Effect of mild restriction of food intake on the speed of racing Greyhounds

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Objective—To determine whether mild restriction of food intake affects clinicopathologic variables, body composition, and performance of dogs undertaking intense sprint exercise.

Animals—9 trained healthy adult Greyhounds.

Procedure—Dogs were offered food free choice once daily for 9 weeks until body weight and food intake stabilized. Dogs were then randomly assigned to be fed either 85% or 100% of this quantity of food in a crossover study (duration of each diet treatment period, 9 weeks). Dogs raced a distance of 500 m twice weekly. Clinicopathologic variables were assessed before and 5 minutes after racing; food intake, weight, body composition, body condition score, and race times were compared at the end of each diet period.

Results—Compared with values associated with unrestricted access to food, there were significant decreases in mean body weight (by 6%) and median body condition score (from 3.75 to 3.5 on a 9-point scale) and the mean speed of the dogs was significantly faster (by 0.7 km/h) when food intake was restricted. Body composition and most clinicopathologic variables were unaffected by diet treatment, but dogs given restricted access to food had slightly fewer neutrophils, compared with values determined when food intake was unrestricted.

Conclusions and Clinical Relevance—Results indicate that the common practice among Greyhound trainers of mildly restricting food intake of racing dogs to reduce body weight does improve sprint performance. A body condition score of approximately 3.5 on a 9-point scale is normal for a trained Greyhound in racing condition. (*Am J Vet Res* 2005;66:1065–1070)

The ideal body condition for optimum athletic performance in dogs is unknown. Many Greyhound trainers mildly restrict food intake because they believe that dogs run faster when they are leaner, but there appear to be no published studies to support this practice. Our laboratory group recently reported the results of 2 experiments[1,2] that indicated that diet composition affects sprint performance in trained healthy Greyhounds. In crossover design experiments, Greyhounds were raced repetitively over a distance of 500 m, which provided an effective method to determine the factors that affect performance. However, it was noted that the dogs used for those experiments were lean when they were donated by their trainers and gained 1 to 2 kg (approx 5% of body weight) when fed commercial dry dog food free choice. Dogs did not become obese, and their body condition score after body weight stabilized remained slightly below what is considered optimal for other breeds. This finding confirmed that Greyhound trainers generally restrict the amount of food fed to racing dogs.

Sprinting involves short-duration supramaximal exercise. Greyhounds sprint at approximately 60 km/h for 17 to 60 seconds over a distance of 300 to 900 m, whereas sled dogs undertake long-distance submaximal endurance exercise, running at approximately 7 km/h for many kilometers over many hours while pulling heavy loads. The few studies[3-6] that have examined the effect of body condition on performance in dogs have all been performed with breeds other than Greyhounds undertaking endurance exercise. Brzezinska et al[3] reported a negative correlation between time to exhaustion and body weight in mongrel dogs running at 4 to 6 km/h on a 21% slope. Young[4] varied the incline of the treadmill to maintain a constant work load and found that the endurance of Beagles running at 6 km/h doubled when the dogs lost weight after 5 days without food. In another study,[5] Young also determined that energy expenditure at rest and during exercise did not change during gradual weight gain, and Constable et al[6] reported that body weight and body conformation were not associated with whether dogs finished the Iditarod Trail Race.

Among human athletes, gradual weight reduction through calorie restriction does not appear to greatly affect performance, maximal oxygen consumption, strength, or endurance, provided enough carbohydrate, protein, and essential nutrients are included in the diet to maintain glycogen stores and muscle mass.[7-9] Among American football players, body fat was lower among

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running backs than linemen but there was no relationship between the amount of body fat and sprint performance when individuals accelerated to 32 km/h over a distance of 45 m.[10] Gradual weight reduction also did not affect 30-m sprint performance among wrestlers.[11] However, there is some evidence that fat mass may act as a dead weight in human endurance athletes because long-distance runners perform better when fat mass is restricted.[12] We are unaware of any study that has examined the relationships among food restriction, body condition, and sprint performance in dogs. Therefore, the purpose of the study reported here was to determine whether mild restriction of food intake affects clinicopathologic variables, body composition, and performance of trained healthy racing Greyhounds undertaking intense sprint exercise.

Materials and Methods

Dogs—Nine trained Greyhounds (4 females and 5 males) were donated by Greyhound breeding kennels for use in this study; the mean ± SD weight of the dogs was 28.1 ± 3.5 kg, and their age range was 2 to 5 years. All dogs were sexually intact, and testosterone[a] (1 mg/kg) was administered IM every 2 weeks to female dogs to prevent estrus (testosterone is widely used to prevent estrus in female racing Greyhounds in training). Dogs were determined to be clinically healthy and were cared for as described previously.[1,2] Dogs were cared for according to the principles outlined in the National Institutes of Health Guide for the Care and Use of Laboratory Animals.[13] The study was approved by the University of Florida Institutional Animal Care and Use Committee.

