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Feeding the Canine Athlete

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Most veterinarians have clients who participate with their dog in various sports or activities, and they may seek information on how to appropriately feed their active dogs. This article provides practical advice for feeding active dogs, whether pulling a sled in Minnesota, chasing Frisbees,® or chasing fox.

Exercise Intensity

The majority of performance dog nutrition research has been conducted using either endurance sled dogs or greyhounds. However, most performance dogs are neither. Instead, they are hunting dogs, service dogs, and working dogs that participate in a wide range of physical activities. Table 1 lists a sampling of canine athletic activities and their level of intensity. Exercise intensity is usually discussed in terms of VO_2 or workload. VO_2 max is the maximum rate of oxygen consumption when exercising intensely, thus it is used as an indicator of relative exercise intensity in conditioned dogs.[1]

Dogs fed 16% protein (vs 24%), as a percent of calories, had more soft-tissue injuries.

Exercise can be loosely divided into three categories based on VO_2 max. High intensity exercise is greater than 75% VO_2 max, and relies heavily on anaerobic metabolism. In conditioned individuals, as VO_2 max increases from 65% to 90%, the proportion of energy derived from carbohydrates (vs. fat) increases. Moderate intensity exercise occurs between 30 to 50% VO_2 max and is primarily aerobic in nature. At this intensity, energy is mostly provided by free fatty acids (FFA), with lesser amounts derived from carbohydrates and small amounts from protein. Finally, low intensity exercise is exercise up to 30% VO_2 max and is completely aerobic in nature, utilizing primarily free fatty acids for fuel.[1]

Endurance Canine Athletes

Canine endurance athletes, like sled dogs, typically exercise for an extended time period in the low-to-moderate intensity range with very short bouts of high intensity going up a hill or at the finish of a race. Therefore, the primary fuel for canine endurance athletes is free fatty acids. Dogs are more efficient at fat metabolism than most other species.[2] Further, through a combination of training and diet, there can be an increase in the amount of circulating FFA available for use as an energy substrate.[1] Muscle FFA can contribute 60% or more of energy during the first 2 to 3 hours of exercise.[3]

An appropriate feeding regimen for endurance sled dogs includes approximately 35% of calories from protein, 45% calories from fat, and 20% of calories from carbohydrates (Table 2). However, these are estimates and all dogs should be fed to maintain appropriate body condition for the sport in which they are participating. Sled dogs exercising at low-to-moderate intensity with short bouts of high intensity work need a minimum of 24% of calories from protein in the diet to prevent soft tissue injury.[4] Dogs fed 16% protein, as a percent of calories, had more soft-tissue injuries than dogs fed more protein.[4]

Canine endurance athletes have a tremendous requirement for energy. Working sled dogs' calorie requirements can range up to 6,000 to 10,000 kilocalories/day depending on environmental conditions, exercise intensity and duration.[1] Daily energy requirements are usually greater than 5X resting energy rate. High dietary energy density is key for these canine athletes. Since fat has about 2.25 times more energy than either protein or carbohydrate per gram, high fat diets help to meet the energy needs of these athletes. Small amounts of complex carbohydrates are useful in stabilizing gut motility in endurance canine athletes. Sled dogs fed diets without carbohydrate were more susceptible to "stress" diarrhea than those that had 17% carbohydrate in their diets.[5]

Long distance endurance events cause an increase in lipid peroxidation and free radical production. The extremely high fat diets required by endurance sled dogs can exacerbate this phenomena so increased antioxidants like vitamin E and selenium have been recommended to help minimize the effects of free radicals.[1]

Sprint/Weight-Pulling Canine Athletes

Dogs involved in sprinting and weight-pulling activities undergo short periods of very intense exercise. These athletes typically do not have higher energy requirements than those of moderately active pet dogs. A greyhound expends approximately 75 kcal per race.[6] The energy required for these activities is solely anaerobic and comes from the muscle energy stores. Most canine athletes engaged in sprint-type activities have an energy requirement of 1.6 to 2 X resting energy rate.[1] An appropriate feeding regimen for sprint-type canine athletes consists of a diet that contains approximately

Table 1. Canine Athletic Activities, Exercise Intensities and Relative Energy Requirements. (Adapted from Toll and Reynolds, 2002.)[1]

Athletic Activity	Relative Intensity at Time of Activity	Relative Energy Requirements for Exercising Dogs	Relative Energy Requirements (x RER*)
Sled races	Low	Very high	3 - 5+ X RER
Pack hound hunts	Low to medium	High	2-3 X RER
Working livestock	Low to medium	High	2-3 X RER
Field trials	Medium	High to medium	1.8 - 2.5 x RER
Search and rescue	Medium	High to medium	1.8 - 2.5 x RER
Flyball-Flying disc trials	Medium to high	Medium to low	1.6 - 2.2 x RER
Agility trials	Medium	Low	1.6 - 2.0 x RER
Recreational runs	Medium to high	Low	1.6 - 2.0 x RER
Lure-course races	Most intense	Low	1.6 - 2.0 x RER

* Typical energy needs relative to resting energy requirements during the period of exercise activity. Note that the needs of individual dogs will vary, independent of exercise intensity.

