Alterations in thyroid hormone concentrations in healthy sled dogs before and after athletic conditioning

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Objective—To determine effects of athletic conditioning on thyroid hormone concentrations in a population of healthy sled dogs.

Animals—19 healthy adult sled dogs.

Procedure—Serum concentrations of thyroxine (T_4), triiodothyronine (T_3), thyroid-stimulating hormone (TSH), free T_4 (fT_4), free T_3 (fT_3), and autoantibodies directed against T_3, T_4, and thyroglobulin were measured in sled dogs that were not in training (ie, nonracing season) and again after dogs had been training at maximum athletic potential for 4 months.

Results—Analysis revealed significant decreases in T_4 and fT_4 concentrations and a significant increase in TSH concentration for dogs in the peak training state, compared with concentrations for dogs in the untrained state. Serum concentrations of T_4 and fT_4 were less than established reference ranges during the peak training state for 11 of 19 and 8 of 19 dogs, respectively; fT_4 concentration was greater than the established reference range in 9 of 19 dogs in the untrained state.

Conclusions and Clinical Relevance—Decreased total T_4 and fT_4 concentrations and increased serum concentrations of TSH were consistently measured during the peak training state in healthy sled dogs, compared with concentrations determined during the untrained state. Although thyroid hormone concentrations remained within the established reference ranges in many of the dogs, values that were outside the reference range in some dogs could potentially lead to an incorrect assessment of thyroid status. Endurance training has a profound impact on the thyroid hormone concentrations of competitive sled dogs. (*Am J Vet Res* 2004;65:333–337)

Competitive sled dogs are a unique population of canine athletes that have a relatively sedentary lifestyle during the nonracing season (ie, off-season), but they are endurance athletes with rigorous training schedules during the racing season. It has been reported[1-3] that normal conditioned sled dogs commonly have serum **thyroxine (T_4)** concentrations lower than the reference range established for other breeds, yet clinical hypothyroidism is uncommon.

Thyroid hormones control the body's metabolic rate, and these hormones can be altered via feedback mechanisms as a consequence of metabolic rate. Intensive physical exertion alters metabolic rate and affects thyroid hormone concentrations in a number of species. Results for humans have revealed that exercise can have a variable impact on thyroid hormone concentrations depending on the intensity, type, and duration of exercise,[4,5] amount of training,[6,7] adequacy of caloric intake,[7] and time of collection of blood samples.[8,9] Studies[6,10-12] performed on the effects of athletic training on thyroid hormone concentrations in humans have yielded similarly conflicting results.

The effect of exercise on thyroid hormone concentrations in dogs has been evaluated in a few studies.[3,13-15] Training and sprint racing did not have a significant impact on serum concentrations of **free T_4 (fT_4)**, **triiodothyronine (T_3)**, or **thyroid-stimulating hormone (TSH)** in racing Greyhounds, but it did decrease total T_4 concentrations.[13] Racing Greyhounds evaluated in another study[14] had serum total T_4 and fT_4 concentrations that were typically as much as 40% lower than those for the general population of pet dogs. Resting total T_4 concentrations are slightly decreased in Beagles undergoing repetitive long-distance aerobic exercise on a treadmill, compared with concentrations for sedentary dogs.[15] When conditioned Alaskan sled dogs racing in a 1,600-km race were evaluated before and after the race, plasma T_3 and T_4 concentrations were decreased after dogs completed the race, compared with prerace concentrations. Plasma concentrations of thyroid hormones are reportedly[3] lower than the reference range in 20% to 40% of conditioned dogs prior to a race.

We hypothesized that thyroid hormone concentrations in dogs may be altered by a consistent endurance training program and that differences in thyroid hormone concentrations may be evident between sedentary (nonracing season) states and conditioned (peak training) periods. The purpose of the study reported here was to characterize alterations in thyroid gland function that result from intensive endurance training by evaluating a full panel of thyroid hormones in a group of competitive sled dogs during their sedentary and trained states. A secondary goal was to help establish breed-related data on thyroid hormone concentrations and complete thyroid hormone patterns. This information would be of use to veterinarians in the evaluation of thyroid gland function in sled dogs and, potentially, other canine athletes.