Experimental design—All dogs were fed a commercial dry dog food[b] once daily after their morning exercise. During a 9-week acclimatization period, each dog was offered approximately 100 g of food in excess of its estimated **metabolizable energy (ME)** requirement (155 kcal ME/kg of $BW^{0.75}$ daily, where BW represents body weight)[1] and allowed to eat for 30 to 40 minutes. Excess food was removed once each dog had voluntarily stopped eating. The amounts of food offered and any residual food were weighed to determine food intake. Each dog was weighed after urination but immediately before exercise each week throughout the study. Dogs gained weight initially during the acclimatization period, but body weight and food intake stabilized after 4 to 6 weeks. Mean daily food intake for each dog during the last 2 weeks of the acclimatization period was assessed to be the quantity of food necessary for that dog to maintain its weight when fed free choice; 85% of this amount was fed each day during the food restriction period. Dogs were randomly assigned to 1 of 2 groups; group 1 included 5 dogs, and group 2 included 4 dogs. Dogs in group 1 were fed free choice during weeks 1 to 9, but food intake was restricted during weeks 10 to 18. Dogs in group 2 were fed restricted amounts of food during weeks 1 to 9 but were fed free choice during weeks 10 to 18. Representative samples of food and all feces produced by the dogs over 4 days during weeks 8 and 17 were collected and stored at –20°C. Nutrient composition, apparent digestibility, and ME of the food samples were measured as previously described.[1] The masses of crude protein, fat, ash, insoluble fiber, and moisture were subtracted from total mass of food to obtain the mass of **nitrogen-free extract (NFE)** in the food. This NFE provided a measure of the carbohydrate content of the diet.

Dogs were raced in pairs (when there was an odd number of dogs, 1 race involved 3 dogs) for a distance of 500 m on a 400-m oval sand and clay track with 10° banking on the corners. During racing, dogs chased a mechanical lure maintained 10 to 20 m in front of the lead dog. Dogs were randomly assigned to race and starting position. During each 9-week treatment period, dogs were rested for the first week, raced once during the second week, and raced twice weekly for each of the remaining 7 weeks.

Race times were measured with the aid of a photo finish camera[c] during the final 5 weeks of each diet period. The ambient temperature when dogs were raced varied from 0° to 19.4°C. During week 9 of each diet period, rectal body temperature was measured and venous blood samples were obtained from each dog in the kennel before racing and at the track 5 minutes after racing. Body condition score was assessed and body composition measured on the following day. Clinicopathologic measurements were performed on each blood sample, as described previously.[1] Body condition score was assessed independently by 2 assessors (RCH and DAS) who were unaware which dogs were assigned to which treatment, using a 9-point scale in which dogs with a score of 1 are extremely underweight and dogs with a score of 9 are extremely overweight.[14] For most breeds, dogs with a score of 5 would be regarded as normal. Lean body mass was estimated from total body water measured by deuterium dilution, as previously described.[2] The mean of measurements from venous blood samples obtained 2, 4, and 6 hours after deuterium infusion was used to estimate total body water.

Statistical analyses—Statistical analyses were performed by use of a standard software package.[d] For each animal, body condition scores from the 2 assessors were averaged to obtain a mean score. The median and range of the mean scores are reported. Mean scores were compared between dietary treatments by use of the Wilcoxon rank sum test.[15] Other results are presented as mean values ± SD. Average daily food intake (weight of food as fed) and average daily ME intake relative to metabolic body weight (kg $BW^{0.75}$) were calculated for each week of the study and then averaged for weeks 5 through 9 of each treatment period. Data regarding race times and body weight were compared from weeks 5 through 9 of each treatment period. Race times were not obtained for all dogs on every race day because of technical problems with the camera. Race times were only compared for race days when times were obtained for all 9 dogs.

A normal probability plot of the data was inspected visually, and the Shapiro-Wilk test was performed to assess whether data were normally distributed. Variables that appeared not to be normally distributed at all time points or had evidence of unequal variances were logarithmically transformed prior to analysis. Data were analyzed as a 2-period crossover design with a within-period repeated-measures factor, using generalized least squares estimation.[16] Measurements over time within each period (body weight and race times) and measurements before and after racing were treated as repeated measures. An autoregressive covariance structure was used to explicitly model the correlation between measurements obtained at these time points. Moreover, a random effect for each subject was included. We included diet, period, and sequence as factors and also tested for diet-by-time interaction. If sequence effects were found, then differences were tested involving data from the first period only. This is essentially the method of analysis suggested by Hills and Armitage.[17]

