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Physiologic Responses in Healthy Labrador Retrievers during Field Trial Training and Competition

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Ten healthy Labrador Retrievers (4 females and 6 males aged 3–6.5 years [mean, 4.5 years]) training with a professional trainer were studied. The dogs were in training during the entire study. Dogs were monitored within 5 minutes after retrieving birds on land and in water on 2 consecutive days during training and on 2 consecutive days at the Atlanta Retriever Club Fall Field Trial. Baseline samples were taken in the morning on a separate day before the dogs were loaded onto a truck. Venous samples were analyzed with a portable blood analyzer. Measurements included hematocrit, sodium, potassium, chloride, blood urea nitrogen (BUN), glucose, lactate, blood pH, P_{CO_2}, P_{O_2}, HCO_3, and TCO_2 plus rectal temperature, pulse rate, and respiratory rate. Ambient temperatures were recorded. Distances and times were estimated. Compared to baseline, significant increases occurred in rectal temperature, pulse rate, respiratory rate, chloride, lactate, and pH postexercise ($P < .05$); sodium, potassium, BUN, P_{CO_2}, and TCO_2 were significantly decreased postexercise. Blood pH was markedly higher after retrieves on land than after retrieves in water. Estimated mean speeds were 11.4 mph (18.3 km/h) during a triple retrieve on land and 5.6 mph (9.0 km/h) during a retrieve in water. Maximal ambient temperatures were 84–86°F (29–30°C). In summary, Labrador Retrievers training with a professional trainer had evidence of hyperthermia, respiratory alkalosis, hypocapnia, and mild metabolic acidosis monitored within 5 minutes postexercise during training and field trial competition when maximal ambient temperatures were 85°F (29°C). The results provide a baseline against which physiologic responses of dogs with poor performance can be compared.

Key words: Dog; Exercise; Hyperthermia; Hypocapnia; Metabolic acidosis; Portable blood analyzer; Respiratory alkalosis.

Matwichuk et al[1] described the physiologic responses of healthy field trial Labrador Retrievers after a 10-minute retrieving drill. This drill provides a standardized exercise protocol. To our knowledge, no additional data have been published on retrievers during training or competition. Field trial retrievers need to be studied in the same way as sledding dogs[2–6] and other canine athletes in order to understand the specific physiologic changes these dogs experience. The information also may serve as a reference for the evaluation of dogs with poor performance or exercise-induced collapse.

Monitoring onsite is facilitated by a commercially available battery-operated blood analyzer that requires 1-mL blood samples. Various cartridges provide an array of CBC and biochemical assays, and results are available within minutes.

In this study, we monitored the physiologic responses of a group of healthy black Labrador Retrievers in training with a professional trainer (CL). The dogs were monitored after completing land and water retrieves during training and at the Atlanta Retriever Club Fall Field Trial in 2002.

Materials and Methods

Dogs

The sample was composed of 10 black Labrador Retrievers (4 intact females and 6 intact males aged 3–6.5 years; mean age, 4.5 years). All dogs were competitive field trial dogs in training with a professional trainer (CL). Dogs were considered healthy on the basis of their history, the opinion of the trainer, and a brief physical examination. Diet was a commercial dog food formulated for performance dogs.[a] Dogs were training and competing during the entire study. Dogs trained a minimum of 4 days per week. Typical training consisted of retrieves on land in the morning and retrieves in water in the afternoon. On weeks when the dogs were entered in field trials, they sometimes ran 7 days per week. Four of the dogs ran in the National Open Retriever Championship later the same year.

Measurements

The study was approved by the Tuskegee University Animal Care and Use Committee. For baseline values, 10 dogs were sampled. The dogs were evaluated on 2 consecutive days during training in May and on 2 consecutive days at the field trial in September. During training and field trials, 6–8 of the dogs were sampled, depending on which of the dogs were training and competing on those specific dates.

