

# An epidemiological study of myopathies in Warmblood horses

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## Summary

**Reasons for performing study:** There are few detailed reports describing muscular disorders in Warmblood horses.

**Objectives:** To determine the types of muscular disorders that occur in Warmblood horses, along with presenting clinical signs, associated risk factors and response to diet and exercise recommendations, and to compare these characteristics between horses diagnosed with polysaccharide storage myopathy (PSSM), those diagnosed with a neuromuscular disorder other than PSSM (non-PSSM) and control horses.

**Methods:** Subject details, muscle biopsy diagnosis and clinical history were compiled for Warmblood horses identified from records of biopsy submissions to the University of Minnesota Neuromuscular Diagnostic Laboratory. A standardised questionnaire was answered by owners at least 6 months after receiving the muscle biopsy report for an affected and a control horse.

**Results:** Polysaccharide storage myopathy (72/132 horses) was the most common myopathy identified followed by recurrent exertional rhabdomyolysis (RER) (7/132), neurogenic or myogenic atrophy (7/132), and nonspecific myopathic changes (14/132). Thirty-two biopsies were normal. Gait abnormality, 'tying-up', Shivers, muscle fasciculations and atrophy were common presenting clinical signs. Forty-five owners completed questionnaires. There were no differences in sex, age, breed, history or management between control, PSSM and non-PSSM horses. Owners that provided the recommended low starch fat supplemented diet and regular daily exercise reported improvement in clinical signs in 68% (19/28) of horses with a biopsy submission and 71% of horses diagnosed with PSSM (15/21).

**Conclusions:** Muscle biopsy evaluation was a valuable tool to identify a variety of myopathies in Warmblood breeds including PSSM and RER. These myopathies often presented as gait abnormalities or overt exertional rhabdomyolysis and both a low starch fat supplemented diet and regular exercise appeared to be important in their successful management.

**Potential relevance:** Warmbloods are affected by a variety of muscle disorders, which, following muscle biopsy diagnosis can be improved through changes in diet and exercise regimes.

## Introduction

The application of the muscle biopsy technique to horses with neuromuscular disorders has contributed to the identification of polysaccharide storage myopathy (PSSM) (Valberg *et al.* 1992), recurrent exertional rhabdomyolysis (RER) (Lentz *et al.* 1999), mitochondrial myopathy (Valberg *et al.* 1994), myotonic dystrophy (Hegreberg and Reed 1990) and immune-mediated myopathies (Lewis *et al.* 2007). These disorders are largely reported in Quarter Horse related breeds, Thoroughbreds, and draught and Arabian horses in North America.

Although Warmbloods are popular breeds, there are very few reports of myopathies in these horses. Draught crosses and Warmblood type breeds constituted only 1% of the total population of horses with exertional rhabdomyolysis (ER) in Great Britain (Harris 1991), and only 2 of 65 Warmblood horses studied in Australia (Cole *et al.* 2004). Quiroz-Rothe *et al.* (2002) described a Warmblood with back pain and PSSM, and a Warmblood and draught cross were described with PSSM in the UK (McGowan *et al.* 2003). Additionally, 3 draught Thoroughbred crosses (Valentine *et al.* 1998), and an unspecified number of Warmblood horses, were included in a group reported to have PSSM in North America by Valentine *et al.* (2001b). However, these studies provide minimal information regarding the prevalence or typical clinical manifestations of PSSM in Warmblood horses.

Importation of European Warmblood horses has increased in the US over the past decade, as has the production of North American Warmbloods by crossing draught, Warmblood and light breeds. The development of specialised neuromuscular diagnostic laboratories and the adaptation of the biopsy technique as a routine diagnostic tool in North American equine veterinary practices have provided a means to study myopathies in a wide spectrum of horses (McCue *et al.* 2006).

Based on evaluation of over 1400 muscle biopsies from North American horses with suspected neuromuscular disorders, a recent study found that Warmbloods were the fourth most common breed group for which muscle biopsies were submitted (McCue *et al.* 2006). This report described the prevalence of PSSM in Warmbloods with suspected neuromuscular diseases; however, it provided limited detail regarding specific breeds affected by various myopathies, their clinical characteristics, and response to treatment.