A probability of type I error of ≤ 0.05 was considered significant. Assuming at least 8 dogs completed the study, the study had a probability of type II error of ≤ 0.2 to detect a difference in body weight of 2 kg; in race time of 0.5 seconds; in total body water of 5%; in the number of RBCs of $0.6 \times 10^6/\mu L$; in the number of WBCs, neutrophils, and lymphocytes of 1,000/µL; in the number of monocytes and lymphocytes of 300/µL; in venous blood pH of 0.03; in the venous PCO_2 and PO_2 of 8 mm Hg; in the plasma concentration of lactate of 5 mmol/L; in serum concentration of bilirubin of 0.1 mg/dL; in serum concentration of protein, albumin, globulin, or creatinine of 0.3 mg/dL; in serum concentration of potassium, calcium, or phosphorus of 1 mEq/L; in serum concentration of

Table 1—Nutrient composition and metabolizable energy (ME) content of the diet (as fed) provided to 9 trained healthy adult Greyhounds undertaking intense sprint exercise given unrestricted or restricted access to food in a crossover study (9-week diet treatment periods).

Nutrient	Amount	Nutrient	Amount
Protein (%)	27.8 (28% ME)	Magnesium (g/kg)	1.1
Fat (%)	15.6 (38% ME)	Iron (mg/kg)	261
Linoleic acid (%)	2.66	Copper (mg/kg)	14
Linolenic acid (%)	0.11	Zinc (mg/kg)	220
Arachidonic acid (%)	0.05	Manganese (mg/kg)	17
Eicosapentanoic acid (%)	0.003	Selenium (mg/kg)	0.3
Docosohexenoic acid (%)	0.008	Iodine (mg/kg)	1.8
n3:n6 fatty acid ratio	1:16	Vitamin A (U/g)	12.9
Nitrogen-free extract (%)	33.6 (34% ME)	Vitamin E (U/kg)	93
Ash (%)	9.1	Vitamin D_3 (U/kg)	860
Crude fiber (%)	1.2	Vitamin B_1 (mg/kg)	2.2
Total dietary fiber (%)	6.5	Vitamin B_2 (mg/kg)	5.0
Insoluble fiber (%)	5.9	Vitamin B_3 (mg/kg)	37
Moisture (%)	8.0	Vitamin B_6 (mg/kg)	1.5
ME density (kcal/g)	3.68	Vitamin B_{12} (mg/kg)	0.1
Calcium (g/kg)	19.8	Pantothenic acid (mg/kg)	17
Phosphorus (g/kg)	13.5	Folic acid (mg/kg)	0.9
Sodium (g/kg)	5.8	Choline chloride (mg/kg)	1.3
Potassium (g/kg)	5.9	Biotin (g/kg)	0.1

Table 2—Race time, body weight, and body composition of 9 trained healthy adult Greyhounds undertaking intense sprint exercise given unrestricted or restricted access to food in a crossover study (9-week diet treatment periods).

Variable	Restricted food intake	Unrestricted food intake
Race time (s)*	32.14 ± 0.37	32.57 ± 0.49
Mean speed (km/h)*	56.00 ± 0.64	55.27 ± 0.82
Weight (kg)*	28.2 ± 3.0	29.9 ± 3.6
Total body water (%)	73 ± 2	71 ± 4
Lean body mass (%)	100 ± 2	98 ± 5
Lean body mass (kg)*	28.1 ± 3.3	29.0 ± 2.9
Fat mass (%)	0 ± 2	2 ± 5
Fat mass (kg)*	0.0 ± 0.7	0.8 ± 1.4

Values are given as means ± SD.
*Value significantly ($P < 0.05$) different between diet treatments.

sodium, chloride, or bicarbonate of 2 mEq/L; in BUN concentration of 2 mg/dL; in serum concentrations of glucose and triglycerides of 20 mg/dL; in serum concentration of cholesterol of 10 mg/dL; in serum activities of alanine aminotransferase, aspartate aminotransferase, and alkaline phosphatase of 10 U/L; a difference in serum activity of creatine kinase of 300 U/L; in Hct of 3%; or a difference in hemoglobin of 1 mg/dL.