25% calories from protein, 30% calories from fat, and 45% calories from carbohydrates (Table 2).

Greyhounds can deplete up to 70% of their muscle glycogen during a race.[7] However, it seems that excessive "carb loading" as described for humans does not benefit these canine athletes.[8] Hill et al demonstrated that greyhounds ran faster when carbohydrate was increased from 30 to 45% ME at the expense of protein, but they ran slower when fed 54% carbohydrates at the expense of protein and fat.[9]

While vitamins E and C provide protection against oxidative damage, they do not appear to enhance racing performance. On the contrary, super-supplementation with these antioxidant vitamins actually slowed greyhounds.[10] However, as part of their diet, many racing dogs are fed raw meat or fish, which can be high in unsaturated fatty acids and susceptible to oxidation. Therefore, the amount of vitamin E included in the diet should be proportional to the fat levels in the diet.[11]

Most dogs that participate in canine athletic events are considered "intermediate" athletes who use a combination of aerobic and anaerobic fuels.

Intermediate Canine Athletes

Most canine athletes fall into the nebulous category of "intermediate" exercise intensity. Some dogs, like the family retriever who does double duty as the duck-retrieving dog on the weekend, are "weekend warriors." These dogs exercise hard, sometimes for many hours on the weekends, but may not exercise during the week. A recent survey of foxhound hunting clubs reported that formal hunts last from 2 to 6 hours, and the average distance covered was between 8 to 10 miles but could range up to 20 miles.[12] Other canine athletes may exercise more regularly at moderate to low intensity.

Table 1 lists a few of the activities in which dogs may participate. Intermediate athletes can be subdivided into two categories — those that exercise at a low-moderate frequency and duration and those that exercise at a higher duration and frequency. There may be short bursts of intense activity, like running up a hill or sprinting after a bird in the case of a hunting dog or completing an agility course in the case of agility dogs, but the majority of inter-

mediate canine athletes exercise at an intensity level well below 75% VO_2 max. Therefore, the exercise of these intermediate athletes more closely resembles endurance exercise rather than sprint exercise.

Canine intermediate athletes require at least 25% of calories as protein (Table 2). Protein requirements increase in relation to increased work.[1] Exercise causes an increased need for structural proteins (muscle, collagen) and functional proteins (enzymes).[1] As exercise frequency increases through continued work or training, the enzymes for energy metabolism are up-regulated, requiring more protein.[13] Blood volume increases with continued aerobic exercise, and there is a concomitant increase in plasma volume that requires additional protein.[14] Thus there is an enhanced rate of protein synthesis associated with regular exercise. There is also an enhanced rate of protein catabolism. Branch-chain amino acids, leucine, isoleucine and valine, are oxidized for energy, contributing between 5 to 15% of the energy used during aerobic exercise.[15] These essential amino acids must be replaced through diet.

Table 2. Guidelines for Approximate Protein, Fat and Carbohydrate Levels in Canine Athletes

Activity Level	Protein % of Calories	Fat % of Calories	Carbohydrate % of Calories
Sprint	25	30	45
Endurance	35	>55	10-20
Intermediate	>=25	35-65	10-40

Adapted from Toll and Reynolds, 2002,[1] and Hill (in press).[7]

Physical activity necessitates an increase in metabolism, which in turn increases the need for energy. Fat is the most energy-dense nutrient available to fulfill this need. During moderately intense work, both FFA and carbohydrates are metabolized for energy. Training in conjunction with higher fat diets increased a dog's capacity for using FFA by raising its carbohydrate threshold.[1] The carbohydrate threshold is the point at which dogs switch from aerobic FFA metabolism to aerobic carbohydrate metabolism.

