responses to excrete the excess volume and salt. Some crewmembers, however, may be hypohydrated at the end of a mission due to over-exertion, decreased fluid intake due to multiple factors, e.g., less palatable water or food, or incomplete recovery from an earlier bout of space adaptation syndrome. Those crewmembers would have the most to gain from a fluid-loading countermeasure.

Another consideration is that, during a nominal Shuttle mission, during the two hours after fluid loading crewmembers are re-exposed to gravity: approximately 1.1 to 1.6 g during reentry (Appendix A) and one g after landing. In response to the hydrostatic forces, body fluids will redistribute to the lower body, promoting the hormonal and neural responses that act to retain

body fluids. We expect that a fluid-loading solution which proves effective in a hydrated individual may be even more effective during a Shuttle landing.

Fluid Loading and Orthostatic Tolerance after Short Exposures to Microgravity

The major purpose of the fluid-loading countermeasure is to improve orthostatic tolerance during and after landing. There are an abundance of studies [8, 9, 10, 11, 12] which have shown that acutely expanding plasma volume with an isotonic fluid after a short-term bed rest or space flight may improve orthostatic responses and that the mechanism is most likely due to expansion of plasma volume. Grigoriev [9] concluded that the effect from the salt tablet and water countermeasure is most likely due to a beneficial effect to increase circulating blood volume. On the other hand, Kakurin [12] commented that the beneficial effects seen during an LBNP challenge 8 to 10 hours after intake of fluid and salt could also be related to an effect of sodium chloride on vascular tone. Changes in extracellular sodium concentration have been shown to increase the sensitivities of both arterial and cardiopulmonary baroreceptor responses [1]. However, prolonged exposures to elevated levels of plasma sodium result in depressed carotid baroreflex function [3]. It is unlikely that a sodium or osmotic effect would have a major influence on orthostatic responses after drinking isotonic solutions similar to those tested in this study since they did not significantly alter plasma osmolality or sodium concentration.

Fluid Loading and Orthostatic Responses after Longer Space Flights

We have hypothesized that, after longer space flights, a fluid-loading countermeasure will become less effective [5]. This generalization is based on our findings from a 13-day bed rest study in which an LBNP/fluid-loading countermeasure restored plasma volume during bed rest, but did not improve LBNP responses [6]. Vernikos et al. reviewed similar observations of lack of correlation between changes in plasma volume and orthostatic responses during several bed rest studies [13]. Therefore, it is important to note that the present fluid-loading solutions are designed to restore plasma volume, which is only one of the mechanisms for postflight orthostatic intolerance. As flight duration increases, additional countermeasures will be required to restore baroreflex function, decrease venous compliance, maintain skeletal muscle mass and tone, etc.

CONCLUSIONS

1. Both salt tablets with water and Astro-ade improved maintenance of plasma volume approximately 2 to 3 hours after fluid ingestion, in contrast to the control group whose plasma volume declined by 6% during this same time interval. Both drinks appeared equally effective in maintaining plasma volume.

2. Side effects were reported in approximately one out of six subjects after both drinks. These results agree with our ground-based experiences and with Russian reports [9, 12] that a single salt tablet and water dose "turned out to be unpromising, since it elicited a number of unpleasant subjective sensations and dyspeptic phenomena."

3. For crewmembers who have an aversion toward or severe side effects from salt tablets with water, Astro-ade may offer an alternate countermeasure to restore plasma volume. However, this solution also provoked unpleasant sensations and further work is needed to identify more palatable drinks with fewer side effects. Alternative solutions may include

bouillon, isotonic salt/sugar solutions, salty foods and fluid supplements, multiple salt/fluid doses, and pharmacological aids such as Florinef or inhaled Antidiuretic Hormone.

4. Once a promising fluid-loading solution is identified (one that not only improves plasma volume but also has no side effects), further studies will be required to verify its effectiveness in improving orthostatic responses after varying periods of simulated weightlessness.

REFERENCES

[1] Andreson, M. C. and D. L. Kunze. Ionic sensitivity of baroreceptors. *Circulation Res.* 61:Suppl 1:I66-I71, 1987.

[2] Bungo, M. W., J. B. Charles, and P. C. Johnson. Cardiovascular deconditioning during space flight and the use of saline as a countermeasure to orthostatic intolerance. *Aviat. Space Environ. Med.* 56:985-990, 1985.