Results

The food contained 28% ME as crude protein, 38% ME as fat, and 34% ME as NFE, and the essential nutrient composition conformed to American Association of Feed Control Officials recommendations for adult dogs (**Table 1**).[18] The apparent digestibilities of the major nutrients were high and unaffected by dietary restriction: crude protein, fat, and NFE digestibilities were 83 ± 3%, 95 ± 1%, and 91 ± 1%, respectively. Dogs receiving unrestricted food intake consumed 544 ± 78 g/d or 157 ± 17 kcal/kg $BW^{0.75}$ daily, whereas dogs receiving restricted food intake consumed 459 ± 53 g/d or 138 ± 12 kcal/kg $BW^{0.75}$ daily. When food intake was restricted, dogs weighed 6% less but race times were 0.43 seconds shorter and mean speeds (calculated from race times) were 0.7 km/h faster ($P < 0.001$), compared with data obtained when dogs had unrestricted access to food (**Table 2**; **Figure 1**). Race times varied ($P < 0.001$) from week to week, but the firmness of the sand track

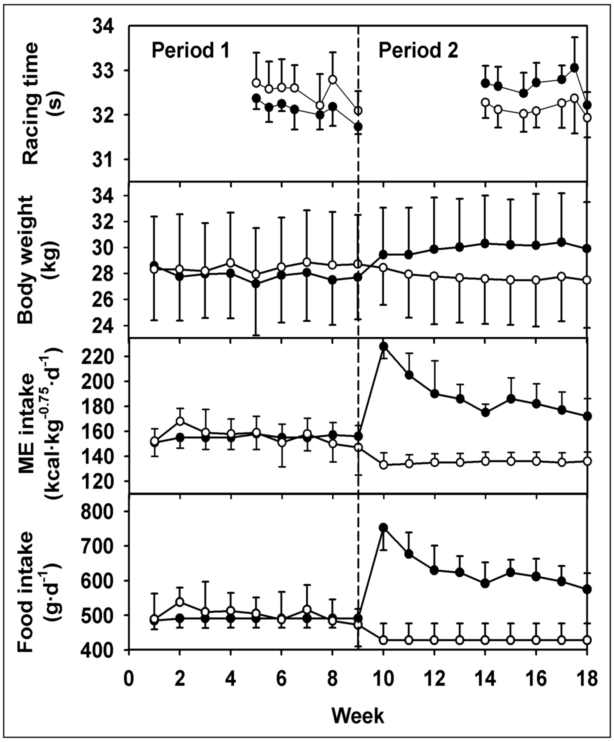

Figure 1—Race times, body weight, metabolizable energy (ME) intake relative to metabolic body weight, and food intake of 2 groups of racing Greyhounds during 2 consecutive 9-week periods during which dogs were allowed either unrestricted access to food or access to food was restricted to 85% of the unrestricted amount. Period 1 (weeks 1 to 9) is shown on the left side, and period 2 (weeks 10 to 18) is shown on the right side of the figure; the dotted line represents the treatment crossover point of the study. Food access in group 1 dogs (open circles; n = 5) was unrestricted during period 1 and restricted during period 2; food access in group 2 dogs (solid circles; n = 4) was restricted during period 1 and unrestricted during period 2. Data represent the means for each group for each week of the study or for each race; error bars represent the SD value. Food and energy intakes are mean intakes for the preceding week. Body weights were lower ($P < 0.001$) and race times were shorter ($P < 0.001$) when food intake was restricted, compared with values obtained during the period of unrestricted food intake.

Table 3—Rectal body temperature and venous blood gas and clinicopathologic variables assessed before and after a race in 9 trained healthy adult Greyhounds given unrestricted or restricted access to food in a crossover study (9-week diet treatment periods).