Rectal temperature, pulse rate, respiratory rate, and blood samples were taken within 5 minutes postexercise, as soon as the dog was returned to the truck. Blood was collected from the cephalic vein into a heparinized 1-mL tuberculin syringe[b] for immediate analysis with an i-Stat portable analyzer by means of CG4+ and 6+ cartridges.[c] Because the ambient temperature on each day approached 86°F (30°C, the high end of the operating range of the i-Stat unit), this equipment was operated in an air-conditioned vehicle or put on an ice pack, as recommended by the supplier.

Times were recorded on digital stopwatches. Distances were measured as the straight-line distance from the line (the location at the starting point from which the dog is sent to retrieve) to the location of the bird. Distances were estimated by the trainer and verified by a range finder.[d]

Locations

Baseline measurements were taken in the yard at the kennel on a morning before the dogs were loaded onto the truck. The training sessions occurred on 2 consecutive days in north Georgia. Day 1 training (Table 1) consisted of a triple retrieve in water (100, 110, and 210 yd [91, 100, and 192 m]). On day 2, training consisted of a 400-yd (366 m) land blind retrieve in the morning, a triple land retrieve (75, 125, and 200 yd [69, 114, and 183 m]) at midday, and a 250-yd (229 m) water blind in late afternoon. Physiologic monitoring was per-

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Table 1. Speeds and distances measured during training sessions and retriever field trial competition.

	Distance, yd (m)[a]	Mean Outrun Speed, mph (km/h)	Mean Return Speed, mph (km/h)	Mean Time per Retrieve	Total Distance[b]/ Mean Total Time
Training Day 1: Inline Triple Retrieve in Water (n = 6). Average Ambient Temperature: 74°F (23°C)					
1st retrieve (short bird)	100 (91)	3.0 (4.8)	2.6 (4.1)	2 minutes 32 seconds	840 yd (768 m)/
2nd retrieve (middle bird)	110 (100)	5.8 (9.4)	2.9 (4.7)	2 minutes 21 seconds	9 minutes 38 seconds
3rd retrieve (long bird)	210 (192)	3.1 (5.0)	3.4 (5.4)	4 minutes 44 seconds	
Training Day 2: Single Land Blind Retrieve[c] (n = 2). Average Ambient Temperature: 77°F (25°C)					
	400 (366)	9.7 (15.6)	18.0 (29)	—	800 yd (732 m)/ 2 minutes 27 seconds
Training Day 2: Triple Retrieve on Land (n = 6)					
1st retrieve (short bird)	75 (69)	7.9 (12.8)	9.3 (15.0)	43 seconds	800 yd (732 m)/
2nd retrieve (middle bird)	125 (114)	7.7 (12.4)	9.5 (15.2)	1 minute 30 seconds	4 minutes 34 seconds
3rd retrieve (long bird)	200 (183)	12.4 (19.9)	10.5 (16.8)	1 minute 8 seconds	
Field Trial Day 1: Triple Retrieve on Land with Retired Gun (n = 9). Average Ambient Temperature: 79°F (26°C)					
1st retrieve (long bird)	284 (260)	Mean overall speed (start to finish of test): 11.4 mph (18.4 km/h)			1,168 yd (1,068 m)/
2nd retrieve (middle bird)	260 (238)				3 minutes 32 seconds
3rd retrieve (short flier)	40 (37)				
Field Trial Day 2: Combined Water and Land Retrieves (n = 8). Average Ambient Temperature: 79°F (26°C)					
		Mean overall speed (start to finish of test): 5.6 mph (9.1 km/h)			
1st retrieve (water)	158 (144)				920 yd (841 m)/
2nd retrieve (land)	302 (276)				5 minutes 45 seconds

[a] Refers to the straight-line distance from the line to the location of the bird. The "line" is the location at the starting point from which the dog is sent to retrieve.

[b] Total distance is calculated as the straight-line distance from the line to the bird × 2.

[c] Blind: the dog is sent to retrieve a bird that it did not see fall. The dog is expected to take hand, voice, and whistle signals to direct it to the bird.

formed for the triple land retrieve. During training, all dogs wore an electronic training collar. For some dogs, the collar was activated one or more times by the trainer as needed.