[3] Creager, M. A., M. A. Roddy, K. M. Holland, A. T. Hirsch, and V. J. Dzau. Sodium depresses arterial baroreceptor reflex function in normotensive humans. *Hypertension* 17:989-996, 1991.

[4] Dill, D. B. and D. L. Costill. Calculation of percentage changes in volumes of blood, plasma, and red blood cells in dehydration. *J. Appl. Physiol.* 37:247-248, 1974.

[5] Fortney, S. M. Development of lower body negative pressure as a countermeasure for orthostatic intolerance. *J. Clin. Pharmacol.* 31:888-892, 1991.

[6] Fortney, S. M., L. Dussack, T. Rehbein, M. Wood, and L. Steinmann. Effect of prolonged LBNP and saline ingestion on plasma volume and orthostatic responses during bed rest. In: Proceedings of the First Joint NASA Cardiopulmonary Workshop, *NASA Conference Publication 10068*, December 5-7, 1990, pgs. 61-70.

[7] Frey, M. A. B., J. Riddle, J. B. Charles, and M. W. Bungo. Blood and urine responses to ingesting fluids of various salt and glucose concentrations. *J. Clin. Pharmacol.* 31:880-887, 1991.

[8] Greenleaf, J. E., G. Geelen, C. G. R. Jackson, F-L. Saumet, L. T. Juhos, D. Egan-Meyer, A. Dearborn, H. Hingofer-Szalkay, and J. H. Whittam. Vascular uptake of rehydration fluids in hypohydrated men at rest and exercise. *NASA Technical Memo 103942*, August 1992.

[9] Grigoriev, A. I., B. S. Katkovskiy, A. A. Savilov, V. S. Georgiyevskiy, B. R. Dorokhova, and V. M. Mikhaylov. Effects of hyperhydration on human endurance of orthostatic and LBNP tests. *Kosm. Biol. Aviakosm Med.* 12:20-24, 1978.

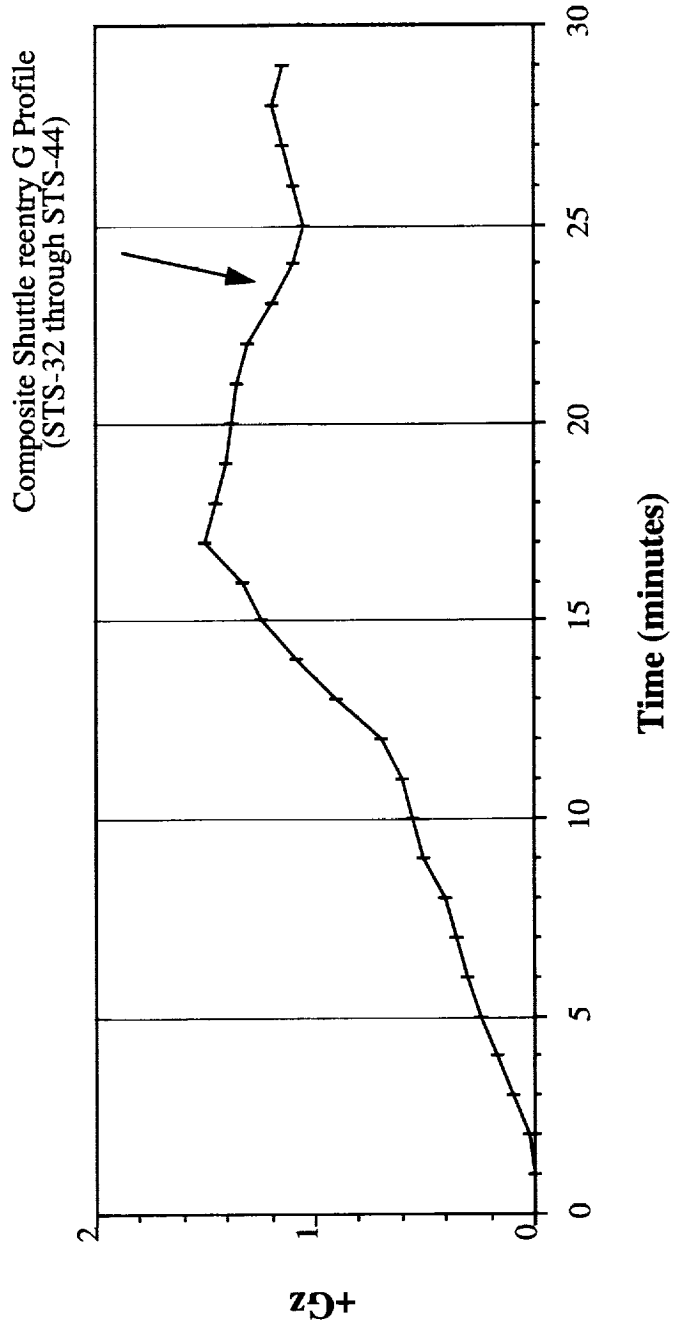
[10] Grigoriev, A. I., B. L. Lichardus, V. I. Lobachik, N. Mihailowsky, V. V. Zhidkov, and Yu V. Sukhanov. Regulation of man's hydration status during gravity-induced blood redistribution. *Physiologist* 226:S28-S29, 1983.