Materials and Methods

Animals—Nineteen sled dogs involved in competitive racing were used in the study. The study was performed in the

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northern part of the province of Saskatchewan, Canada. All dogs were sexually intact Alaskan husky and Siberian husky crossbred dogs. There were 13 males and 6 females that ranged from 2.6 to 8.0 years of age (mean, 4.0 years). Dogs were used for middle-distance races (ie, 660 to 1,320 km).

Procedure—Dogs were housed outdoors during the entire course of the study. Blood samples were collected from each dog during late summer (ambient temperature for the month of September, 12° to 25°C; mean, 19°C) when they were in an untrained state.[a] Blood samples were again collected from this same group of dogs approximately 4 months later during their peak training and racing season (ambient temperature for the month of December, –23° to –10°C; mean, –16°C).[a]

On the basis of results of a physical examination performed at the time of each blood sample collection, all dogs were considered to be in good health. The body condition score of the dogs ranged from 3 to 4 (scale of 1 to 9) for each dog at both sample collection periods. Body weight of dogs ranged from 20 to 31.8 kg (mean, 24.5 kg); body weight of each dog varied 0.3 to 0.5 kg (mean, 0.32 kg) between sample collection periods.

Dogs were cared for by their owners or trainers who maintained a training log on each dog to document the number of kilometers run by each dog during each week of training. During peak training, each dog ran between 152.0 and 198.4 km/wk (mean, 174.4 km/wk). Dogs typically were trained 4 or 5 d/wk (range, 7.3 to 9.6 h/wk; mean, 8.0 h/wk) at a mean speed of 22.2 km/h (range, 19.7 to 27.2 km/h). Evidence of illness was not detected in the dogs, nor were any medications administered during the month prior to sample collection. None of the dogs received thyroid hormone supplements at any time during the study.

During the sedentary (nonracing) season, dogs were fed a diet that consisted of 45% beef, 45% chicken, cooked rice, wheat germ oil, canola oil, fish oil, a commercial zinc supplement, bone meal, egg and shell, and dry kibble. This diet contained approximately 50% protein, 25% to 30% fat, and 20% to 25% carbohydrates. This diet was fed once daily in the evening. During peak training and racing, dogs were fed a diet containing 40% beef, 40% chicken, cooked rice, wheat germ oil, canola oil, fish oil, corn oil, a commercial zinc supplement, bone meal, egg and shell, and dry kibble. This diet was fed once daily in the evening; however, dogs were also fed 114 g of chicken fat for each hour they ran during training. Thus, this diet contained approximately 40% protein, 40% to 45% fat, and 10% to 15% carbohydrates.

Collection of samples—Blood was collected in late summer (nonracing season) and again 4 months later (peak training). Food was withheld from dogs on the morning of sample collection, and dogs had not participated in a training run for ≥ 8 hours before collection of blood samples. Blood samples were collected at approximately the same time of day for both seasons. Blood samples were collected from a cephalic vein and placed in serum separator tubes. Serum was harvested within 6 hours after blood collection, frozen at –70°C, and shipped by courier to the Endocrinology Laboratory at the Animal Health Diagnostic Laboratory of the Michigan State University for hormonal analysis.

Measurement of hormone concentrations—Serum concentrations of T_4, T_3, TSH, fT_4, **free T_3 (fT_3)**, and autoantibodies directed against T_3, T_4, and thyroglobulin were measured. Concentration of fT4 was determined by use of equilibrium dialysis. Reference ranges for all thyroid gland hormones cited in the study were those established by the laboratory.[16-20]

Statistical analysis—Mean ± SD values were examined to describe and assess the distribution of raw data. Paired *t* tests were used to assess the magnitude and significance of differences in various measures of thyroid gland function between the nonracing season and peak training. When there was concern that the differences between these values were not normally distributed and that the assumptions for the paired *t* test had been violated, a Wilcoxon signed-rank test was used. Associations between various measures of thyroid gland function were analyzed by use of a generalized estimating equation method to account for repeated measures within each dog. Data were analyzed by use of a commercial statistical computer software program.[21,b] Model specifications included normal distribution of data, identity link function, repeated statement with subject equal to dog identification, and an autoregressive correlation structure.[1] Variables remaining in the final multivariable model at values of $P <$ 0.05, on the basis of robust empirical SEs produced by generalized estimating equation analysis, were considered significant. Thyroid hormone concentrations of the sled dogs were compared with reference ranges that had been established by the endocrinology laboratory for all dogs.[16-20]