Variable	Restricted food intake		Unrestricted food intake	
	Before racing	After racing	Before racing	After racing
Rectal temperature (°C)*	38.8 ± 0.4	41.4 ± 0.5	38.8 ± 0.4	41.6 ± 0.4
Blood pH*	7.40 ± 0.01	7.06 ± 0.05	7.39 ± 0.03	7.09 ± 0.02
Bicarbonate (mEq/L)*	26.9 ± 1.1	8.2 ± 1.6	26.1 ± 1.0	8.4 ± 1.7
PCO_2 (mm Hg)*	44 ± 3	30 ± 8	43 ± 4	29 ± 6
PO_2 (mm Hg)*†	49 ± 5	75 ± 17	51 ± 6	85 ± 11
Hct (%)*	59 ± 3	67 ± 4	59 ± 3	67 ± 3
RBCs ($\times 10^6/\mu L$)*	9.2 ± 0.5	10.4 ± 0.5	9.2 ± 0.4	10.3 ± 0.4
Hemoglobin (g/dL) *	21.6 ± 1.1	23.7 ± 0.8	21.5 ± 0.9	24.0 ± 0.9
WBCs ($\times 10^3/\mu L$)*†	3.6 ± 1.1	4.3 ± 1.0	4.3 ± 0.8	6.1 ± 1.1
Band neutrophils (bands/µL) †	53 ± 76	30 ± 76	10 ± 20	3 ± 10
Neutrophils ($\times 10^3/\mu L$)*†‡	2.2 ± 0.8	2.9 ± 1.0	2.7 ± 0.5	4.6 ± 0.8
Lymphocytes ($\times 10^3/\mu L$)	0.9 ± 0.3	1.0 ± 0.4	1.2 ± 0.5	1.1 ± 0.4
Monocytes ($\times 10^3/\mu L$)	0.3 ± 0.4	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1
Eosinophils ($\times 10^3/\mu L$)	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.2	0.2 ± 0.3
Sodium (mEq/L)*	146 ± 1	156 ± 3	145 ± 0	157 ± 2
Potassium (mEq/L)*	4.2 ± 0.3	4.1 ± 0.3	4.4 ± 0.2	4.1 ± 0.2
Chloride (mEq/L)*	114 ± 2	111 ± 1	114 ± 1	112 ± 2
Calcium (mg/dL)*	9.2 ± 0.4	10.1 ± 0.7	9.3 ± 0.3	10.1 ± 0.3
Phosphorus (mg/dL)*	3.2 ± 0.4	2.4 ± 0.6	3.5 ± 0.5	2.3 ± 0.6
Total protein (g/dL)*	5.4 ± 0.3	6.0 ± 0.9	5.4 ± 0.1	6.4 ± 0.3
Albumin (g/dL)*†	3.2 ± 0.2	3.7 ± 0.2	3.3 ± 0.2	3.8 ± 0.2
Globulin (g/dL)*	2.2 ± 0.2	2.6 ± 0.2	2.1 ± 0.2	2.6 ± 0.3
Creatinine (mg/dL)*	1.3 ± 0.2	1.5 ± 0.2	1.3 ± 0.2	1.5 ± 0.2
BUN (mg/dL)*	18 ± 3	20 ± 3	20 ± 4	20 ± 3
Lactate (mmol/L)*	0.5 ± 0.2	25.5 ± 3.1	0.7 ± 0.3	25.5 ± 2.3
Glucose (mg/dL)*	105 ± 8	155 ± 20	103 ± 8	151 ± 12
Triglyceride (mg/dL)*†	28 ± 11	122 ± 28	33 ± 11	129 ± 31
Cholesterol (mg/dL)*	140 ± 24	163 ± 24	139 ± 20	160 ± 25
ALT (U/L)*	39 ± 12	54 ± 13	39 ± 13	57 ± 20
AST (U/L)*	34 ± 12	70 ± 19	33 ± 6	72 ± 20
ALP (U/L)*	42 ± 20	52 ± 17	51 ± 12	59 ± 15
CK (U/L)*	180 ± 132	295 ± 157	121 ± 41	195 ± 47
Total bilirubin (mg/dL)*†	0.18 ± 0.04	0.12 ± 0.04	0.14 ± 0.07	0.10 ± 0.00

Values are given as means ± SD.

*Significant ($P \leq 0.05$) difference between values before and after racing. †Significant ($P \leq 0.05$) difference between diet treatments. ‡Significant ($P \leq 0.05$) interaction between diet treatment and time relative to racing.

ALT = Alanine aminotransferase. AST = Aspartate aminotransferase. ALP = Alkaline phosphatase. CK = Creatine kinase.

appeared to be primarily responsible. As a result of restricted food intake, mean weight of the dogs decreased ($P < 0.001$) by 1.7 kg and mean lean body mass and mean fat mass decreased ($P = 0.05$) by 0.9 and 0.8 kg, respectively; however, lean body mass and fat mass as a percentage of total body weight did not change when food intake was restricted. There was also a small but significant ($P = 0.02$) reduction in median body condition score (9-point scale) from 3.75 (range, 3.5 to 4.0) to 3.5 (range, 2.75 to 3.75) when food intake was restricted. There was no statistical evidence of sequence effects.

Compared with values determined in dogs before a race, racing increased rectal temperature and most clinicopathologic variables but decreased venous blood pH and PCO_2 and serum bicarbonate, potassium, chloride, and phosphorus concentrations ($P \leq 0.05$; **Table 3**). Compared with values obtained during unrestricted food intake, restricting food intake decreased ($P < 0.001$) the total WBC count: the concentration of circulating neutrophils was 19% and 37% lower ($P < 0.001$) before and after racing, respectively, when food was restricted, but the concentration of circulating band neutrophils was greater ($P \leq 0.05$) in dogs receiving restricted food intake both before and after racing; other WBC counts were unaffected by food restriction. Restricting food intake also caused clinically unimportant but significant ($P \leq 0.05$) changes in venous PO_2 and serum albumin, triglyceride, and total bilirubin concentrations; other clinicopathologic values were unaffected by food restriction. There were no sequence effects.