[11] Hyatt, K. H. and D. A. West. Reversal of bedrest-induced orthostatic intolerance by lower body negative pressure and saline. *Aviat. Space Environ. Med.* 48:120-124, 1977.

[12] Kakurin, L. I., B. S. Katkovskiy, V. A. Tishler, G. I. Kozyrevskaya, V. S. Shashkov, V. S. Georgiyevskiy, A. I. Grigoriev, V. M. Mikhaylov, O. D. Anashkin, G. V. Machinskiy, A. A. Savilov, and Ye P. Tikhomirov. Substantiation of a set of preventive measures referable to the objectives of missions in the Salyut orbital station. *Kosm. Biol. Aviakosm. Med.* 12:20-27, 1978.

[13] Vernikos, J., M. F. Dallman, G. Van Loon, and L. C. Keil. Drug effects on orthostatic intolerance induced by bedrest. *J. Clin. Pharmacol.* 31:974-984, 1991.

Appendix A. G Profile for Simulated Shuttle Reentry



Appendix B. Individual and Mean Blood Results

Trials	Hematocrits Time (hours) after start of fluid loading						Hemoglobin (g/dL) Time (hours) after start of fluid loading						Osmolality (mOsm/kg) Time (hours) after start of fluid loading					
	Baseline	1.0	1.5	2.5	3.5	4.5	Baseline	1.0	1.5	2.5	3.5	4.5	Baseline	1.0	1.5	2.5	3.5	4.5
Astro-ade																		
1	42.7	41.5	41.8	41	42.3	42.7	14.7	14.7	14.6	14.4	14.7	15	277	276	275	275	275	278
2	41.5	40.5	40.2	39.7	39.9	40.7	13.4	13.9	13.8	13.7	13.5	13.8	283	280	283	278	282	285
3	39.5	41.8	40.2	39.5	41.1	39.7	13.4	14.3	13.6	13.6	14.1	13.7	282	278	279	280	281	277
4	43.1	42.1	41.7	41.5	43	42	14.9	14.6	14.6	14.4	15.1	14.7	282	282	283	285	288	275
5	36.4	36.3	35	35.1	35.9	36.4	12.4	12.5	12	12.1	12.3	12.6	274	277	274	281	279	279
6	41.6	43.3	42.4	42.2	42.5	44	14.4	15	14.4	14.4	14.5	14.7	289	290	293	293	292	291
Mean	40.80	40.92	40.22	39.83	40.78	40.92	13.87	14.17	13.83	13.77	14.03	14.08	281.17	280.50	281.17	282.00	282.83	280.83
STDEV	2.49	2.44	2.71	2.54	2.64	2.68	0.96	0.90	0.99	0.90	1.01	0.90	5.19	5.13	6.94	6.32	6.18	6.01