Results

Serum total T_4 and fT_4 concentrations measured in the peak training period were decreased, compared with concentrations measured in this group of sled dogs during the sedentary (nonracing) season **(Fig 1)**. Differences in concentrations between seasons were significant ($P < 0.001$) for total T_4 and fT_4 **(Table 1)**. Concentrations of TSH increased significantly ($P < 0.001$) between the nonracing season and peak training. We did not detect evidence of alterations in serum concentrations of total T_3, fT_3, or autoantibodies against thyroglobulin between the nonracing and peak training seasons. Mean ± SD value for thyroglobulin autoantibodies was 105% ± 103% and 109% ± 166% during the nonracing and peak training seasons, respectively. In addition, we did not detect autoantibodies against T_3 or T_4 during either season.

Associations between concentrations of total T_4 and fT_4, T_4 and TSH, and fT_4 and TSH were analyzed by use of regression analysis to account for repeated measures within each dog. Concentrations of fT_4 increased at a rate similar to that for total T_4 concentrations; this relationship was quantified by the following equation: total T_4 concentration = 8.725 + (1.055 × fT_4 concentration; **Fig 2**). Decreases in total T_4 and fT_4 concentrations resulted in predictable increases in TSH

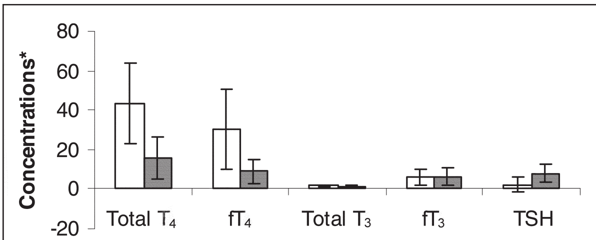

Figure 1—Mean ± SD concentrations of total thyroxine (T_4), free T_4 (fT_4), total triiodothyronine (T_3), free T_3 (fT_3), and thyroid-stimulating hormone (TSH) in 19 sled dogs measured during the nonracing season (white bars) and during peak training of the racing season (black bars). Reference ranges for each hormone were as follows: total T_4, 15 to 67 nmol/L; free T_4, 8.0 to 26 pmol/L; total T_3, 1.0 to 2.5 nmol/L; free T_3, 4.5 to 12 pmol/L; and TSH, 0 to 37 mU/L.
*Concentrations for hormones are as follows: total T_4 and total T_3, nanomoles per liter; fT_4 and fT_3, picomoles per liter; and TSH, milliunits per liter.

Table 1—Differences in concentrations of thyroid gland hormones measured in 19 sled dogs during the nonracing and peak training (racing) seasons

Variable	Mean difference	95% CI	P*
Total T_4 (nmol/L)	26.526	18.367, 34.686	< 0.001
Total T_3 (nmol/L)	0.1842	–0.0391, 0.4071	0.100
fT_4 (pmol/L)	20.474	11.937, 29.010	< 0.001
fT_3 (pmol/L)	0.006	–0.820, 0.831	0.989
TSH (mU/L)	–6.0526	–8.427, –3.678	< 0.001 (0.002)†
TGAAA (%)	–1.632	–34.351, 31.0.87	0.918 (0.251)†

*Values determined by use of a paired *t* test. †Values determined by use of a nonparametric test (Wilcoxon signed-rank test) because assumptions for a paired *t* test were potentially violated.
CI = Confidence interval. T_4 = Thyroxine. T_3 = Triiodothyronine. fT_4 = Free T_4. fT_3 = Free T_3. TSH = Thyroid-stimulating hormone. TGAAA = Thyroglobulin autoantibodies.

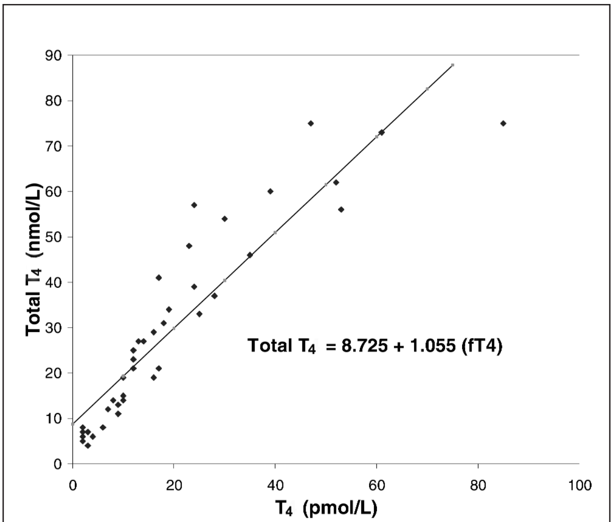

Figure 2—Association between total T_4 and fT_4 concentrations in 19 sled dogs during the nonracing and racing seasons, as measured by use of regression analysis. Notice the equation for the line of best fit.