Discussion

Results of the present study indicated that when food intake was slightly restricted, racing Greyhounds ran 0.7 km/h faster over a short sprint race and weighed 6% less than dogs that were fed free choice. This change in performance is substantial. The increase in speed is equivalent to a gain of 6 m over a distance of 500 m, which would often represent the difference between winning and losing a race. The speeds determined in our study were similar to those recorded in other scientific studies[1,2,19] at our facility and elsewhere, but the difference in race time was greater than that observed with other dietary treatments. In the present study, dogs ran slightly slower than would be expected at commercial race tracks but this is not surprising since dogs were donated because they were too slow to be competitive in commercial racing. Also, a soft sand and clay track was used to minimize the risk of injury, and dogs cannot run as fast on this surface as they can on a hard commercial track. However, it is possible that the effect of diet determined in the dogs of our study may not apply to faster dogs running on a firm track.

Our data raise the question of why the dogs ran faster when they weighed less. Greyhounds utilize considerable amounts of energy accelerating at the start of a race.[e] Force equals mass multiplied by acceleration; therefore, for a given muscular force, lightweight dogs would accelerate faster than heavier dogs. If loss of body weight does not affect the force that can be generated by that muscle (probably proportional to muscle mass), then acceleration is likely to be greater in lightweight dogs. Beagles running on a treadmill at 6 km/h consumed less energy as they lost weight during 15 days of food deprivation, even when work load was adjusted for weight.[4] If this relationship applies to Greyhounds during a sprint, then less energy would be required by lightweight dogs than heavier dogs to complete a race. Furthermore, Greyhounds mostly rely on anaerobic and aerobic metabolism of carbohydrates during a 30-second race.[e] If lightweight dogs require less energy to complete a race, then a greater proportion of that energy could be provided by carbohydrate metabolism, which supports a higher rate of work than does fat metabolism. When trotting at the same velocity, ponies that were fed restricted amounts of food were observed to run with a flatter gait because they flexed their joints more than ponies fed ad libitum.[20] Therefore, it is possible that a change in gait may improve performance. Heavy dogs may also sink more in the soft track than dogs that weigh less.

Food deprivation may affect the rate of mobilization of food stores. A decrease in blood glucose concentrations detected in well-fed Beagles during endurance exercise was not evident in food-deprived Beagles, which suggested that delivery of glucose to muscle matched the demand in food-deprived but not well-fed dogs.[4] However, in the Greyhounds evaluated in the present study, serum glucose concentrations increased after a 30-second race, compared with the values before the race, and serum glucose concentrations after racing were unaffected by restricted access to food. Increasing body temperature has also been observed to limit performance in exercising dogs,[4,21] but the increase in rectal temperatures during a race was unaffected by food deprivation in these Greyhounds.

Among human athletes, restricting food intake may reduce intake of essential nutrients below that recommended for a typical adult.[8,11] Deficiencies or toxic effects are unlikely in the study of this report because the diet used conformed to American Association of Feed Control Officials recommendations for sedentary adult dogs[18]; furthermore, the dogs consumed only slightly more food daily than the amount recommended for moderately active adult dogs (132 kcal/kg $BW^{0.75}$) by the National Research Council.[22]

Dogs consumed 15% less food when food intake was restricted, but after the change in body weight was taken into account, the reduction in nutrient intake relative to body weight was only 12%. For example, dogs fed a restricted amount of food consumed 12% less crude protein (10.5 ± 0.9 g/kg $BW^{0.75}$ vs 11.8 ± 1.2 g/kg $BW^{0.75}$), fat (5.9 ± 0.5 vs 6.6 g/kg $BW^{0.75} \pm 0.7$ g/kg $BW^{0.75}$), or NFE (12.6 ± 1.1 g/kg $BW^{0.75}$ vs 14.3 ± 1.5 g/kg $BW^{0.75}$) daily, compared with amounts consumed by dogs fed free choice. The proportion of dietary protein, fat, and carbohydrate that results in optimal performance of Greyhounds has yet to be determined. The diet used in the present study contained a moderate amount of protein (28% ME), a moderate amount of fat (38% ME), and a moderate amount of carbohydrate (34% ME as NFE), compared with the contents of other commercial diets. A previous experiment[2] revealed that Greyhounds ran faster when dietary protein content was decreased from 37% to 24% ME and the NFE content in the diet increased from 30% to 43% ME; another experiment[1] revealed that performance of Greyhounds improved when dietary fat content increased from 25% to 32% ME with a corresponding adjustment (54% to 43% ME) in the carbohydrate content of the diet. Together, results of those preliminary experiments suggested that 24% ME protein may be sufficient in Greyhounds fed free choice but that increased fat and potentially increased carbohydrate dietary content may have beneficial effects on performance. However, in the study reported here, the changes in performance were larger and the changes in nutrient intake much smaller than those in the earlier experiments. Any nutrient effect on performance was probably trivial, compared with the effect of weight loss.