The Atlanta Retriever Club Fall Field Trial also was located in north Georgia. Dogs were monitored on 2 consecutive days. The triple retrieve on the 1st day was considered mildly to moderately strenuous, with relatively steep uphill terrain for both the long and middle bird; the total straight-line distance (from the line to the bird and return) was estimated at 1,168 yd (1,068 m) (Table 1). On the following day, dogs ran a 158-yd (144 m) water retrieve that was immediately followed by a 302-yd (276 m) land retrieve. Dogs retrieved ducks that weighed approximately 2.5–4 lb (1.14–1.8 kg).

Weather Conditions

The daily maximal and average ambient temperatures, wind speed, and humidity were recorded from weather reports published for the local area.

Statistical Analysis

The data were analyzed by the General Linear Models procedure of SAS[7,e] with baseline, training, and field trials (treatments) as the main effects and dogs as blocks. Baseline physiologic responses of the dogs were measured only once. These baseline observations served as the control and were compared with the measurements taken after training sessions and field trial competition. Significantly different main effects (treatments) for various physiologic responses were further classified by the all-pairs Tukey-Kramer honest significance difference test.[8]

Results

Weather conditions were similar on the days of data collection. Maximal temperatures on the 4 days ranged from 84 to 86°F (29–30°C). Minimal temperatures ranged from 63 to 72°F (17–22°C). Average temperatures ranged from 74 to 79°F (23–26°C). Average wind speeds ranged from 3.6 to 8.3 mph (5.8–13.4 km/h). Humidity (midday and range) for the 4 days was 69% (range, 55–100%), 54% (range, 51–88%), 83% (range, 62–100%), and 89% (range, 66–100%).

For baseline values, most dogs had blood values and body temperatures within the reference ranges (Table 2). However, some dogs were excited and panting; the highest individual pH value was 7.42, and the highest rectal temperature was 103°F (39.5°C).

Table 1 includes estimations of distances, times, and speeds for retrieves on land and in water during training and at the field trial.

The physiologic measurements taken within 5 minutes postexercise are presented in Table 2. These data provide evidence of hyperthermia, respiratory alkalosis, hypocapnia, and mild metabolic acidosis. Rectal temperature, pulse rate, respiratory rate, chloride, lactate, and pH of the dogs during training and field trials were significantly higher ($P < .05$) than the baseline measurements. Blood pH after retrieves on land was significantly higher ($P < .05$) than after retrieves in water. The measurements of sodium, potassium, blood urea nitrogen (BUN), P_{CO_2}, and TCO_2 of the dogs during training and field trials were significantly lower ($P < .05$) than the baseline measurements.

Discussion

In this study, baseline values were obtained in the morning before the dogs were loaded onto the truck for transport

Table 2. Physiologic values (mean ± SEM, range) for healthy adult Labrador Retrievers measured with a portable blood analyzer within 5 minutes postexercise during training and field trial competition.[a]