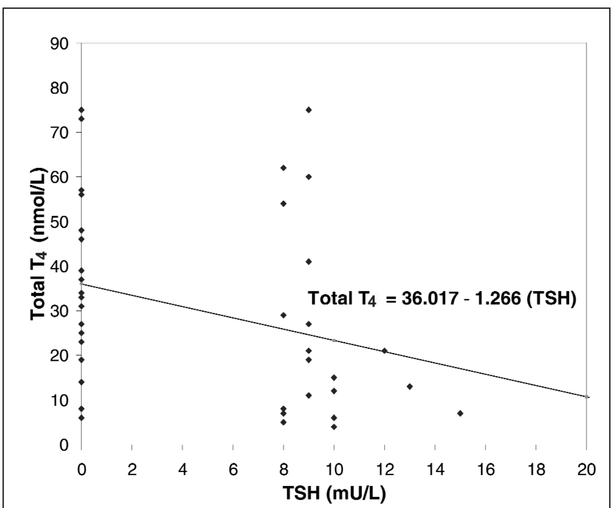

Figure 3—Association between total T_4 and TSH concentrations in 19 sled dogs during the nonracing and racing seasons, as measured by use of regression analysis. Notice the equation for the line of best fit.

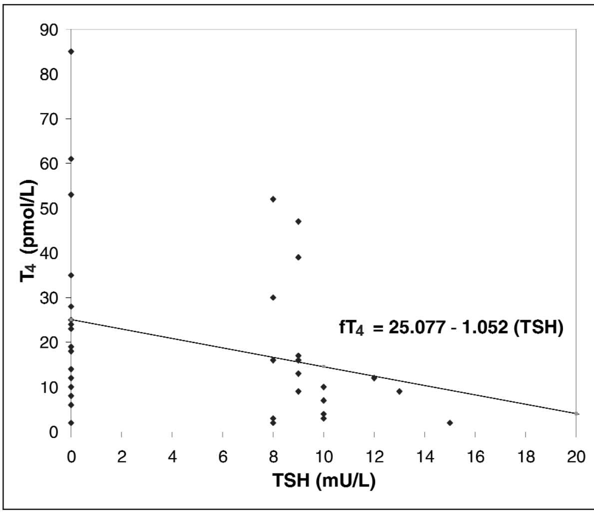

Figure 4—Association between fT_4 and TSH concentrations in 19 sled dogs during the nonracing and racing seasons, as measured by use of regression analysis. Notice the equation for the line of best fit.

concentration, as quantified by the following equations: total T_4 concentration = 36.017 – (1.266 × TSH concentration; **Fig 3**) and fT_4 = 25.077 – (1.052 × TSH concentration; **Fig 4**). The relationship among T_4, fT_4, and TSH concentrations did not change during peak training.

Mean values obtained for sedentary (nonracing) and conditioned (peak training) states were within reference ranges established for dogs by the endocrinology laboratory (Fig 1; Table 1). Serum concentrations of T_4 and fT_4 measured during peak training were less than the reference range for 11 of 19 and 8 of 19 dogs, respectively. For dogs evaluated during the nonracing season, serum T_4 concentration was greater than the established reference range for 3 dogs and less than the established reference range for 2 dogs, whereas concentration of fT_4 was greater than the established reference range for 9 dogs and less than the established reference range for 1 dog.

Discussion

Training appeared to have a profound impact on results of tests of thyroid gland function in this group of middle-distance sled dogs. The dogs in this study had significant decreases in serum total T_4 and fT_4 concentrations and increases in serum TSH concentrations during the sedentary period, compared with concentrations of those hormones during the peak training period.