SE	1.02	0.99	1.11	1.04	1.08	1.09	0.39	0.37	0.40	0.37	0.41	0.37	2.12	2.09	2.83	2.58	2.52	2.46
n	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Salt Tablets																		
1	43.1	43.5	43.5	42.7	42.1	41.8	15.2	15	15	14.5	14.7	14.7	272	276	277	276	283	281
2	40.4	42.3	41.5	40.6	41.1	40.3	14.1	14.6	14.4	14.1	14.3	14.4	287	291	287	294	293	291
3	35.2	36.4	35.8	36.3	36.2	36.8	12.1	12.4	12.3	12.3	12.4	12.7	284	285	285	288	289	287
7	44.7	44.1	44.8	43.3	45	44.3	15.4	15.2	15.1	14.8	15.1	15	287	288	291	293	290	291
5	39.8	40.3	41.2	40.2	39.9	40.6	13.8	13.7	13.9	13.8	13.5	13.5	284	286	280	282	283	283
8	35.6	36.1	35.8	34.5	35.2	35.1	11.9	12.3	12	11.7	11.9	11.9	283	283	287	287	289	286
Mean	39.80	40.45	40.43	39.60	39.92	39.82	13.75	13.87	13.78	13.53	13.65	13.70	282.83	284.83	284.50	286.67	287.83	286.50
STDEV	3.85	3.50	3.82	3.51	3.69	3.35	1.49	1.28	1.34	1.25	1.29	1.22	5.56	5.12	5.13	6.80	4.02	4.09
SE	1.57	1.43	1.56	1.43	1.51	1.37	0.61	0.52	0.55	0.51	0.53	0.50	2.27	2.09	2.09	2.78	1.64	1.67
n	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Controls																		
1	42.3	43.7	43.8	44	43.5	43.8	14.7	14.9	15.1	15	15	15.2	291	286	287	286	283	287
2	40.9	40.7	41.2	42.3	42.7	43.5	13.8	14.1	14	14.3	14.4	14.6	289	282	283	289	286	288
8	35.6	35.9	35.6	35.7	36.7	36	12.1	12.2	12.3	12.3	12.5	12.4	280	279	280	282	283	283
9	40.2	43.2	43.2	44	44.4	45.1	13.9	14.9	15	15	15.1	15.3	287	285	285	287	285	285
10	40.6	41.1	41.8	41.1	41.1	42.4	13.8	14	14.1	14.2	14.2	14.6	290	288	289	283	283	283
11	43	45.4	45.5	45.7	45.1	45.6	14.9	15.5	15.5	15.7	15.3	15.7	288	290	290	285	288	285
Mean	40.43	41.67	41.85	42.13	42.25	42.73	13.87	14.27	14.33	14.42	14.42	14.63	287.50	285.00	285.67	285.33	284.67	285.17
STDEV	2.60	3.31	3.42	3.53	3.05	3.49	0.99	1.16	1.16	1.17	1.03	1.17	3.94	4.00	3.78	2.58	2.07	2.04
SE	1.06	1.35	1.40	1.44	1.25	1.43	0.40	0.47	0.47	0.48	0.42	0.48	1.61	1.63	1.54	1.05	0.84	0.83
n	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