Variable	Resting Baseline (N = 10)	Training Day 1: Inline Triple Retrieve in Water (N = 6)	Training Day 2: Triple Retrieve on Land (N = 6)	Field Trial Day 1: Triple Retrieve on Land (N = 9)	Field Trial Day 2: Combined Water and Land Retrieves (N = 8)	Reference Range[b]
Rectal temperature	101.9 ± 0.3°F	105.2 ± 0.4°F A	105.0 ± 0.4°F A	105.5 ± 0.4°F A	103.5 ± 0.4°F A,B	
	38.8 ± 0.2°C	40.7 ± 0.2°C	40.6 ± 0.2°C	40.8 ± 0.2°C	39.7 ± 0.2°C	
	(100.8–103.3°F)	(104.0–108.0°F)	(104.0–106.0°F)	(103.8–106.8°F)	(101.8–106.0°F)	
	(38.2–39.6°C)	(40.0–42.2°C)	(40.0–41.1°C)	(39.9–41.6°C)	(38.8–41.1°C)	
Pulse rate (beats/min)	103 ± 8	136 ± 10	143 ± 10 A	127 ± 10	119 ± 9	
	(60–150)	(114–156)	(120–174)	(112–168)	(72–180)	
Respiratory rate (breaths/min)	106 ± 19	156 ± 25	181 ± 27	252 ± 23 A	158 ± 22	
	(36–198)	(72–300)	(150–240)	(168–300)	(36–258)	
Biochemistry/CBC						
Sodium (mmol/L)	145 ± 0.5	143 ± 0.6 A	142 ± 0.7 A	143 ± 0.5 A	145 ± 0.6	142–150
	(143–148)	(140–146)	(141–143)	(140–145)	(143–146)	
Potassium (mmol/L)	4.1 ± 0.1	3.5 ± 0.1 A	3.8 ± 0.2	4.0 ± 0.1	3.9 ± 0.1	3.4–4.9
	(3.7–4.6)	(2.6–4.1)	(3.4–4.3)	(3.7–4.4)	(3.5–4.2)	
Chloride (mmol/L)	117 ± 1	122 ± 1 A	120 ± 1.1	121 ± 1 A	118 ± 1 C	106–127
	(115–120)	(118–129)	(116–122)	(119–123)	(116–121)	
Blood urea nitrogen (mg/dL)	19 ± 1	14 ± 1 A	14 ± 1 A	18 ± 1	18 ± 1 C,D	10–26
	(14–24)	(12–18)	(11–18)	(15–24)	(13–23)	
Glucose (mg/dL)	94 ± 5	98 ± 7	99 ± 7	110 ± 5	103 ± 5	60–115
	(85–101)	(76–125)	(79–132)	(92–128)	(82–132)	
Lactate (mmol/L)	0.90 ± 0.32	3.15 ± 0.46 A	3.75 ± 0.46 A	2.26 ± 0.42	2.18 ± 0.42	0.6–2.9
	(0.46–1.64)	(2.08–5.01)	(2.82–6.31)	(0.95–3.12)	(0.76–3.99)	
Hematocrit (%)	44 ± 3	41 ± 1	42 ± 3	42 ± 4	44 ± 4	35–50
	(39–49)	(39–42)	(38–46)	(35–47)	(39–51)	
Venous blood gas /acid base						
pH	7.382 ± 0.020	7.413 ± 0.028	7.539 ± 0.028 A,C	7.556 ± 0.023 A,C	7.398 ± 0.025 B,D	7.35–7.45
	(7.283–7.492)	(7.389–7.456)	(7.388–7.625)	(7.483–7.686)	(7.358–7.451)	
P_{CO_2} (mm Hg)	32.6 ± 2.0	25.3 ± 2.8	18.2 ± 2.8 A	16.7 ± 2.4 A	29.0 ± 2.6 B,D	35–38
	(25.2–42.0)	(14.8–32.7)	(11.3–34.4)	(12.9–20.6)	(22.0–36.3)	
P_{O_2} (mm Hg)	36 ± 4	49 ± 5	39 ± 5	46 ± 4	48 ± 5	
	(27–59)	(42–53)	(30–50)	(27–65)	(31–63)	
HCO_3 (mmol/L)	19 ± 1	16 ± 1	15 ± 1	15 ± 1	18 ± 1	
	(15–22)	(10–21)	(10–21)	(13–17)	(14–21)	
TCO_2 (mmol/L)	20 ± 1	17 ± 1	15 ± 1	15 ± 1 A	19 ± 1	17–25
	(16–23)	(11–22)	(10–22)	(13–17)	(15–22)	

[a] Comparisons within the same row are designated by letters A through D, $P < .05$. A, significantly different from baseline; B, significantly different from field trial day 1; C, significantly different from training day 1; D, significantly different from training day 2.

[b] Heska Corp (Fort Collins, CO) i-Stat portable clinical analyzer reference ranges. The reference values represent universally accepted ranges of normal, with the exception of potassium and hematocrit. Because of differences in methodology for the portable blood analyzer, i-Stat–specific reference ranges have been derived for potassium and hematocrit.

to the training field. The baseline values probably reflect an anticipatory response in some of the dogs, accounting for values above normal reference ranges in rectal temperature, pulse rate, and respiratory rate. An alternative approach would have been to record baseline measurements in the kennel on a day when the dogs were not training or when the dogs were in a home environment.