The objectives of the present study were: 1) to describe through an in depth retrospective design, the types of muscular

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disorders occurring in Warmblood horses in North America, in addition to the gender, associated history and clinical signs; and 2) to determine if the breed and gender distribution, age of onset, clinical signs and response to diet and exercise recommendations differed between Warmbloods diagnosed with PSSM, Warmbloods with a neuromuscular disorder other than PSSM and control horses (those unaffected by a neuromuscular disorder).

## Materials and methods

### Retrospective study (Group 1)

Records of 2234 horses with neuromuscular disorders that had muscle biopsies submitted to the University of Minnesota Neuromuscular Diagnostic Laboratory between January 1996 and September 2006 were reviewed to identify Warmblood horses, defined as those classified as Warmbloods, Warmblood crosses or draught crosses by the referring veterinarians on the submission information form. Information regarding the specific Warmblood breed was requested on the form, but was not always available.

**Histopathology:** This was reviewed and horses were placed into categories that included PSSM (*Grade 1* and *2*), RER, atrophy (myogenic or neurogenic), nonspecific myopathic signs and no abnormalities. A diagnosis of *Grade 1* PSSM was based on the presence of periodic acid Schiff (PAS) positive cytoplasmic or subsarcolemmal aggregates of granular polysaccharide, which were typically amylase sensitive. A diagnosis of *Grade 2* PSSM was made if muscle fibres contained PAS-positive, abnormal crystalline inclusions which were resistant to amylase digestion.

A diagnosis of RER was based on a history of chronic episodes of rhabdomyolysis, no evidence of abnormal polysaccharide and the presence of increased numbers of centrally located myonuclei, with or without myonecrosis in haematoxylin and eosin (H&E) stains.

Muscle atrophy was defined by muscle fibre diameter, or shape that was less than the expected norm for that age of horse. Muscle atrophy was classified as neurogenic if angular atrophied fibres were present and myogenic if fibres had anguloid atrophy (Cummings *et al.* 1994).

Nonspecific signs of a myopathy included mild variation in muscle fibre sizes, rimmed vacuoles, macrophage infiltration or mild increases in centrally displaced nuclei without a history of exertional rhabdomyolysis.

Muscle biopsies were considered normal if no histological abnormalities were evident.

**Clinical information:** Information regarding age at the time of biopsy, gender, history and presenting clinical signs were evaluated for each diagnostic category. Based on information provided by the referring veterinarians at the time of muscle biopsy submission, clinical signs exhibited at the time of presentation were grouped into 5 nonexclusive categories: 'tying-up', gait abnormality, muscle atrophy/wasting, muscle fasciculations and shivers. A diagnosis of shivers was based on the description of the following characteristics: reluctance to back-up or pick up the hind legs, hyperflexion and abduction of the rear limbs with delayed placement on the ground, tail hike and trembling (Baird *et al.* 2006).

**Statistics:** For the purposes of statistical comparison, horses were placed into 2 broad categories: those diagnosed with PSSM and those without evidence of PSSM.

### Follow-up survey (Group 2)

Owners were selected for a follow-up study if their Warmblood horse had a muscle biopsy submitted a minimum of 6 months prior to initiating the present study. Although this delay may have created recall bias it was important in order to allow enough time for the recommended diet to take effect. The same researcher (L.M.H.) attempted to contact owners of 116 horses that fitted these criteria to complete a standardised closed ended questionnaire by telephone. A minimum of 3 attempts was made to contact each owner. Reasons for horses not being included in the study included unwillingness of the owner to participate, unsuccessful attempts to contact owner (changed or disconnected telephone number, owner moving away), and the horse being sold or lost to follow-up or subjected to euthanasia. Horse owners were also asked to complete an identical questionnaire for a similar normal horse to form a control cohort, which was not matched for age, gender or time of possession.

