

Electrolyte Replacement in Urban Search and Rescue Dogs: A Field Study

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■ ABSTRACT

Urban search and rescue (USAR) dogs provide an important service in search, patrol, and explosive detection in urban and natural disasters. These dogs are exposed to stressful and dangerous conditions that can lead to dehydration and electrolyte imbalances. Oral electrolyte and carbohydrate supplementation decreases electrolyte disturbances and improves endurance in other animal species. A field study was performed to determine the effect of oral electrolyte supplementation on performance and electrolyte balance of USAR dogs performing moderate-intensity work. Nine Pennsylvania Task Force 1 USAR dogs were randomly assigned to water or electrolyte replacement solution (Electramine[®], Vitae Inc., Breckenridge, CO) on two separate training days, one in winter and one in summer. There was no clinically significant or repeatable improvement in plasma electrolyte composition or performance in electrolyte-supplemented dogs. Although other electrolyte formulations must be tested to determine potential benefits, the overall benefits of electrolyte supplementation do not seem to outweigh the expense and burden of including these replacement fluids in USAR gear.

■ INTRODUCTION

Disaster medicine is a relatively new field of veterinary medicine. The US government has canine teams associated with the 27 Federal Emergency Management Association (FEMA) urban search and rescue (USAR) teams. The federal government initiates deployment of USAR teams, which are required to be mobilized within 6 hours of notification. These teams are subject to strict requirements, including rapid mobilization and self-sufficiency for 10 days, and are limited to carrying only essential gear.

Search and rescue teams locate, extricate, and provide initial medical treatment for victims of structural collapse. Dogs are a valuable asset to disaster teams and are used for explosive detection and search and patrol work in urban and natural disasters. These animals are expected to work in a variety of adverse environmental and physical conditions.

Electrolyte disturbances have been reported in human, equine, and canine athletes.¹⁻⁶ Dehydration and electrolyte imbalances are theoretic risks to USAR dogs exposed to a variety of adverse working conditions. Oral electrolyte supplementation has proven beneficial in other species.^{1,7-9}

The primary objective of the study presented here was to determine whether electrolyte- and carbohydrate-supplemented fluids are beneficial to USAR dogs during moderate work. Because of the diverse weather conditions these dogs may experience, the study was performed once in the winter and once in the summer.

■ MATERIALS AND METHODS

Demographics

The study was a blinded placebo-controlled randomized field trial that was limited by the availability of dogs. Thus dogs were used in both test groups as necessary. The winter study included nine trained, large-breed dogs from the Pennsylvania Task Force 1 USAR Team (three Labrador retrievers, two German shepherds, one Belgian Malinois, one golden retriever, and two mixed-breed dogs), ranging in age from 11 months to 9 years. Three animals were spayed and three castrated, and there was one intact male and two intact females. Five dogs were assigned to electrolyte replacement and four to water.

The summer study included seven of the nine dogs that participated in the winter study (three Labrador retrievers, one German shepherd, one golden retriever, and two mixed-breed dogs), ranging in age from 18 months to 8 years. Neither of the intact females from the winter group was available for the summer study. Four dogs were assigned to electrolyte replacement and three to water.

The climate and exercise (C/E) control group consisted of 11 large-breed dogs from private owners (3 Labrador retrievers, 3 German shepherds, 2 Rhodesian ridgebacks, 1 German shorthair pointer, 1 Australian cattle dog, and 1 mixed breed), ranging in age from 1 to 10 years. Six dogs were castrated and 4 spayed, and there was 1 intact male. Data were collected on 7 dogs receiving water and 8 receiving electrolyte solution. Four of the dogs

were crossed over and data were collected from them, on separate days, for both water and electrolyte solution.

Study Conditions

Winter testing took place in Philadelphia, PA on January 24, 1998. The high temperature was 10°C (50°F) and the low temperature 1.7°C (35.1°F). The average wind speed was 11.3 mph with strong gusts. The day was overcast, with humidity ranging from 69% to 100% and 0.12 inches of rainfall (National Climatic Data Center). The study included 8 hours of canine-component training, including a rubble pile search (locating a victim buried in approximately 22,000 square feet of broken concrete), obedience training (climbing ladders, directional commands, crossing wire, walking across boards balanced on a barrel), and searching an empty four-story building. Investigators and handlers were blinded.