The advantage to this change is twofold. Fats have more energy per gram so each gram oxidized nets more fuel for exercise. Carbohydrates are available in very limited supply in the body therefore sparing them until needed is beneficial. Working dogs consuming higher fat diets respond to an exercise bout by releasing more FFA than dogs fed an isocaloric diet of lower fat content.[14] Finally, increased fat in a balanced diet has been shown to increase the maximal rate of fat oxidation by 20 to 30% in dogs exercised at a moderate intensity (less than 75% VO_2 max), which leads to an increased oxidative capacity.[16]

On the other hand, canine athletes in this category also may have short periods of more intense activity, requiring them to utilize muscle glycogen for energy. Appropriate feeding of carbohydrates can aid in maintaining and restoring muscle glycogen, as described in "Canine Athletes and Carbohydrate Management During Exercise" on page 6.

Like endurance dogs, intermediate canine athletes are susceptible to lipid peroxidation of membranes. Diets with extra antioxidants like vitamins E and C and selenium would help to minimize excessive free radical production especially when dogs are consuming higher fat diets.[13]

Practical Feeding Management of Intermediate Canine Athletes

As important as the nutrients fed to canine athletes are the feeding practices used to manage the delivery of those nutrients. Three things need to be considered when managing food intake in canine athletes: diet digestibility, hydration and feeding time.

Intermediate canine athletes can vary in energy requirements depending on the sport in which they are participating, the environmental conditions, and the frequency of exercise. Diet digestibility should be at least 80% to promote adequate uptake of the nutrients without excess fecal bulk. Highly digestible, high energy foods allow these athletes to ingest enough calories to meet energy needs while in training and competing in athletic events.[1] The more energy dense the food is, the less voluminous the stool, which is advantageous in exercising dogs. Kronfeld et al estimated that racing sled dogs with full colons were handicapped equivalent to a jockey and racehorse being assessed a 20 lb handicap.[5]

Hydration is important in exercising dogs for two reasons. Exercise is a heat-producing activity and water is required to help dissipate heat. About 60% of heat dissipated by dogs during exercise is through water evaporation in the respiratory tract.[17] Also, water is needed to remove the byproducts of energy metabolism. It is very important to keep exercising dogs hydrated because this may be the most important determinant of endurance and performance.[1] Yet, in many cases, exercising dogs may be distracted by their task or the environment, so are not motivated to drink. Dogs should be actively encouraged to drink water during extended periods of exercise. Unlike humans, sweat is not a primary

avenue for thermoregulation for dogs. Therefore, they do not benefit from electrolyte replacement drinks.

Finally, timing of meals is important in canine athletes. Exercise alters gastrointestinal transit time and therefore can change nutrient digestion and absorption.[18] Exercise also can cause mild hypoxia in the gut due to redistribution of blood flow.[1] In addition, the heat of digestion can increase heat load in exercising dogs that are already at risk for excessive heat production. Due to the heat of digestion, dogs fed 4 hours before exercise had higher core temperatures than those fed 17 hours before exercising.[19] Approximately 23 hours are required for the complete digestion of a large meal in a dog.[18] Dogs fed less than 23 hours before an exercise event may have fecal matter in the colon that can compromise performance by adding extra weight to the dog.

It is very important to keep exercising dogs hydrated because this may be the most important determinant of endurance and performance.

Some researchers and dog enthusiasts theorize that feces in the colon can also cause cecal slap.[1] Cecal slap is a condition during which the residual feces "slaps" against the colon causing irritation of the surrounding epithelium and perhaps inducing diarrhea during and after exercise. It is recommended that intensely exercising dogs be fed approximately 24 hours before an intense exercise bout to help alleviate problems associated with a full colon. If the sporting activity in which they are participating is a multiple day event, then dogs should be fed as soon as possible after exercise so that they have the maximum amount of time to digest the meal before the next exercise bout. It is appropriate to feed a dog only when it is no longer panting or exhibiting signs of heat stress or dehydration. Most dogs can be fed within 45 minutes of cessation of exercise.

Summary

Athletic dogs generally require more energy, protein and antioxidants than sedentary dogs. The extra nutrients required are directly related to the exercise intensity, frequency and duration. Most dogs that participate in canine athletic events are considered intermediate athletes that use a combination of aerobic and anaerobic fuels. Though most of the research on the nutrient requirements of exercising dogs has been completed using either greyhounds or sled dogs, recommendations can still be drawn from this work and applied to intermediate canine athletes. Feeding management practices, including diet digestibility, hydration, and timing of feeding, are vitally important to canine athletes and can directly affect canine athletic performance.

About the Authors

- Dr. Jill Cline is a Research Scientist with Nestlé Purina PetCare and has over 8 years' experience in the pet food industry. She has an active interest in sporting dog nutrition and has lectured widely on this topic. Jill and her husband live in Arkansas with their "intermediate" sporting dogs.