The results of this study confirm many of the trends reported by Matwichuk et al[1] for Labrador Retrievers performing a retrieving drill. In that study, 14 healthy Labrador Retrievers exercised for 10 minutes by retrieving a dummy thrown 40–50 yd (37–46 m) on land, with rest periods of less than 5 seconds between retrieves. In both studies, mean lactate increased 3-fold immediately after exercise. Mean glucose rose 11% in the retrieving drill compared to 17% in this study. The highest pH in the dogs in the drill was 7.680 compared to 7.686 for a dog completing a triple retrieve on land in this study. Rectal temperature increased up to 5.4°F (3°C) in the drill compared to mean increases of 3°F (1.7°C) after land retrieves in this study.

Both in this study and the retrieving drill,[1] the dogs developed concurrent respiratory alkalosis and metabolic acidosis. These changes are considered reflective of hyperventilation and strenuous anaerobic activity.[1] Dogs respond to exercise with hyperventilation (panting).[9] Hyperventilation may be caused by increased body temperature, increased oxygen demand, excitement, metabolic acidosis, stimulation of the brainstem respiratory centers, or some combination of these factors.[1,10,11] In an experiment that used healthy human subjects, passive increases in core tem-

perature induced rapid, shallow breathing, suggesting that increased core temperature stimulates the central respiratory pacemaker.[12] Hyperventilation leads to decreased P_{CO_2} (hypocapnia). The decrease in P_{CO_2} increases blood pH by increasing the ratio of bicarbonate HCO_3^- to P_{CO_2}.

The possibility exists that increased body temperature and respiratory alkalosis in field trial retrievers are associated with poor performance or exercise-induced collapse. Research on respiratory alkalosis has documented alterations in electrolyte balances, shifting of the oxyhemoglobin dissociation curve, and alterations in cerebral and cardiac blood flow. However, much of the research has been performed on anesthetized dogs with hypocapnia induced by mechanical hyperventilation. Those findings may not be entirely applicable to spontaneous hyperventilation in dogs during strenuous exercise.

Acute respiratory alkalosis is associated with minor alterations in electrolyte concentrations.[10] Concentrations of sodium, potassium, and phosphate are reduced because of increased cellular uptake, and there is a reduction in ionized calcium because the fraction of protein-bound calcium is increased.[10] Serum chloride concentration usually is normal or slightly increased.[11] We measured sodium, potassium, and chloride concentrations and found trends consistent with respiratory alkalosis (decreased sodium and potassium concentrations and increased chloride concentration). Although these electrolyte alterations were small, the changes were statistically significant on several days during training and field trial competition. It remains to be determined if these dogs experience alterations in calcium ion concentrations. In one study in which acute respiratory alkalosis was induced in humans by voluntary hyperventilation, plasma potassium initially increased (+0.3 mmol/L) and was followed by a hypokalemic overshoot during recovery.[13] In the drill reported by Matwichuk et al,[1] postexercise increases were reported for serum potassium (4.6–5.0 mmol/L) and sodium (152–154 mmol/L) concentrations. Magnesium is another electrolyte that has been reported to show reduced serum concentrations during strenuous exercise and heat stress.[14]

Changes in body temperature and blood pH shift the oxyhemoglobin dissociation curve. A rise in temperature decreases the affinity of O_2 for hemoglobin (shifting the oxyhemoglobin dissociation curve to the right), thereby increasing the release of oxygen to the tissues. In contrast, an increase in pH shifts the oxyhemoglobin dissociation curve to the left.[15,16] For example, with oxygen tension held constant at 40 mm Hg, the percentage of hemoglobin saturation rose from 78% at pH 7.4 to 83% at pH 7.6.[16]

