FEEDING FAT TO MANAGE MUSCLE DISORDERS

STEPHANIE VALBERG AND ERICA MCKENZIE
University of Minnesota, St. Paul, Minnesota

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Exertional rhabdomyolysis has been recognized in horses for more than 100 years as a syndrome of muscle pain and cramping associated with exercise. In the last ten to twelve years, research advances have provided greater insight into this syndrome. Of greatest importance is the realization that exertional rhabdomyolysis comprises several myopathies that, despite similarities in clinical presentation, differ considerably in regards to pathogenesis (cellular events, reactions, and other pathologic mechanisms occurring in the development of disease).

Tying-up is a common disorder in Thoroughbred racehorses. During the 1995 racing season, 1000 Thoroughbreds at Canterbury Park were evaluated. Five percent of the horses exhibited signs of tying-up during the season. Of the two- and three-year-old horses that presented with tying-up, 15% could not be raced at all that season. Interestingly, if the horses that experienced tying-up could race, there was no difference between their performances and those of matched control horses.

Exertional rhabdomyolysis continues to be a performance-limiting or career-ending disorder for many equine athletes. Advances in the management of horses with exertional rhabdomyolysis, particularly in the way they are fed, have significantly reduced the impact of the disorder.

Clinical Signs of Rhabdomyolysis and Differential Diagnoses

Clinical signs of exertional rhabdomyolysis usually occur shortly after the beginning of exercise. The most common sign is firm and painful muscles over the lumbar (loin) and sacral (croup) regions of the topline, including the large gluteal muscles. Excessive sweating, tachypnea (quick, shallow breathing), tachycardia (rapid heartbeat), and muscle fasciculations are also noticed. In extreme cases, horses may be reluctant or refuse to move and may produce discolored urine due to the release of myoglobin from damaged muscle tissue. Episodes of ER vary from subclinical to severe in which massive muscle necrosis and renal failure from myoglobinuria occurs.

In order for exertional rhabdomyolysis to be confirmed, serum creatine kinase (CK) and aspartate transaminase (AST) activity must be elevated during periods of muscle stiffness. When muscle cells are damaged, CK and AST are released

into the bloodstream within hours. AST activity may be heightened in asymptomatic horses with chronic exertional rhabdomyolysis. If CK and AST values are not above normal, differential diagnoses should be considered for horses that are reluctant to move, recumbent, or producing off-colored urine. Such diagnoses include lameness, colic, laminitis, pleuropneumonia, tetanus, aorto-iliac thrombosis, intravascular hemolysis, bilirubinuria, or neurological disease. Causes of non-exercise-associated myopathies include infectious and immune-mediated myopathies (influenza, *Clostridium* sp., *Streptococcus* sp., *Sarcocystis* sp.); nutritional myodegeneration; traumatic or compressive myopathy; idiopathic pasture myopathy; and toxic muscle damage from the ingestion of monensin, white snake root, or vitamin D-stimulating plants.

Etiology and Pathophysiology of Exertional Rhabdomyolysis

Exertional rhabdomyolysis can be subdivided into one of two distinct forms–sporadic and chronic. Horses that experience a single episode or infrequent episodes of muscle necrosis with exercise are categorized as having sporadic exertional rhabdomyolysis, whereas horses that have repeated episodes of exertional rhabdomyolysis accompanied by increased muscle enzyme activity, even with mild exertion, are classified as having chronic exertional rhabdomyolysis.

Sporadic Exertional Rhabdomyolysis

Sporadic exertional rhabdomyolysis occurs most commonly in horses that are exercised in excess of their level of conditioning. This happens frequently when a training program is accelerated too abruptly, particularly after an idle period of a few days, weeks, or months. Endurance competitions held on hot, humid days may elicit sporadic exertional rhabdomyolysis in susceptible horses because of high body temperatures, loss of fluid and electrolytes in sweat, and depletion of muscle energy stores. These metabolic imbalances can lead to muscle dysfunction and damage. In some instances, horses seem more prone to exertional rhabdomyolysis following respiratory infections. Therefore, horses should not be exercised if they have a fever, cough, nasal discharge, or other signs of respiratory compromise.