Summer testing took place in Harrisburg, PA, on August 1, 1998. The high temperature was 28.3°C (82.9°F) and the low temperature 13.3°C (55.9°F). The average wind speed was 5.8 mph. The day was sunny and clear with no precipitation, with humidity ranging from 30% to 84% (National Climatic Data Center). The study included 8 hours of full-team training at an imploded 12-story building site (more stressful conditions and less controlled than in the winter study). Exercise included directed search and obedience training. The dog handlers were blinded, but the investigators were not.

Climate and exercise control testing took place at the Veterinary Hospital of the University of Pennsylvania. The dogs were maintained for 8 hours in indoor runs kept at approximately 22.2°C (72.1°F). The investigators were blinded.

Study Design

Dogs were randomly assigned to receive ei-

ther an electrolyte amino acid solution (Electramine®, Vitae Inc., Breckenridge, CO) or water colored to resemble the electrolyte solution. Individual packets of electrolyte powder were reconstituted with 480 ml of water and a small amount of food coloring to maintain blinding. The electrolyte solution contained dextrose, salt, glycine, dipotassium phosphate, citric acid, ascorbic acid, yeast extract, and potassium citrate. The company's analysis reported 9% crude protein, 65% dextrose, 14.2% sodium chloride, and 2.1% potassium. The wholesale cost of the solution was \$1.40 per packet. No other liquid or food was provided during the study period.

Samples

Data were obtained at the beginning, middle (for winter and C/E controls only), and end of the study. Temperature, pulse, respiration, weight, and fluid consumption were recorded and blood samples drawn for all dogs. An upright scale was used in winter, a portable analog scale in summer, and a fixed digital scale for C/E controls. For the summer training, the method of measurement was changed from a weight-based measurement to a volumetric measurement and handlers were given individual gallon jugs rather than designated water bowls. Blood samples were drawn from the cephalic vein and placed in heparinized vacutainer tubes on ice. Sodium, potassium, chloride, glucose, and lactate were analyzed on an automated blood gas and electrolyte analyzer (Nova Stat 9, NOVA Biomedical, Waltham, MA). Packed cell volume and total solids were measured from microhematocrit tubes. Because of the distance between the field exercise and the analyzer, winter samples were analyzed within 2 hours, summer samples were analyzed once approximately 15 hours after initial and 7 hours after final sample collection, and C/E group control samples were analyzed immediately. At the completion of the training exercis-

es, handlers were asked to evaluate their dog's performance as poor, average, or good.

Data Analysis

To determine differences between electrolyte and water treatment among the three groups, a two-way analysis of variance (ANOVA) on the change scores (final–initial) of the various biochemical and physical parameters was performed. To evaluate the three collection times for winter and C/E control groups, differences between electrolyte and water treatment were determined by two-way ANOVA in repeated measures. Four of the 11 dogs in the C/E control group were crossed over and had data collected on separate days for both electrolyte supplementation and water. Due to repetition (crossover) of some of the same dogs in the three groups, the degrees of freedom were reduced appropriately for the various hypothesis tests that were made. Significance was set at $P = .05$. All analyses were performed using statistical analysis system software.

■ RESULTS

Physical Parameters

There were no statistically significant effects of electrolyte supplementation on physical parameters in any of the groups (Tables 1 to 3). The windy field conditions made accurate weight assessment with an upright scale difficult; thus a portable analog scale was used for the summer training.

Biochemical Parameters

Winter Group

Compared with baseline, electrolyte-supplemented dogs tested in winter had statistically significant decreases in sodium (151 ± 2.7 to 147 ± 1.1 mEq/L) and total solids (7.5 ± 0.6 to 7.0 ± 0.6 g/dl) and an increase in chloride (106 ± 7.6 to 112 ± 0.9 mEq/L) at the end of the exercise (Table 1).