Deuterium dilution provides an estimate of body fat that is lower than that obtained via **dual energy X-ray absorptiometry (DEXA)** or carcass lyophilization but accurately measures changes in total body water and fat mass.[23,24] In our study, mean percentage fat mass measured by use of deuterium dilution was only 2% in the Greyhounds fed free choice. This is only slightly less than the value reported previously in trained Greyhounds.[2] The small decrease (2%) in fat mass detected by use of isotope dilution improved sprint performance markedly, even in dogs with a comparatively low fat mass. However, substantial fat reserves are probably not important for sprint racing because sprinting dogs do not burn large amounts of fat during a race. Therefore, in sprinting dogs, fat mass represents a dead weight but it is by no means certain that further weight and fat mass reduction associated with more severe food intake restriction than in the present study would be of benefit. Lean body mass also decreased in these dogs when food was restricted. This loss of lean mass did not slow the speed of the dogs in the present study, but further loss of lean mass may have a detrimental effect on performance.

The median body condition score obtained by use of a 9-point scale was 3.5 for dogs receiving restricted food intake and 3.75 when dogs were fed free choice. This 9-point scale has been reported to correlate well with body fat measured by DEXA in dogs of various breeds.[14] A score of 3.75 corresponds to a mean body fat content (assessed via DEXA) of approximately 12% to 13%, whereas a supposedly normal score of 5 on this scale corresponds to a mean body fat content of 17% to 20%.[23] This corroborates findings of a previous study[25] that Greyhounds of normal weight have more muscle mass and less fat than other breeds of dog; it also suggests that a body condition score of approximately 3.5 is normal for a trained Greyhound in racing condition.

In the dogs of the present study, most clinicopathologic variables were unaffected by food restriction or the changes were so small as to be unimportant. The number of mature neutrophils per microliter of blood decreased when food was restricted, but this decrease was small and probably unimportant. The cause of this small decrease in neutrophil count is unknown. Lymphopenia, but not neutropenia, has been detected in sedentary dogs during starvation.[26,27] However, it is possible that the concentration of neutrophils in blood samples may have declined with food restriction as a result of an increase in neutrophil margination rather than a decrease in absolute numbers of circulating neutrophils. Nevertheless, clinicians should be aware that the neutrophil count may be very low in trained racing Greyhounds, especially when these dogs have undergone slight weight restriction. The concentration of circulating segmented neutrophils was < 3,000 cells/µL in 8 of 9 dogs fed a restricted amount of food and 6 of 9 dogs fed free choice; the concentration was < 2,000 cells/µL in 4 of 9 dogs fed a restricted amount of food. Dogs with < 3,000 circulating neutrophils/L are usually regarded as neutropenic and at increased risk of infection, but this is probably not so in racing Greyhounds. The range of neutrophil counts in the Greyhounds fed free choice (2,000 to 5,800 cells/µL) was lower than the range reported for other breeds of dog (3,000 to 11,500 cells/µL)[28] but similar to that previously reported for Greyhounds by this laboratory group[1,2] and others.[19,29]

The changes in clinicopathologic variables that were detected after racing were similar to those that have been reported for Greyhounds raced over a distance of 500 m by this laboratory group[1,2] and others.[30,31] There was a marked lactic acidosis after racing. Large increases in serum glucose and triglyceride concentrations probably also represented increased release of these nutrients into the circulation, but small increases in most other serum biochemical variables probably resulted from fluid shifts, splenic contraction, and dehydration.

Our data substantiate that mild food restriction that results in a slight decrease in body weight markedly improves sprint performance in Greyhounds. However, it remains to be determined whether this change in performance results simply from a reduction in mass or a change in metabolism.

a. Testosterone propionate, Steris, Phoenix, Ariz.
b. Performance, Kal Kan Petfoods Inc, Vernon, Calif.
c. FinishLynx, Etherlynx 2000, Lynx Systems Developers Inc, Woburn, Mass.
d. SAS/STAT, version 6.12, SAS Institute Inc, Cary, NC.
e. Staaden R. *The exercise physiology of the racing greyhound.* PhD thesis, School of Veterinary Studies, Murdoch University, Perth, Australia, 1984.