Chronic Exertional Rhabdomyolysis

Chronic exertional rhabdomyolysis arises frequently from heritable myopathies such as polysaccharide storage myopathy (PSSM) or recurrent exertional rhabdomyolysis (RER). Other causes of chronic exertional rhabdomyolysis are probable; however, their etiopathologies remain unknown.

Polysaccharide storage myopathy affects primarily Quarter Horses and horses with Quarter Horse bloodlines such as Paints and Appaloosas. In addition, warmbloods and Morgans have been diagnosed with this disorder. PSSM is a glycogen storage disorder characterized by the accumulation of glycogen and abnormal polysaccharide complexes in 1-40% of skeletal muscle fibers. Muscle glycogen concentrations in affected horses are 1.5 to 4 times greater than in normal horses. Horses with PSSM typically have calm dispositions and are in good body condition. A change in exercise routine often triggers an episode of rhabdomyolysis. This change need not be profound; something as subtle and seemingly harmless as unaccustomed stall confinement may provoke an episode. Signs of PSSM include sweating, stretching out as if posturing to urinate, muscle fasciculations, and rolling or pawing following exercise. Severe cases may display stiffness and hesitance to move within minutes of starting exercise, and extreme cases may result in the horse being unable to stand and in discomfort even when lying down. Serum creatine kinase (CK) activity may be persistently elevated despite an extended period of rest.

A similar glycogen storage disorder has been reported in draft breeds. This syndrome is referred to as equine polysaccharide storage myopathy (EPSM). While similarities exist between PSSM and EPSM, draft horses with EPSM often exhibit signs not indicative of PSSM, including normal serum creatine kinase, difficulty backing and holding up limbs, a shivers-like gait, and loss of muscle mass. Some drafts afflicted with EPSM also show recumbency and weakness with only slight increases in serum CK and AST, and this combination of signs is not seen in horses with PSSM.

Recurrent exertional rhabdomyolysis commonly afflicts Thoroughbreds and likely Standardbreds and Arabians. In Thoroughbreds, RER has been identified as a heritable defect in intracellular calcium regulation leading to excessive muscular contraction and necrosis with exercise. In one investigation of heritability, a farm had 18 horses tie-up repeatedly over three years. Fourteen of the broodmares on this farm were bred to a particular stallion; all of the offspring experienced tying-up. When the same mares were bred to another stallion, only two of the offspring tied-up. On a different farm, one mare prone to tying-up produced six offspring with the disorder. At this juncture, a genetic connection is almost certain.

The most severely affected horses are nervous young (two-year-old) fillies in race training at tracks. The sex predilection for females, however, is not obvious in older horses with RER. Episodes of RER occur most often when horses are restrained during exercise, and incidences of RER may become more frequent as level of fitness increases. Clinical expression of RER is often stress-induced, and horses with RER are typically described as having nervous or very nervous temperaments. Older horses with RER may have muscle stiffness and soreness but only show overt evidence of tying-up after steeplechase or cross-country phases of a three-day event.

Diagnostic Approach to Chronic Exertional Rhabdomyolysis

A thorough and systematic diagnostic approach is recommended to help accurately establish and address possible causative factors for chronic exertional rhabdomyolysis. Muscle enzyme activity levels following light exercise (15 minutes of trotting on a longe line) may provide evidence for a diagnosis of subclinical rhabdomyolysis. In addition, horses experiencing intermittent episodes of rhabdomyolysis may also show abnormal elevations in CK after the same exercise test. The amount of exercise a horse tolerates without developing rhabdomyolysis can be used as a starting point for returning a horse to training.

Muscle biopsies are helpful in distinguishing PSSM from RER and in identifying other disorders that contribute to clinical signs of muscle stiffness. Biopsies taken on site are from the middle gluteal muscle using a modified Bergstrom biopsy needle and frozen immediately. Biopsies shipped by referring veterinarians are of the semimembranosus/tendinosis muscles performed by an open surgical technique. An experimental approach to identifying RER is to perform contracture tests on small intact pieces of muscle taken from between the ribs. The technique measures how the muscle responds to electrical stimulation (simulation of exercise) and to chemicals that are known to create cramps in human diseases similar to tying-up. Muscle from Thoroughbreds that tied-up reacted very differently compared to muscle from Thoroughbreds without the disorder in that it was much more sensitive to contractions induced by halothane, caffeine, and potassium. The contracture reaction indicated a possible problem with the way calcium is regulated inside the muscle cell.