TABLE 1. Effects of Electrolyte Supplementation in the Winter Group*

<i>Physical Parameters</i>	<i>Water Only (n = 4)</i>			<i>Electrolyte Supplementation (n = 5)</i>		
	<i>Before Exercise</i>	<i>During Exercise</i>	<i>After Exercise</i>	<i>Before Exercise</i>	<i>During Exercise</i>	<i>After Exercise</i>
Body weight (kg)	26.8 ± 3.2	28.2 ± 4.1	28.9 ± 5.5	31.7 ± 3.6	31.2 ± 3.5	31 ± 3.5
Temperature (°C)	39.2 ± 0.2	39.1 ± 0.4	39.1 ± 0.2	39.0 ± 0.3	39.1 ± 0.4	38.9 ± 0.3
Temperature (°F)	102.5 ± 0.4	102.6 ± 0.8	102.3 ± 0.3	102.2 ± 0.6	102.3 ± 0.8	102.0 ± 0.5
Heart rate (bpm)	98 ± 13	126 ± 27	98 ± 17	116 ± 29	114 ± 20	90 ± 19
Respiratory rate [†] (breaths/min)	2 panting 38 ± 2	1 panting 34 ± 9	39 ± 4	4 panting 30	4 panting 30	3 panting 45 ± 30
<i>Biochemical Parameters</i>						
Packed cell volume (%)	46 ± 6.6	46 ± 1.9	44 ± 0.8	40 ± 8.4	46 ± 9	43 ± 6.5
Total solids (g/dl)	6.8 ± 0.4	6.3 ± 0.2	6.3 ± 0.3	7.5 ± 0.6 [‡]	7.4 ± 0.5	7.0 ± 0.6 [‡]
Sodium (mEq/L)	147 ± 3	149 ± 2	149 ± 1	151 ± 2.7 [‡]	148 ± 1	147 ± 1.1 [‡]
Potassium (mEq/L)	4.5 ± 0.2	4.6 ± 0.1	4.5 ± 0.1	4.8 ± 0.6	4.5 ± 0.2	4.5 ± 0.1
Chloride (mEq/L)	110 ± 1.5	113 ± 1.2	113 ± 1.0	106 ± 7.6 [‡]	112 ± 1.9	112 ± 0.9 [‡]
Lactate (mmol/L)	1.3 ± 0.4	1.0 ± 0.3	1.2 ± 0.1	1.9 ± .05	1.3 ± 0.3	1.3 ± 0.6
Dextrose (mg/dl)	100 ± 3	98 ± 18	103 ± 3	91 ± 17	93 ± 15	92 ± 7

*All values are mean ± SD.

[†]No SD given if <2 dogs had countable rates.

[‡]Significantly different based on two-way analysis of variance ($P < .05$).

Summer Group

The only statistically significant difference between the water and electrolyte groups for the dogs tested in the summer was an increase in glucose in the electrolyte group (67 ± 8 to 86 ± 11 mg/dl; Table 2). Evaluations of changes over time in the water group could not be determined because of sample handling and insufficient blood for complete analysis.

Climate and Exercise Control Group

There were no significant biochemical changes in the C/E control group (Table 3).

Fluid Consumption and Performance Evaluation

All dogs in the water-only winter exercise group were rated as good. Only two of the five

dogs in the supplemented group were rated as good, and three were rated as average. The handlers in the summer exercise group did not feel that participation in the study affected their dog's performance in any way. Never was there a significant difference between volumes of water or electrolyte consumption (Table 4). Based on the average consumption of the electrolyte solution, the wholesale cost of electrolyte supplementation is \$5.12 per 8-hour day per dog.

Difficulty in measuring the exact volumes consumed contributed to the excessive standard deviation and the relatively high volumes reportedly consumed by the winter group. In addition, two dogs refused to drink the electrolyte solution and one dog in the water group (although the handler was convinced it was in the