In humans, endurance training increases metabolism and clearance of thyroid hormones as well as volume of distribution and disposal rate.[9,22] There is evidence that body tissues of endurance-trained people process thyroid hormones in a manner different from that for tissues from untrained people, resulting in increased turnover of thyroid gland hormones.[9,22] This could account for the decrease in total T_4 and fT_4 concentrations observed in the conditioned dogs in our study. Thyroid hormones seem to be altered most dramatically during the course of a training period (ie, during the transition from the sedentary to the trained state) rather than immediately in response to an episode of physical exertion, such as a race.[9,22] Results in the study reported here may largely reflect increased metabolism and disposal of thyroid gland hormones caused by the rigorous endurance training program competitive sled dogs undertake seasonally.

In well-conditioned cross-country skiers, prolonged heavy exercise (ie, a 60-km race) can result in mild decreases in T_4 and T_3 concentrations as well as a substantial increase in serum TSH concentrations.[9] Concentrations of T_4 and T_3 typically increase immediately after exertion, but then decrease to concentrations less than those measured initially, with a return to preexercise values delayed for 3 to 4 days after exertion.[9] Concentrations of TSH increase most dramatically 24 hours after exercise, increasing up to 175% of initial values and then remaining high for 4 days, presumably in response to an exercise-induced peripheral demand for thyroid gland hormones.[9] The sled dogs in the study reported here had decreases in serum T_4 and fT_4 concentrations and increases in serum TSH concentrations when evaluated during peak training, compared with concentrations during their sedentary evaluation. With repetitive prolonged daily exercise, such as that practiced to achieve peak conditioning in these dogs, it is apparent that there may be a decrease in available thyroid gland hormones, resulting in an increase in pituitary secretion of TSH.

Additional factors could have affected the results of the thyroid hormone concentrations in the group of dogs in this study. There were substantial differences between the 2 evaluation periods with respect to diet and ambient temperatures. Sled dogs competing in long-distance races have extremely high metabolic rates, with energy expenditures often exceeding 10,000 kcal/d.[23] The dogs in the study reported here had adjustments to the diet during training to increase the caloric intake to meet the high demands associated with racing and training. Although a negative energy balance can alter metabolism of thyroid gland hormones in humans,[24] it was not considered likely that the dogs in our study had a consistent negative energy balance at the time of evaluation, as determined on the basis of their stable body condition throughout the study period. Increased dietary fat, which was fed during the training period, and increased plasma free fatty acid concentrations induced by exercise during this evaluation period could have served to displace thyroid hormones from their plasma transport proteins.[25] This would typically cause a decrease in measured total T_3 and total T_4 concentrations in combination with an increase in serum fT_4 concentrations. Similarly, exposure to cold temperatures can alter binding of carrier proteins to thyroid gland hormones, resulting in a decrease in the measured concentrations of total T_3 and total T_4 and an increase in concentrations of fT_4.[26] The dogs in the study reported here had a decrease in fT_4 concentrations during the training period, making it unlikely that dietary and environmental factors had a substantial impact on results of the study.

Obviously a control group of sled dogs maintained on the same diet, that were not exercised, and that were maintained in the same environment would have allowed a more definitive statement regarding training as the cause for the alteration of thyroid gland function. There is also the possibility that thyroid gland hormones may have been in a state of flux during the testing performed during this study.

Mean serum concentrations of total T_4 and fT_4 in this group of conditioned sled dogs were still within the reference range established for all dogs; however, values for the sled dogs were near the low end of the reference range. It is possible that these dogs, as a group, may have been considered hypothyroid by use of an alternate reference. Certainly, some dogs within the group had concentrations of thyroid gland hormones suggestive of hypothyroidism when evaluated during the peak training period. A diagnosis of hypothyroidism should only be considered likely when results of tests of thyroid gland function are abnormal in a dog with clinical findings suggestive of the disorder.

The study reported here documented that extreme alterations in thyroid hormone concentrations can result from intensive endurance training in sled dogs. These changes may be directly related to increases in metabolism and disposal rate of thyroid gland hormones secondary to exercise-induced demand. The unique stresses and activities of working sled dogs make it important to evaluate thyroid gland function in these dogs within the context of their current athletic conditioning and activity.

[a]Environment Canada for 2002. Available at: ww.mscsmc.ec.gc.ca/climate/temperature_precipitation/temperature_graphs/YXE.gif. Accessed April 20, 2003.

[b]Proc GenMod, SAS, version 8.2 for Windows, SAS Institute Inc, Cary, NC.

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