Nutritional Management

Diet manipulation is becoming the method of choice in controlling exertional rhabdomyolysis, particularly in equine athletes that are closely monitored for pharmacological substances. A well-designed exercise program and a nutritionally balanced diet with appropriate caloric intake and adequate vitamins and minerals are the core elements of treating exertional rhabdomyolysis.

Vitamin E and selenium. Adequate amounts of vitamin E and selenium prevent the detrimental interaction of peroxides with lipid membranes of the muscle cell. Most horses with chronic rhabdomyolysis have adequate or more than adequate blood concentrations of vitamin E and selenium, and further supplementation has not been found to have protective effects on muscle integrity in exercising horses. Many feeds, particularly those designed for horses with rhabdomyolysis, provide adequate selenium supplementation and caution should be taken not to provide excessive selenium in the diet. Likewise, sufficient vitamin E is provided in most diets by green grasses, well-cured hay, and rice bran.

Electrolytes and minerals. Horses performing in hot weather often develop electrolyte imbalances. Free-choice access to loose salt or a salt block should be provided to these horses, or alternatively, one to four ounces of salt can be added to the feed daily. Extreme climatic conditions may necessitate the use of commercial electrolyte mixtures containing a 2:1:4 ratio of sodium:potassium:chloride. Fresh water should be available to horses at all times, especially if they are being supplemented with electrolytes.

Dietary imbalances of electrolytes, particularly deficiencies of sodium, potassium, and calcium, have been implicated in exertional rhabdomyolysis. Correction of imbalances may be crucial in the management of some exertional rhabdomyolysis cases.

Chromium. Supplementation with oral chromium (5 mg/day) has been reported to calm horses and improve their responses to exercise (e.g., lower peak concentrations of insulin, cortisol, and lactic acid). Chromium may assist glucose and glycogen metabolism, possibly by potentiating the action of insulin. The purported calming effect of chromium may be beneficial in horses with recurrent exertional rhabdomyolysis because it appears that stress is a critical precipitator of this disorder. Because PSSM horses display abnormal sensitivity to insulin, however, chromium supplementation may be counterproductive in these animals.

Effect of Modulation of Dietary Fat and Starch

Although PSSM and RER possess distinct etiologies, increasing dietary fat supplementation and decreasing dietary starch have resulted in beneficial effects to horses with both disorders. PSSM horses have enhanced insulin sensitivity, and reducing dietary starch as much as possible (by eliminating all grain) decreases the inevitable rise in glucose and insulin that occurs after consumption of concentrate feeds. With PSSM horses, even a slight amount of fat supplementation of a low to moderate caloric intake provides a favorable effect. In addition to diet alterations, improvement in clinical signs of muscle stiffness requires the addition of incrementally increasing amounts of daily exercise over one month.

While fat supplementation also helps horses with recurrent exertional rhabdomyolysis, the mechanism for this is not clearly understood. Unlike horses with PSSM, fat supplementation is only beneficial to RER horses when total dietary caloric intake is high. The beneficial effects of fat supplementation in RER horses may be due to the exclusion of dietary starch rather than specific protective effects of high dietary fat. Given the close relationship between nervousness and tying-up in horses with RER, assuaging anxiety and excitability by reducing dietary starch and increasing dietary fat may decrease predisposition to RER by making these horses calmer prior to exercise.

Fat Sources

Animal- and vegetable-based fats are the major sources of fat available for equine consumption. Examples of vegetable oils used for supplementation include corn, soy, peanut, coconut, safflower, linseed, flaxseed, and canola. Corn and soy oils are the most palatable. Vegetable oils are highly digestible (90-100%) and energy dense. While it can be messy to dole out, unpalatable to some horses, prone to rancidity in warm weather, and difficult to feed in large amounts, oil is an effective way to boost daily energy intake and may be the most economical way of providing fat to horses that do not require large amounts of supplementation. Horses receiving large amounts of oil may need vitamin E supplementation.