TABLE 2. Effects of Electrolyte Supplementation in the Summer Group*

<i>Physical Parameters</i>	<i>Water Only (n = 3)</i>		<i>Electrolyte Supplementation (n = 4)</i>	
	<i>Before Exercise</i>	<i>After Exercise</i>	<i>Before Exercise</i>	<i>After Exercise</i>
Body weight (kg)	29.7 ± 0.7	31.1 ± 2.5	27.6 ± 4.0	28.8 ± 4.7
Temperature (°C)	39.2 ± 0.3	39.1 ± 0.6	38.9 ± 0.5	39.3 ± 0.6
Temperature (°F)	102.6 ± 0.6	102.3 ± 1.0	101.9 ± 0.9	102.8 ± 1.0
Heart rate (bpm)	115 ± 15	115 ± 5	111 ± 32	112 ± 36
Respiratory rate [†] (breaths/min)	2 panting 54	1 panting 71 ± 41	2 panting 35 ± 7	1 panting 42 ± 21
<i>Biochemical Parameters</i>				
Packed cell volume (%)	53 ± 2.9 ^{‡§}	51 ± 4.0 ^{**}	50 ± 8.2 [§]	53 ± 2.6 ^{**}
Total solids (g/dl)	7.9 ± 0.6 ^{‡§}	7.4 ± 0.4 ^{**}	7.4 ± 0.4 [§]	7.4 ± 0.4 ^{**}
Sodium (mEq/L)	148 ^{‡§}	146 ± 2.3 ^{**}	147 ± 2.0 [§]	147 ± 1.0 ^{**}
Potassium (mEq/L)	4.8 ^{‡§}	4.5 ± 0.1 ^{**}	4.7 ± 0.2 [§]	4.5 ± 0.2 ^{**}
Chloride (mEq/L)	111 ^{‡§}	113 ± 1.5 ^{**}	111 ± 0.6 [§]	113 ± 1.7 ^{**}
Lactate (mmol/L)	6.4 ^{‡§}	4.3 ± 0.9 ^{**}	5.6 ± 0.8 [§]	3.3 ± 0.7 ^{**}
Dextrose (mg/dl)	57 ^{‡§}	70 ± 13 ^{**}	67 ± 8 ^{‡‡}	86 ± 11 ^{**‡‡}

*All values are mean ± SD.

[†]No SD given if <2 dogs had countable rates.

[‡]Only one sample was available.

[§]Approximately 15-hour delay until assay.

^{**}Approximately 5-hour delay until assay.

^{‡‡}Significantly different based on two-way analysis of variance ($P < .05$).

electrolyte group) was removed from the study after drinking excessively and vomiting.

■ DISCUSSION

Dehydration is a risk to USAR dogs. Subtle changes in osmolarity are usually sufficient to trigger thirst and subsequent rehydration through ingestion of water. In such stressful situations as high-intensity USAR missions, dogs may not be interested in drinking. There are no studies to determine whether USAR dogs develop dehydration or electrolyte imbalances during training exercises or deployments. The use of oral electrolyte and carbohydrate supplementation in USAR dogs was investigated in this field trial based on previous studies that have shown such supplements to be beneficial to athletes of other species.^{1,7-9}

Despite the finding of statistically significant changes from baseline in sodium, chloride, and total solids in the electrolyte-supplemented dogs in the winter group, all values remained within normal reference ranges. The low initial values and increase in glucose at the end of the summer exercise were attributed to the delay in analysis resulting in increased glucose consumption¹⁰ in the earlier samples.

Most studies evaluating electrolyte and carbohydrate changes in exercise have been performed with high-endurance athletes (e.g., sled dogs, horses, humans) or sprinters (e.g., greyhounds).^{1-7,11} Humans and horses experience large losses of sodium and potassium in sweat during exercise.¹¹⁻¹³ Canine athletes do not dissipate significant amounts of heat through sweat but rely on evaporative cooling via the

TABLE 3. Effects of Electrolyte Supplementation in the Climate and Exercise Control Group*