References

1. Hill RC, Bloomberg MS, Legrand-Defretin V, et al. Maintenance energy requirements and the effect of diet on performance of racing greyhounds. *Am J Vet Res* 2000;61:1566–1573.
2. Hill RC, Lewis DD, Scott KC, et al. Effect of increased dietary protein and decreased dietary carbohydrate on performance and body composition in racing Greyhounds. *Am J Vet Res* 2001;62:440–447.
3. Brzezinska Z, Kaciuba-Uscilko H, Nazar K. Physiological responses to prolonged physical exercise in dogs. *Arch Int Physiol Biochim* 1980;88:285–291.
4. Young DR. Effect of food deprivation on treadmill running in dogs. *J Appl Physiol* 1959;14:1018–1022.
5. Young DR. Effect of body composition and weight gain on performance in the adult dog. *J Appl Physiol* 1960;15:493–495.
6. Constable PD, Hinchcliff KW, Farris J, et al. Factors associated with finishing status for dogs competing in a long-distance sled race. *J Am Vet Med Assoc* 1996;208:879–882.
7. Horswill CA, Hickner RC, Scott JR, et al. Weight loss, dietary carbohydrate modifications, and high intensity, physical performance. *Med Sci Sports Exerc* 1990;22:470–476.
8. Fogelholm M. Effects of bodyweight reduction on sports performance. *Sports Med* 1994;18:249–267.
9. McMurray RG, Ben-Ezra V, Forsythe WA, et al. Responses of endurance-trained subjects to caloric deficits induced by diet or exercise. *Med Sci Sports Exerc* 1985;17:574–579.
10. McArdle WD, Katch FI, Katch VL. Physique, performance and physical activity. In: *Exercise physiology: energy, nutrition, and human performance.* 4th ed. Baltimore: The Williams & Wilkins Co, 1996;577–601.
11. Fogelholm GM, Koskinen R, Laakso J, et al. Gradual and rapid weight loss: effects on nutrition and performance in male athletes. *Med Sci Sports Exerc* 1993;25:371–377.
12. Cureton KJ, Sparling PB. Distance running performance and metabolic responses to running in men and women with excess weight experimentally equated. *Med Sci Sports Exerc* 1980;12:288–294.
13. National Research Council. *Guide for the care and use of laboratory animals. Publication No. 85-23 (rev).* Bethesda, Md: National Institutes of Health, 1985.
14. Laflamme D. Development and validation of a body condition score system for dogs. *Canine Pract* 1997;22(4):10–15.
15. Cody RP, Smith JK. *Applied statistics and the SAS programming language.* Upper Saddle River, NJ: Prentice-Hall Inc, 1997.
16. Littell RC, Milliken GA, Stroup WW, et al. *SAS system for mixed models.* Cary, NC: SAS Institute Inc, 1996.
17. Hills M, Armitage P. The two period cross-over clinical trial. *Br J Clin Pharmacol* 1979;8:7–20.
18. Association of American Feed Control Officials. *Official Publication.* Atlanta: Association of American Feed Control Officials Inc, 1994.
19. Ilkiw JE, Davis PE, Church DB. Hematalogic, biochemical, blood-gas, and acid-base values in Greyhounds before and after exercise. *Am J Vet Res* 1989;50:583–586.
20. Back W, Schamhardtt HC, Barneveld A, et al. Longitudinal development of kinematics in Shetland ponies and the influence of feeding and training regimes. *Equine Vet J* 2002;34:609–614.
21. Sneddon JC, Minnaar PP, Grosskopf JFW, et al. Physiological and blood biochemical responses to submaximal treadmill exercise in Canaan dogs before, during and after training. *J S Afr Vet Assoc* 1989;60:87–91.
22. National Research Council. *Nutrient requirements of dogs.* Washington, DC: National Academy Press, 1985.
23. Son HR, d'Avignon DA, Laflamme DP. Comparison of dual-energy x-ray absorptiometry and measurement of total body water content by deuterium oxide dilution for estimating body composition in dogs. *Am J Vet Res* 1998;59:529–532.
24. Burkholder WJ, Thatcher CD. Validation of predictive equations for use of deuterium oxide dilution to determine body composition of dogs. *Am J Vet Res* 1998;59:927–937.
25. Gunn HM. The proportions of muscle, bone and fat in two different types of dog. *Res Vet Sci* 1978;24:277–282.
26. Dionigi R, Zonta A, Dominioni L, et al. The effects of total parenteral nutrition on immunodepression due to malnutrition. *Ann Surg* 1977;185:467–474.
27. de Bruijne JJ. Biochemical observations during total starvation in dogs. *Int J Obes* 1979;3:239–247.
28. Meinkoth JH, Clinkenbeard KD. Normal hematology of the dog. In: Feldman BF, Zinkl JG, Jain NC, eds. *Schalm's veterinary hematology.* Baltimore: Lippincott Williams & Wilkins, 2000;1057–1063.
29. Porter JA Jr, Canaday WR Jr. Hematologic values in mongrel and Greyhound dogs being screened for research use. *J Am Vet Med Assoc* 1971;159:1603–1606.
30. Rose RJ, Bloomberg MS. Responses to sprint exercise in the Greyhound: effects on haematology, serum biochemistry and muscle metabolites. *Res Vet Sci* 1989;47:212–218.
31. Snow DH, Harris RC, Stuttard E. Changes in haematology and plasma biochemistry during maximal exercise in Greyhounds. *Vet Rec* 1988;123:487–489.