Animal fat varies in digestibility (75-90%). Because animal fat is more saturated, it tends to be solid at room temperature and would need to be melted before being top-dressed on feed. Most horses find animal-based fats less palatable than vegetable-based fats.

Rice bran contains about 20% fat as well as a considerable amount of vitamin E. Products containing rice bran are readily accepted by most horses. Commercial rice bran products are usually in powder or pellet form and are considerably more stable than animal fat and vegetable oils. Many rice bran-based products are balanced for calcium and phosphorus or are concurrently fed with a mineral supplement to offset the naturally high phosphorus content.

Controlled and field studies have shown that feeding 1.1 to 5 pounds of rice bran or rice bran-based products (Re-Leve by Hallway Feeds, Lexington, KY) to both PSSM and RER horses has resulted in significant improvement in disease.

Recommended Diets for Horses with PSSM and RER

Feeding recommendations for horses with chronic exertional rhabdomyolysis are displayed in Tables 1, 2, and 3. As with any horse, feeding forage at a rate of 1.5-2% of body weight is a fundamental part of the diet. The amount of fat supplied to horses with PSSM and RER is controversial. Part of this debate may be due to the fact that the diseases are often not distinguished. If PSSM horses are exercised regularly, many respond to low-calorie, low-starch diets that are only lightly supplemented with fat. Conversely, RER horses seem to benefit from fat supplementation only when they require high caloric intakes. Therefore, not all horses with exertional rhabdomyolysis require diets in which 25% of daily caloric intake is supplied by fat. In fact, such a diet is not always appropriate, is difficult to achieve in the face of high caloric requirements, and may result in problems with weight gain and unpalatable diets. Once caloric needs are assessed, a diet should be designed with an appropriate amount of fat and starch.

In Quarter Horse-related breeds, PSSM can usually be managed with grass hay or mixed hay and a fat supplement that is balanced for vitamins and minerals.

Starch should be decreased to less than 10% of daily digestible energy (DE) intake by eliminating grain and molasses. Rice bran can be gradually introduced

into the diet as powder or as a pelleted feed. Some horses that will not eat powder will consume pelleted forms of rice bran (Equi-Jewel, Kentucky Performance Products, Versailles, KY). It is important for owners to understand that if horses eat the rice bran at a slower rate than sweet feed this can be beneficial as it reduces rapid absorption of starch. Depending on the caloric requirements of the horse, 1-5 pounds of rice bran can be fed but must be combined with a reduction in dietary starch to less than 10% of DE. An alternative source of fat is corn oil added to alfalfa pellets. An upper limit of 600 ml of oil per day is recommended, and additional vitamin E should be added to the diet. It is not possible to achieve the high caloric requirements for intense exercise using oil supplementation of alfalfa pellets, sweet feed, or rice bran without exceeding recommended maximum amounts of these products. To achieve the appropriate caloric intake for PSSM horses performing intense exercise, high-fat, low-starch pelleted feeds designed for PSSM horses in intense exercise are recommended (Table 1). Supplying fat at 6-10% by weight (or 15-20% of DE) of the entire ration to PSSM Quarter Horses (unless a higher energy intake is required for exercise) is likely quite sufficient for managing PSSM and further benefit from more fat has not been demonstrated in controlled trials. Note, however, that none of these diets will result in clinical improvement of muscle stiffness and exercise tolerance without gradually increasing the amount of daily exercise and maximizing access to turn-out.

Table 1. Feeding recommendations for an average-sized horse (500 kg) with chronic exertional rhabdomyolysis at varying levels of exertion.

	Maintenance	*Light exercise*	*Moderate exercise*	*Intense exercise*
Digestible Energy (Mcal/day)	16.4	20.5	24.6	32.8
% DE as NSC, PSSM horses	<10%	<10%	<10%	<10%
% DE as NSC, RER horses	20%	<20%	<20%	<20%
% DE as fat, PSSM horses	20%	20%	15%-20%	15%-20%
% DE as fat, RER horses	15%	15%	15%-20%	20-25%
Forage (% bwt)	1.5- 2.0 %	1.5- 2.0 %	1.5- 2.0 %	1.5- 2.0 %
Protein (grams/day)	697	767	836	906
Calcium (g)	30	33	36	39
Phosphorus (g)	20	22	24	26
Sodium (g)	22.5	33.5	33.8	41.3
Chloride (g)	33.8	50.3	50.6	62
Potassium (g)	52.5	78.3	78.8	96.4
Selenium (mg)	1.88	2.2	2.81	3.13
Vitamin E (IU)	375	700	900	1000