Appendix B. Individual and Mean Blood Results

Trials	Sodium (mEq/L) Time (hours) after start of fluid loading						Glucose (mg/dL) Time (hours) after start of fluid loading						% Change Plasma Volume Time (hours) after start of fluid loading					
	Baseline	1.0	1.5	2.5	3.5	4.5	Baseline	1.0	1.5	2.5	3.5	4.5	Baseline	1.0	1.5	2.5	3.5	4.5
Astro-ade																		
1	137	135	135	135	136	136	92	79	74	69	74	77	0.00	1.69	1.96	4.53	0.56	-2.00
2	144	142	143	144	143	143	66	75	73	82	83	89	0.00	-2.26	-1.15	0.25	1.46	-1.82
3	139	140	142	141	142	140	107	69	74	78	84	77	0.00	-9.20	-2.40	-1.47	-7.02	-2.45
4	139	142	141	142	142	142	101	75	81	84	88	89	0.00	3.50	4.08	5.82	-1.18	2.94
5	141	141	141	142	141	143	91	91	89	85	84	83	0.00	-0.67	5.21	4.20	1.47	-1.59
6	139	143	142	142	143	142	135	88	88	91	81	91	0.00	-6.27	-1.11	-0.83	-1.93	-5.30
Mean	139.83	140.50	140.67	141.00	141.17	141.00	98.67	79.50	79.83	81.50	82.33	84.33	0.00	-2.20	1.10	2.08	-1.11	-1.70
STDEV	2.40	2.88	2.88	3.10	2.64	2.68	22.65	8.43	7.31	7.45	4.68	6.28	0.00	4.81	3.12	3.13	3.21	2.65
SE	0.98	1.18	1.17	1.26	1.08	1.10	9.25	3.44	2.98	3.04	1.91	2.56	0.00	1.96	1.27	1.28	1.31	1.08
n	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Salt Tablets																		
1	139	139	141	141	140	139	88	79	80	79	85	88	0.00	0.76	0.76	5.42	4.87	5.31
2	141	142	143	142	142	141	115	78	84	87	90	92	0.00	-5.93	-3.55	-0.27	-2.34	-1.95
3	140	142	142	143	142	143	89	86	89	86	86	81	0.00	-3.91	-2.38	-3.01	-3.66	-6.67
7	144	143	145	142	141	143	83	100	88	81	83	78	0.00	2.20	1.84	6.17	1.54	3.26
5	143	146	142	138	137	139	91	86	59	75	83	75	0.00	0.05	-2.60	-0.54	2.08	1.11
8	138	138	140	140	140	139	79	91	78	87	87	87	0.00	-3.87	-1.09	3.14	0.51	0.64
Mean	140.83	141.67	142.17	141.00	140.33	140.67	90.83	86.67	79.67	82.50	85.67	83.50	0.00	-1.79	-1.17	1.82	0.50	0.28
STDEV	2.32	2.88	1.72	1.79	1.86	1.97	12.62	8.14	11.00	4.97	2.66	6.53	0.00	3.22	2.10	3.66	3.10	4.20
SE	0.95	1.17	0.70	0.73	0.76	0.80	5.15	3.32	4.49	2.03	1.09	2.67	0.00	1.31	0.86	1.49	1.27	1.72
n	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Controls																		
1	142	142	142	142	141	142	91	107	90	90	91	88	0.00	-3.28	-4.70	-4.34	-3.65	-5.32
2	141	139	140	140	141	141	142	111	105	105	106	105	0.00	-1.86	-1.84	-5.35	-6.54	-8.86
8	141	139	139	139	141	142	117	88	85	85	88	89	0.00	-1.20	-1.63	-1.75	-4.56	-2.92
9	141	143	143	145	143	143	135	64	66	79	73	82	0.00	-10.52	-11.12	-12.13	-13.21	-15.21
10	143	142	142	140	141	141	74	81	76	76	68	71	0.00	-2.10	-3.74	-3.48	-3.48	-7.81
11	144	143	144	143	143	142	102	89	97	97	94	95	0.00	-7.14	-7.27	-8.72	-5.51	-8.59
Mean	142.00	141.33	141.67	141.50	141.67	141.83	110.17	90.00	86.50	88.67	86.67	88.33	0.00	-4.35	-5.05	-5.96	-6.16	-8.12
STDEV	1.26	1.86	1.86	2.26	1.03	0.75	26.15	17.27	14.12	11.00	14.02	11.52	0.00	3.69	3.62	3.81	3.64	4.15
SE	0.52	0.76	0.76	0.92	0.42	0.31	10.68	7.05	5.77	4.49	5.73	4.70	0.00	1.51	1.48	1.55	1.49	1.69
n	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