- Dr. Arleigh Reynolds is an active musher with over 15 years' experience studying the nutritional needs of endurance dogs. Prior to joining Purina, Dr. Reynolds was the Clinical Nutritionist at the veterinary school at Cornell University. Dr. Reynolds currently manages and conducts research at Nestlé Purina's sled dog research facilities in Alaska.

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Canine Athletes and Carbohydrate Management During Exercise

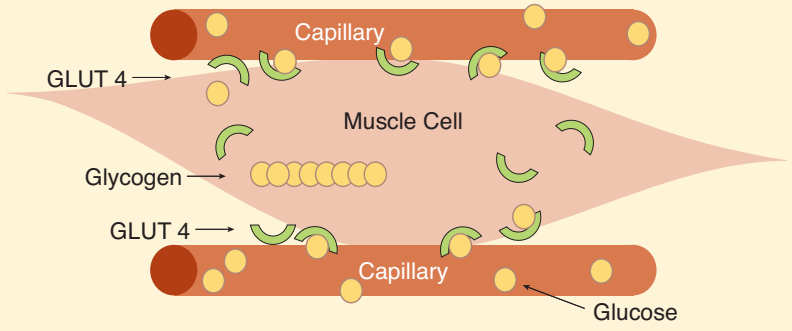
Jill Cline, PhD, and Arleigh Reynolds, DVM, PhD, DACVN

The energy expenditure associated with different activities ranges from extreme (Iditarod sled dogs) to minimal (recreational jogging with people). Though all dogs should be fed a complete and balanced diet, some canine athletes require special nutrient management. For example, dogs that participate in activities such as sled racing, pack hound hunting, field trialing and working livestock will typically have increased energy requirements. These dogs, along with racing greyhounds, flyball, search and rescue, military and police dogs, may also have special requirements for carbohydrates post-exercise.

The Need for Carbohydrate Replenishment

During the first 2 to 5 minutes of exercise, when running up a hill or when short bursts of intense activity are required, glycogen is the primary fuel in dogs. Glycogen is made up of strings of 25 or fewer glucose molecules and is the storage form of glucose in the muscle and liver. However, glycogen stores are very limited in the body. Therefore, this is a critical fuel source that, when depleted, may affect a dog's ability to perform or exercise to the best of its capability. Studies in humans have shown that long-distance runners have decreased speed and a perception of greater fatigue if their muscle glycogen is not repleted during multiple days of running.[1] Likewise, dogs with low glycogen levels are anecdotally described as "not being fresh," "losing focus," or "losing drive." Canine athletes exercise most efficiently when they use free fatty acids as the primary fuel source. However, some glycogen is needed, especially during bouts of increased exercise intensity.[2]

Figure 1. GLUT 4 transporters are externalized during and up to 30 minutes after exercise in dogs. The externalized transporters can take up glucose from the bloodstream independent of insulin concentration. The rapidly taken-up glucose is then converted to glycogen to replenish glycogen stores.



Dogs that were exercised at 75 to 80% VO_2 max then fed a normal meal only replaced 65% of the pre-exercise levels of muscle glycogen within 24 hours when fed a normal food ration.[3] This level of exercise intensity would be similar to the amount of effort hunting foxhounds or sprint sled-racing dogs would typically expend. Dogs that perform intense exercise, especially on successive days or successive times in one day, may have compromised exercise performance because of low muscle glycogen.

Normally, in a sedentary dog, insulin dictates the amount of glucose taken up by the muscle. However, during and for a short period after exercise, the glucose transporter GLUT4 is externalized to the surface of the muscle cell to facilitate glucose uptake.[4] This insulin-independent mechanism allows for rapid uptake of glucose to the cells where it can be used to restore glycogen reserves (Figure 1). This very important change in metabolism allows for the rapid repletion of glycogen to the muscle cells providing there is enough circulating glucose available to be transported by GLUT4. The externalization of GLUT4 is triggered by exercise regardless of intensity. GLUT4 externalization generally lasts up to 30 minutes post exercise.[4] Insulin dependant replenishment of glycogen is slower and may not fully replenish glycogen stores. Thus, optimum restoration of muscle glycogen must begin during the first 30 minutes after exercise.

Methods of Carbohydrate Replenishment

Several schemes have been used to enhance glycogen replenishment in canine athletes. Simple carbohydrates like candy and sucrose are easy to carry and deliver to the dog in the field. However, simple sugars are hydrophilic and can cause gastrointestinal upset. Therefore, either large amounts of water must be administered with the sugar or the body shifts large amounts of water from other tissues to the gut to hydrate the sugars. The end result can be osmotic diarrhea. In addition, the mobilization of water from the tissues to the gut can exacerbate dehydration. Hydration is always a concern in intensely exercised dogs, particularly in extreme heat or cold. Finally, simple sugars are so rapidly absorbed into the bloodstream and taken up by cells that there can be a concomitant insulin spike and resulting rebound hypoglycemia.