Daily requirements derived from multiple research studies (% NSC and % fat) and Kentucky Equine Research recommendations. From: McKenzie, E.M., S.J. Valberg, and J. Pagan. Nutritional management of exertional rhabdomyolysis. In: E. Robinson (Ed.) Current Therapy in Equine Medicine 5.

Thoroughbred horses with frequent episodes of rhabdomyolysis are usually being fed 5-15 pounds of sweet feed per day. The incidence of subclinical rhabdomyolysis is low in Thoroughbreds being fed a moderate caloric intake whether it is in the form of sweet feed or rice bran. However, when calories are increased by the addition of more sweet feed, the incidence of subclinical and clinical rhabdomyolysis is much greater. One way to lower serum CK after exercise when a high caloric intake is required is to feed a low-starch, high-fat ration. For RER horses, the recommendation is to feed no greater than 20% of daily DE as nonstructural carbohydrate and to supply 20-25% of daily DE from fat. The diet should contain no more than five pounds of sweet feed, 600 ml of vegetable oil, and five pounds of rice bran per day. For horses undergoing intense exercise, the combination of sweet feed and oil or sweet feed and rice bran does not achieve an adequate DE without feeding amounts of cereal grains that have been shown to elicit rhabdomyolysis in susceptible horses.

A specialized diet, Re-Leve, has been designed for intensely exercised horses with chronic exertional rhabdomyolysis. Re-Leve contains 13% fat by weight (rice bran and corn oil) or 20% DE as fat and only 9% DE as starch. This type of high-energy diet for RER horses might be provided through a combination of other commercially available grains, several fat supplements, and highly fermentable fiber sources (soy hulls, beet pulp). Other commercially available concentrates contain moderate amounts of fat (6-10%) and have lower NSC values (17–30% by weight). However, they cannot be fed in the quantities necessary to achieve the calories required to sustain intense exercise in RER horses without exceeding recommended NSC limits for these horses. They should therefore be combined with a fat supplement.

Expectations of fat supplementation. The time required for improvement in signs of exertional rhabdomyolysis is controversial. It has been suggested that a minimum of four months of supplementation is required and that relapses are associated primarily with disruption of supplementation. However, in the author's experience clinical improvement with PSSM is more dependent on the amount of daily exercise and turn-out than on the length or amount of dietary fat supplementation. For example, when serum CK was monitored daily post-exercise, levels were almost within the normal range after four weeks of daily exercise, without fat supplementation. In addition, when PSSM horses were turned out 24 hours a day on grass, post-exercise serum CK was normal compared to high activities during the same exercise test with stall-kept horses on a hay diet. Thus, it seems that consistent fat supplementation without implementing a structured daily exercise regime in PSSM horses is highly likely to result in failure, and confinement while consuming high levels of fat is likely to lead to obesity.

Surprisingly, recent studies in RER horses show that significant reductions or normalization of post-exercise serum CK activity occurs within a week of commencing a diet providing 20% DE as fat and 9% DE as starch. This low

serum CK activity compared to the high CK activity observed in the same horses on an isocaloric diet where 40% DE was starch was not the result of any measurable change in muscle glycogen or metabolism during exercise. Potentially, the rapid response to decreasing starch and increasing fat was due to neurohormonal changes that resulted in a calmer demeanor, lower pre-exercise heart rates, and a decreased incidence of stress-induced rhabdomyolysis. Avoiding prolonged stall rest in fit Thoroughbreds with RER is also important since post-exercise CK activity is higher following two days of rest compared to values taken later in the week when performing consecutive days of the same amount of submaximal exercise. It is quite possible that exercise exerts beneficial effects on horses with chronic exertional rhabdomyolysis that are separate from the impact of reduction in dietary starch and/or fat supplementation. Failure to implement an appropriate exercise routine will likely lead to failure to control rhabdomyolysis.