Appendix C. Heart Rates and Blood Pressures

	Vitals Time (hours) after start of fluid loading						Systolic Blood Pressure Time (hours) after start of fluid loading						Diastolic Blood Pressure Time (hours) after start of fluid loading					
Heart Rate	Baseline	1.0	1.5	2.5	3.5	4.5	Baseline	1.0	1.5	2.5	3.5	4.5	Baseline	1.0	1.5	2.5	3.5	4.5
Astro-ade																		
1	40	48	52	48	48	44	114	108	107	104	110	109	76	82	80	78	68	78
2	92	84	84	92	80	80	126	116	112	111	115	122	76	64	71	66	66	72
3	58	60	58	60	64	64	118	130	120	120	115	112	70	75	75	68	80	78
4	64	60	54	54	50	48	120	110	110	112	112	112	84	76	72	70	68	60
5	52	46	44	40	44	46	120	124	136	124	120	120	68	74	74	76	74	70
6	72	70	68	62	58	66	122	132	126	128	128	118	78	74	76	80	76	76
Mean	63.00	61.33	60.00	59.33	57.33	58.00	120.00	120.00	118.50	116.50	116.67	115.50	75.33	74.17	74.67	73.00	72.00	72.33
STDEV	17.88	14.18	14.14	17.92	13.25	14.31	4.00	10.20	11.06	9.03	6.50	5.21	5.75	5.81	3.20	5.76	5.51	6.86
SE	7.30	5.79	5.77	7.32	5.41	5.84	1.63	4.16	4.51	3.69	2.65	2.13	2.35	2.37	1.31	2.35	2.25	2.80
n	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Salt Tablets																		
1	64	52	52	50	60	50	115	112	95	115	102	112	70	74	68	75	69	70
2	72	60	60	54	56	64	132	134	124	114	110	114	70	72	64	64	60	60
3	56	58	56	44	46	50	128	115	125	120	125	130	64	75	80	70	70	72
7	76	70	60	64	56	62	136	136	118	128	126	124	86	90	80	76	76	74
5	50	44	44	40	42	42	126	130	126	124	120	112	74	70	80	76	82	78
8	70	60	54	56	58	58	118	124	114	118	112	118	64	82	72	78	70	72
Mean	64.67	57.33	54.33	51.33	53.00	54.33	125.83	125.17	117.00	119.83	115.83	118.33	71.33	77.17	74.00	73.17	71.17	71.00
STDEV	10.01	8.73	5.99	8.64	7.24	8.43	8.06	9.97	11.73	5.38	9.43	7.31	8.16	7.49	7.04	5.23	7.39	6.03
SE	4.09	3.57	2.44	3.53	2.96	3.44	3.29	4.07	4.79	2.20	3.85	2.99	3.33	3.06	2.88	2.14	3.02	2.46
n	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Controls																		
1	56	48	50	52	56	50	102	104	110	98	114	114	64	62	70	78	78	72
2	62	58	56	72	64	56	102	104	108	120	106	108	62	64	72	84	72	68
8	65	60	60	60	52	60	132	128	122	112	120	122	60	60	70	60	80	76
9	80	70	65	65	58	70	128	122	118	122	132	122	80	80	80	78	86	78
10	76	72	64	64	72	64	112	116	120	120	110	112	78	80	76	74	70	76
11	68	52	52	52	52	58	112	102	106	110	120	116	62	74	78	72	78	80
Mean	67.83	60.00	57.83	60.83	59.00	59.67	114.67	112.67	114.00	113.67	117.00	115.67	67.67	70.00	74.33	74.33	77.33	75.00
STDEV	8.91	9.55	6.21	7.86	7.77	6.86	12.75	10.93	6.81	9.07	9.19	5.57	8.89	9.12	4.27	8.14	5.75	4.34
SE	3.64	3.90	2.54	3.21	3.17	2.80	5.21	4.46	2.78	3.70	3.75	2.28	3.63	3.72	1.74	3.32	2.35	1.77
n	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