<i>Physical Parameters</i>	<i>Water Only (n = 7)</i>			<i>Electrolyte Supplementation (n = 8)</i>		
	<i>Prestudy</i>	<i>Midstudy</i>	<i>Poststudy</i>	<i>Prestudy</i>	<i>Midstudy</i>	<i>Poststudy</i>
Body weight (kg)	36.9 ± 8.6	37.1 ± 8.8	37.2 ± 8.8	37.4 ± 7.5	37.6 ± 7.5	37.4 ± 7.6
Temperature (°C)	38.9 ± 0.3	38.8 ± 0.3	38.4 ± 0.2	38.4 ± 0.9	38.6 ± 0.2	38.6 ± 0.2
Temperature (°F)	102.0 ± 0.6	101.8 ± 0.6	101.2 ± 0.3	102.1 ± 0.9	101.4 ± 0.3	101.5 ± 0.3
Heart rate (bpm)	97 ± 25	98 ± 14	97 ± 13	97 ± 15	94 ± 18	94 ± 16
Respiratory rate [†] (breaths/min)	1 panting 34 ± 11	3 panting 49 ± 48	3 panting 24 ± 9	All panting	4 panting 27 ± 6	6 panting 39 ± 4
<i>Biochemical Parameters</i>						
Packed cell volume (%)	50 ± 2.3	51 ± 4.2	49 ± 3.5	48 ± 3.7	48 ± 3.5	46 ± 4.5
Total solids (g/dl)	6.7 ± 0.3	6.8 ± 0.2	6.8 ± 0.2	6.8 ± 0.3	6.6 ± 0.3	6.7 ± 0.3
Sodium (mEq/L)	147 ± 1.2	146 ± 0.9	148 ± 4.4	149 ± 1.4	148 ± 2.3	148 ± 1.4
Potassium (mEq/L)	4.6 ± 0.2	4.4 ± 0.2	4.5 ± 0.3	4.4 ± 0.2	4.6 ± 0.2	4.5 ± 0.2
Chloride (mEq/L)	110 ± 1.8	109 ± 2.0	106 ± 6.4	112 ± 2.0	113 ± 1.8	113 ± 2.2
Lactate (mmol/L)	2.0 ± 0.6	1.9 ± 0.5	1.9 ± 0.5	1.4 ± 1.2	1.0 ± 1.0	1.7 ± 0.6
Dextrose (mg/dl)	98 ± 16.4	97 ± 9.2	95 ± 10.0	98 ± 6.6	97 ± 9.5	96 ± 8.7

*All values are mean ± SD.

[†]No SD given if <2 dogs had countable rates.**TABLE 4. Fluid Consumption among Test Groups***

<i>Study Group</i>	<i>Water Only (ml/kg)</i>	<i>Electrolyte Supplementation (ml/kg)</i>
Winter	51.3 ± 42.2	29.6 ± 31.2
Summer	29.6 ± 12.6	28.0 ± 8.4
Climate and exercise control	23.3 ± 6.2	23.2 ± 6.5

*All values are mean ± SD.

respiratory tract.¹⁴ Electrolyte losses through panting are minimal in dogs. As a result, it is uncommon for dogs to develop clinically significant exercise-induced electrolyte changes. In extreme conditions, however, canine endurance athletes may develop electrolyte changes due to increased urinary losses.⁶ In addition, Labrador retrievers are reported to have statistically significant increases in sodium, potassium, and chloride immediately after 10 minutes of continuous retrieving drills.¹⁵ Similar to our study

(despite statistical significance), the Labradors' electrolyte values remained within the normal reference range.

Even with minimal physiologic evidence to support the use of replacement electrolyte solutions in working dogs, supplementation may be recommended to increase palatability and fluid consumption. The addition of Eelectramine® to fluids did not result in increased fluid consumption in this study, and two dogs actually refused to drink the solution during

the winter exercises.

Labrador retrievers reportedly have an increased incidence of exercise intolerance during field trial work.¹⁶ None of the dogs in this study had any history of exercise intolerance, nor did they become exhausted, dehydrated, or show any clinical signs of electrolyte changes. They did, however, experience injuries and illnesses similar to those experienced by dogs at the Oklahoma City bombing site.¹⁷ Dogs at the summer training site incurred footpad injuries from hot tar and gravel. One dog cut its leg during the winter exercises and required sutures.

■ CONCLUSION

The moderate-intensity work performed by these conditioned USAR dogs revealed no clinically relevant electrolyte abnormalities. Also, no appreciable or repeatable benefit of Electramine[®] supplementation was noted by handlers or following analysis of electrolyte composition of the blood. However, the small number of dogs enrolled in this study limits our ability to confidently demonstrate subtle differences with electrolyte supplementation. It is also possible that other electrolyte supplement formulations may prove beneficial, but further research is needed. The crossover of several dogs from winter to summer also limited the statistical interpretation of the study. Due to the sampling times and the field nature of this study, acute biochemical or physiologic changes associated with brief intense work may have been missed. As has been clearly demonstrated by Hinchcliff and coworkers,⁴⁻⁶ in their extensive studies of exercise physiology in sled dogs, however, it is clear that field studies are critical to identifying how the working environment influences physiologic response. Therefore, despite the limitations of this field study, the conditions were realistic and the results applicable.