Additional management strategies for chronic exertional rhabdomyolysis. Daily exercise appears to be crucial for successful dietary control of PSSM. It is recommended that turn-out and some exercise be started as soon as stiffness abates following an episode of rhabdomyolysis in PSSM horses, rather than waiting for muscle enzyme activity to normalize. Serum CK activity frequently remains increased in PSSM animals that are stall rested. Severely affected horses may only be able to manage a few minutes of exercise a day, but with gradually increasing intervals of walk and two minutes of trot (but no more than two-minute intervals) per day, many of these horses are capable of eventually accomplishing intense daily exercise without clinical rhabdomyolysis. Stall confinement should be kept to a maximum of 12 hours per day, and pasture turn-out is ideal.

RER horses are often very fit when they develop rhabdomyolysis and require only a few days off before commencing a reduced amount of training. Stall confinement should be kept to less than 24 hours if possible. Since RER appears to be a stress-related disorder, management strategies to reduce stress and excitability in these horses are important. These include turn-out, exercising or feeding these horses before other horses, providing compatible equine company, and the judicious use of low-dose tranquilizers during training. Anecdotal reports of increased nervousness have been received when selenium is supplemented at higher than the recommended levels. Feeds designed for RER should be evaluated for their selenium concentrations and should not be supplemented in addition if adequate levels are provided in the feed.

All supplemental feeds should be reduced in amount on days when energy requirements are not as high, particularly if the horse is at risk of weight gain. Other management strategies may help to decrease the intensity of the postprandial glycemic response, and include feeding small meals, providing at least 1.5-2.0% body weight per day in forage, and feeding a forage source either two hours before or concurrently with any grain. Avoiding high-starch supplements such as molasses is also important.

Table 2. Potential rations for a 500-kg horse with recurrent exertional rhabdomyolysis.

	Light exercise	*Moderate exercise*	*Intense exercise*
FORAGE	7-9 kg quality grass hay or pasture	7-9 kg quality grass hay or pasture	7-9 kg quality grass hay or 20:80 mix alfalfa/grass
PLUS:			
DIET 1:*	1.5 kg sweet feed + 1 kg rice bran	2 kg sweet feed + 1 kg rice bran	2.1 kg sweet feed + 1.4 kg of rice bran + 1.4 kg beet pulp**
OR: DIET 2:	1.5 kg of Re-Leve	3 kg of Re-Leve	5 kg of Re-Leve
OR: DIET 3:*	1 kg of sweet feed + 200 ml oil	2 kg of sweet feed + 500 ml oil	Combination cannot achieve required DE intake

*Vitamin and mineral supplement required for nonfortified feeds. The mineral recommended for the specific rice bran product should be provided (not necessary for Re-Leve).
**Soak beet pulp before feeding.
Addition of 50-100 g of salt per day to all rations is recommended based on level of exertion.
From: McKenzie, E.M., S.J. Valberg, and J. Pagan. Nutritional management of exertional rhabdomyolysis. In: E. Robinson (Ed.) Current Therapy in Equine Medicine 5.

Table 3. Potential rations for a 500-kg horse with polysaccharide storage myopathy.

	Light exercise	*Moderate exercise*	*Intense exercise*
FORAGE	7-9 kg quality grass hay or pasture	7-9 kg quality grass hay or pasture	7-9 kg quality grass hay or 20:80 mix alfalfa/grass
PLUS:			
DIET 1*	1.5 kg rice bran	2.25 kg rice bran	Cannot achieve required DE intake with rice bran alone
DIET 2	1.5 kg Re-Leve	2.5 kg Re-Leve	5 kg of Re-Leve
DIET 3*	1.8 kg alfalfa pellets + 475 ml oil	Combination cannot achieve required DE intake	Combination cannot achieve required DE intake

*Vitamin and mineral supplement required for nonfortified feeds. The mineral recommended for the specific rice bran product should be provided (not necessary for Re-Leve). Addition of 50-100 g of salt per day to all rations is recommended based on level of exertion. From: McKenzie, E.M., S.J. Valberg, and J. Pagan. Nutritional management of exertional rhabdomyolysis. In: E. Robinson (Ed.) Current Therapy in Equine Medicine 5.

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