Fructose, particularly honey, has been used for canine athletes. However, fructose must be converted to glucose in the liver via gluconeogenic path-

ways. This time and energy expending process makes it difficult to process adequate fructose into glucose within the 30-minute window during which the GLUT4 transporters are externalized. Like sucrose, fructose is hydrophilic and may cause GI upset or rebound hypoglycemia.

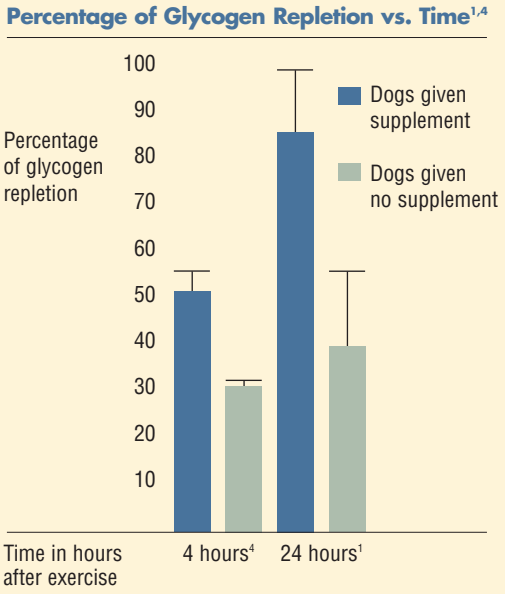
At the opposite end of the carbohydrate spectrum are complex carbohydrates like starches and whole grains. The main disadvantage of these carbohydrates is that they require significant amounts of time in order to be digested and absorbed, making it difficult for large amounts of glucose to be made available during exercise and up to 30 minutes after.

Recent research has shown that the most effective way to replenish carbohydrates in a canine athlete is through provision of modified starches called maltodextrins.[5] Maltodextrins are 8 to 20 glucose units long; therefore, they fall between simple sugar and complex starches in structure. Maltodextrins are rapidly absorbed and taken up by the muscle without the insulin spikes or other associated GI problems attributed to other carbohydrate sources.

Several studies have examined the benefits of post-exercise maltodextrin supplementation in dogs that perform prolonged exercise. Dogs that were given 1.5 to 2.0 g maltodextrins/kg body weight post-exercise were able to recover, on average, about 50% of pre-exercise glycogen stores within 4 hours and about 85% of pre-exercise glycogen within 24 hours, while dogs fed but not supplemented recovered less than 40% of their pre-exercise glycogen after 24-hours (Figure 2).[6]

Further studies confirmed the ability of a maltodextrin bar to enhance plasma glucose levels — an indicator of glucose availability. Dogs given a bar at the beginning and end of a 2-hour exercise period had significantly higher blood glucose concentrations during exercise and up to 90 minutes after exercise compared to unsupplemented dogs, as well as compared to pre-exercise glucose levels. In addition, dogs supplemented with the maltodextrin bar only after exercise had moderately elevated blood glucose levels within 15 minutes of administration. Elevated blood glucose indicates that substrate is available for muscle and liver glycogen repletion.[7] These results indicate that maltodextrin supplementation enhances blood glucose concentration to support muscle function during exercise and muscle glycogen recovery.[7]

Figure 2. Glycogen replenishment was greater in dogs given maltodextrins within 15 minutes of finishing exercise at both 4 hours and 24 hours post-exercise. Dogs whose glycogen is replenished within 24 hours are more likely to perform better during successive days of exercise.



Conclusions

The bulk of research on carbohydrate replacement was conducted with dogs participating in exercise over 30 minutes in length; however, there is application in dogs that participate in primarily anaerobic activity as well. Anaerobic exercise relies mainly on muscle glycogen for fuel.[8,9] For example, greyhounds have significant depletion of muscle glycogen after a race.[10] Also, dogs that may not be physically conditioned to perform in athletic events or exercise may benefit from maltodextrin supplementation for glycogen repletion. Untrained or poorly conditioned dogs, for example, a Labrador retriever at the beginning of hunting season, rely more heavily on carbohydrates as an energy source than a conditioned dog. Conditioned dogs rely on free fatty acids as their primary fuel source when performing exercise more than a few minutes in duration.[8,9] However, any canine sport that requires sudden bursts of speed or bouts of increased intensity could benefit from glycogen replacement post-exercise in conjunction with a regular balanced feeding regimen.

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