In addition, practical issues must be consid-

ered in recommending oral electrolyte and carbohydrate supplementation. The manufacturer recommends providing 100 to 200 ml/kg/day. The average daily wholesale cost for a 30-kg dog is between \$8.75 and \$17.50 per day. During an 8-hour period, the average cost for dogs in this study was \$5.70. The manufacturer also recommends that unused portions be refrigerated and discarded after 24 hours. Palatability, shelf life, expense, weight, and space limitations are legitimate concerns. Thus, in addition to the lack of physiologic or performance benefits, the cost and handling of electrolyte solutions further detract from their routine use.

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■ REFERENCES

1. Francis KT, MacGregor R: Effect of exercise in the heat on plasma renin and aldosterone with either water or a potassium-rich solution. *Aviat Space Environ Med* 49:461-465, 1978.
2. Cohen ND, Roussel AJ, Lumsden JH, et al: Alterations of fluid and electrolyte balance in Thoroughbred racehorses following strenuous exercise during training. *Can J Vet Res* 57:9-13, 1993.
3. McCutcheon LJ, Geor RJ: Sweat fluid and ion losses in horses during training and competition in cool vs. hot ambient conditions: Implications for ion supplementation. *Equine Vet J* 22:54-62, 1996.
4. Hinchcliff KW, Reinhart GA, Burr JR, et al: Effect of racing on serum sodium and potassium concentrations and acid-base status of Alaskan sled dogs. *JAVMA* 210:1615-1618, 1997.
5. Hinchcliff KW, Reinhart GA: Effect of racing on water metabolism, serum sodium and potassium concentrations, renal hormones, and urine composition of

- Alaskan sled dogs. In: Reinhart GA, Carey DP, eds. *Recent Advances in Canine and Feline Nutrition*. Wilmington, Ohio: Orange Frazer Press; 1998:283–294.
6. Hinchliff KW, Reinhardt GA, Burr JR, et al: Exercise-associated hyponatremia in Alaskan sled dogs: Urinary and hormonal responses. *J Appl Physiol* 83:824–829, 1997.
 7. Nicholas CW, Williams C, Lakomy HK, et al: Influence of ingesting a carbohydrate-electrolyte solution on endurance capacity during intermittent, high intensity shuttle running. *J Sports Sci* 13:283–290, 1995.
 8. Marlin DJ, Scott CM, Mills PC, et al: Rehydration following exercise: Effects of administration of water versus an isotonic oral rehydration solution (ORS). *Vet J* 156:41–49, 1998.
 9. Schott HC, Hinchliff KW: Treatments affecting fluid and electrolyte status during exercise. *Vet Clin North Am Equine Pract* 14:175–204, 1998.
 10. Thoresen SI, Havre GN, Morberg H, et al: Effects of storage time on chemistry results from canine whole blood, heparinized whole blood, serum and heparinized plasma. *Vet Clin Pathol* 21:88–94, 1993.
 11. Toll PW, Gaegtgens P, Neuhaus D, et al: Fluid, electrolyte, and packed cell volume shifts in racing Greyhounds. *Am J Vet Res* 56:227–232, 1995.
 12. Shirreffs SM, Maughan RJ: Whole body sweat collection in humans: An improved method with preliminary data on electrolyte content. *J Appl Physiol* 82:336–341, 1997.
 13. McCutcheon LJ, Geor RJ: Sweating: Fluid and ion losses and replacement. *Vet Clin North Am Equine Pract* 14:75–95, 1998.
 14. Blatt CM, Taylor CR, Habal MB: Thermal panting in dogs: The lateral nasal gland, a source of water for evaporative cooling. *Science* 177:804–805, 1972.
 15. Matwichuk CL, Taylor SM, Shmon CL, et al: Changes in rectal temperature and hematologic, biochemical, blood gas, and acid-base values in healthy Labrador retrievers before and after strenuous exercise. *Am J Vet Res* 60:88–92, 1999.
 16. Shelton GD: Exercise intolerance in dogs. *Proc ACVIM Forum* 11:888–891, 1993.
 17. Duhaime RA, Norden D, Corso D, et al: Injuries and illnesses in working dogs used during the disaster response after the bombing in Oklahoma City. *JAVMA* 212:1202–1207, 1998.