Appendix C. Heart Rates and Blood Pressures

	Urine						Fluid Balance					
	Time (hours) after start of fluid loading											
Heart Rate	Baseline	1.0	1.5	2.5	3.5	4.5	Total Out (mL)	Total In (mL)	Diff. (mL)	Wt. Bsln (kg)	Wt. End (kg)	Wt. Diff. (kg)
Astro-ade												
1	0	200	0	0	390	0	590	988	398	65.91	65.91	0.00
2	0	470	0	0	0	420	890	1143	253	76.25	76.02	-0.23
3	0	300	200	300	200	270	1270	1537	267	102.95	102.73	-0.23
4	0	530	0	0	475	0	1005	1160	155	77.09	76.93	-0.16
5	0	275	280	0	0	0	555	1476	921	98.64	99.09	0.45
6	0	1025	0	500	0	100	1625	1377	-248	91.82	90.45	-1.36
Mean	0.00	466.67	80.00	133.33	177.50	131.67	989.17	1280.17	291.00	85.44	85.19	-0.25
STDEV	0.00	300.46	126.49	216.02	213.86	176.23	410.14	215.55	379.31	14.54	14.51	0.60
SE	0.00	122.66	51.64	88.19	87.31	71.95	167.44	88.00	154.85	5.94	5.92	0.25
n	6	6	6	6	6	6	6	6	6	6	6	6
Salt Tablets												
1	0	0	280	0	0	0	280	981	701	66.36	66.36	0.00
2	0	650	0	0	525	0	1175	1162	-13	77.39	76.82	-0.57
3	0	210	360	400	0	350	1320	1500	180	99.55	99.55	0.00
7	0	850	675	0	0	475	2000	1377	-623	91.59	90.91	-0.68
5	0	600	0	0	0	450	1050	1098	48	73.64	73.41	-0.23
8	0	650	440	220	0	260	1570	1282	-288	85.91	85.34	-0.57
Mean	0.00	493.33	292.50	103.33	87.50	255.83	1232.50	1233.33	0.83	82.41	82.06	-0.34
STDEV	0.00	319.79	262.25	169.90	214.33	212.38	575.24	190.37	446.62	12.25	12.19	0.30
SE	0.00	130.55	107.07	69.36	87.50	86.70	234.84	77.72	182.33	5.00	4.98	0.12
n	6	6	6	6	6	6	6	6	6	6	6	6
Controls												
1	0	0	0	0	0	0	0	0	0	66.36	66.36	0.00
2	0	375	0	475	0	0	850	0	-850	78.05	76.91	-1.14
8	0	870	0	540	0	330	1740	0	-1740	77.16	75.11	-2.05
9	0	100	0	100	0	100	300	0	-300	78.30	78.18	-0.11
10	0	975	250	100	0	420	1745	0	-1745	87.61	85.68	-1.93
11	0	175	0	220	90	80	565	0	-565	84.32	83.52	-0.80
Mean	0.00	415.83	41.67	239.17	15.00	155.00	866.67	0.00	-866.67	78.63	77.63	-1.00
STDEV	0.00	412.62	102.06	220.19	36.74	177.51	734.53	0.00	734.53	7.30	6.84	0.87
SE	0.00	168.45	41.67	89.89	15.00	72.47	299.87	0.00	299.87	2.98	2.79	0.36
n	6	6	6	6	6	6	6	6	6	6	6	6

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	Jan/93	Technical Paper

4. TITLE AND SUBTITLE
Fluid-Loading Solutions and Plasma Volume: Astro-Ade and Salt Tablets With Water

5. FUNDING NUMBERS

6. AUTHOR(S)
Suzanne M. Fortney, Laura Steinmann*, Joan A. Young*, Cherylynn N. Hoskin*, and Linda H. Barrows*

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Lyndon B. Johnson Space Center
Houston, Texas 77058

8. PERFORMING ORGANIZATION REPORT NUMBERS
S-756

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, D.C. 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
TP-3456

11. SUPPLEMENTARY NOTES
* KRUG Life Sciences, Houston, Texas

12a. DISTRIBUTION/AVAILABILITY STATEMENT
unclassified/unlimited
Available from the NASA Center for AeroSpace Information, 800 Elkridge Landing Road, Linthicum Heights, MD 21090; (301) 621-0390

Subject Category: 52

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Fluid loading with salt and water is a countermeasure used after spaceflight to restore body fluids. However, gastrointestinal side effects have been frequently reported in persons taking similar quantities of salt and water in ground-based studies. We compared the effectiveness of the Shuttle fluid-loading countermeasure (8 gms salt, 0.97 liters of water) to Astro-ade (an isotonic electrolyte solution), to maintain plasma volume (PV) during 4.5 hrs of resting fluid restriction. Three groups of healthy men (n=6) were studied: a Control Group (no drinking), an Astro-ade Group, and a Salt Tablet Group. Changes in PV after drinking were calculated from hematocrit and hemoglobin values. Both the Salt Tablet and Astro-ade Groups maintained PV at 2-3 hours after ingestion compared to the Control Group, which had a 6% decline. Side effects (thirst, stomach cramping, and diarrhea) were noted in at least one subject in both the Astro-ade and Salt Tablet Groups. Nausea and vomiting were reported in one subject in the Salt Tablet Group. We conclude that Astro-ade may be offered as an alternate fluid-loading countermeasure but further work is needed to develop a solution that is more palatable and has fewer side effects.

14. SUBJECT TERMS
body fluids, astronauts, sicknesses, electrolyte metabolism, plasma

15. NUMBER OF PAGES
25

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclassified	unclassified	unclassified	UL