Acute hypocapnia can cause cerebral vasoconstriction.[10,17] In dogs, hypocapnia (P_{aCO_2}, 20 mm Hg) reduced cerebral blood flow from a mean of 75 to 48 mL per 100 g/min.[18] Hyperventilation and respiratory alkalosis may trigger seizure foci in predisposed dogs.[19] Hypocapnia also affects perfusion of the spinal cord. Hypocapnia to the degree that was encountered in the dogs of this study (20 mm Hg) reduced blood flow in the cervical and thoracic spinal cord segments by 89 and 82%, respectively.[20] In addition, changes in the pH of cerebrospinal fluid occur during respiratory alkalosis.[19] Respiratory alkalosis and high concentrations of catecholamines both are conducive to coronary vasospasm.[14] Studies of dogs during acute hypocapnia have described reductions in both cerebral blood flow and myocardial blood flow,[21] but not all studies have found reduced myocardial blood flow.[22–24]

The retrieving drill has been compared to dogs exercised on a treadmill for similar durations.[1] However, the speed and gradient of the treadmill and the $\dot{V}O_{2max}$ of the individual dogs are additional factors to consider. Calculations based on data for the retrieving drill[1] indicate those dogs were running at speeds of 12–15 mph (19–24 km/h) for 10 minutes. In our study, the Labrador Retrievers may have been running at speeds greater than 10 mph (16 km/h) for retrieves on land (Table 1). Our calculations underestimate the speed, because we used the straight-line distance from the line to the bird, measured with a rangefinder, whereas the dogs traveled more circuitous paths from the line to the bird, often on hilly terrain.

Reference values for specific exercises need to be established before poor performance or exercise intolerance can be evaluated. Responses vary with the duration and intensity of the exercise.[1] Responses also may differ for retrieves on land compared to those in water. In this study, respiratory alkalosis was not as severe when the dogs retrieved in water. Also, their estimated speeds were lower in water than on land. With the drive these dogs possess, many of them appear to sprint with maximal effort for the land marks.

The dogs of this study were fed the same commercial diet the entire season. Although hypoglycemia has been suspected as a cause of collapse in bird dogs, blood glucose concentrations for the dogs of this study were not significantly decreased after exercise. The lowest blood glucose of an individual dog postexercise was 76 mg/dL. The cause of the statistically significant differences in BUN is unknown. Serum creatinine concentrations were not measured. One explanation is that the lower concentrations for BUN reflect the time of day that the blood samples were drawn. Dogs were fed once per day, in late afternoon. The baseline samples were taken in the morning (approximately 12 hours after feeding), whereas the postexercise samples were drawn at midday (approximately 18 hours after feeding).

Weather conditions were similar on the 4 days that these dogs were monitored. Maximal temperatures varied by 2°F (1.2°C), and average temperatures varied by 5°F (2.8°C). The impact of ambient temperature and humidity on exercising dogs is not clearly established. Ambient temperature did not have a marked effect on rectal temperatures recorded immediately after exercise in the retrievers of one study.[1]

The portable blood analyzer used in this study has been used primarily for monitoring patients in critical care units. However, a portable analyzer also can serve to evaluate sporting dogs in the field. This technology avoids the necessity of storing and transporting blood samples. Cartridges are available to analyze many of the components of interest in performance dogs, including blood gases, electrolytes, glucose, and lactate.

In conclusion, this study suggests that healthy Labrador Retrievers training under a professional trainer experience hyperthermia, respiratory alkalosis, and mild metabolic acidosis, along with small but statistically significant changes in electrolyte concentrations, during training and field trial

competition when maximal ambient temperatures are around 85°F (29°C). The effects on performance of these physiologic changes remain to be determined. This evaluation of dogs in the field provides additional reference data pertinent to the examination of Labrador Retrievers exhibiting exercise intolerance or poor performance. Future goals are to evaluate Labrador Retrievers running longer distances and to monitor dogs that are not as well conditioned.

Footnotes

[a] Eukanuba Large Breed Premium Performance, Iams Corp, Dayton, OH
[b] Monoject, 1-mL tuberculin syringes with detachable 25 × 5/8-in. needle, Sherwood Medical, St Louis, MO
[c] i-Stat portable blood analyzer, Heska Corp, Fort Collins, CO (information regarding quality control procedures for this analyzer can be found at www.istat.com/products/docs/qc.pdf)
[d] Nikon Laser 800 Rangefinder, Nikon Corp, Melville, NY
[e] General Linear Models procedure, SAS Institute Inc, Cary, NC

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