Information was collected with respect to subject details, history, breed, sex, date of birth, use, temperament, medical history, diet and exercise regimes, prior to and following muscle biopsy diagnosis. In addition, more detailed information regarding the clinical signs on presentation and the diagnosis based on histological analysis (PSSM, RER, neurogenic atrophy, nonspecific myopathy, no abnormalities) was obtained from the biopsy report for each horse. All horse owners received the same written dietary and exercise recommendations irrespective of the diagnosis made on histology of their horse's muscle biopsy. The aim of these recommendations was to provide a diet with <10% of digestible energy (DE) as nonstructural carbohydrates (NSC), and with 15–20% of DE as fat; with maximal turnout and institution of a regular and gradually increasing exercise regime.

Detailed dietary analysis was not possible to perform in the study. Rather, compliance with dietary recommendations was analysed by grouping the diets into 4 categories based on reported information (Firshman *et al.* 2003) that the horses had received: *Category 1*, cereal grain with no additional fat supplement; *Category 2*, a concentrate that was grain-based but had additional fat added; *Category 3*, a low starch, high fibre, fat supplemented feed with no grain; and *Category 4*, fed hay only.

Feeding diets from *Categories 2* and *3* was considered compliant with dietary recommendations. Increasing the level of turnout and/or frequency of ridden exercise and maintaining regular exercise and turnout were considered compliant with exercise recommendations. Owners were not considered to be in compliance if only the diet or the exercise recommendations were followed. Recommendations were considered effective if the owner reported that the horse showed an improvement in the reported clinical signs and returned to previous or expected levels of performance.

### Statistical analyses

Categorical data (*Group 1*: gender, age, clinical signs; *Group 2*: age, gender, temperament clinical signs, activity at time of clinical signs, horse use, turnout time, diet category, owner compliance, improvement) were evaluated with a Pearson's Chi-square test or Fisher's exact test where appropriate. Normality of the data for

continuous variables was tested using a Kolmogorov-Smirnov test. Normally distributed data (age of onset, time in owners possession) were compared using an unpaired 2 sample *t* test. Values are expressed as mean  $\pm$  s.e. One way ANOVA was used to compare age between control horses, PSSM horses and non-PSSM horses. Data with non-Gaussian distribution (creatinase kinase [CK] and aspartate aminotransferase [AST]) were compared using a Mann-Whitney U test. Values that were not normally distributed are expressed as median and range. The distribution of horses with PSSM was compared to those without PSSM between the responding owners in *Group 2* and the nonresponding owners from *Group 1* using a Fisher's exact test. Significance was set at  $P < 0.05$ .

## Results

### Horses

In *Group 1*, 132 Warmblood or Warmblood-cross horses were identified from the database of the Neuromuscular Diagnostic Laboratory. Owners of 45 horses (*Group 2*) were available for telephone interview and 40 questionnaires were completed for control horses. Thirty-four controls had the same owner as an affected horse, 6 control horses were referred by the owner of an affected horse.

### Diagnosis

In *Group 1*, 72/132 (55%) Warmbloods were diagnosed with PSSM (*Grade 1*: 29/72 [40%], *Grade 2*: 43/72 [60%]). Seven (12%) horses were diagnosed with muscle atrophy (5 neurogenic, 2 myogenic), 7 (12%) were diagnosed with RER, 14 (23%) had a nonspecific myopathy and 32 (53%) showed no abnormalities in the muscle biopsy. These 60/132 horses (45%) were grouped as non-PSSM horses.

The 45 horses available for follow-up from this group had a higher proportion of horses diagnosed with PSSM 32/45 (71%) (20/32 *Grade 1*, 12/32 *Grade 2*) than the group of nonresponding

**TABLE 1: Breed distribution of Warmblood horses**

Breed	Group 1		Group 2		Control horses n = 40
	PSSM n = 72	non-PSSM n = 60	PSSM n = 32	non-PSSM n = 13	
WB	13	14	4	3	2
DWB	12	8	4	1	9
HA	12	6	7	3	6
WBxTB	7	9	5	3	5
WBx	6	4	1	1	1
HO	4	6	1	0	3
FR	4	3	0	0	0
OL	3	1	3	0	4
Draught x	3	2	0	0	0
TRAK	2	3	2	0	2
WE	2	2	1	0	1
GE	1	0	1	0	4
LI	1	2	1	0	1
SWB	1	1	0	1	2
Hessian	1	1	1	1	0
CWB	0	0	1	0	0

WB = unspecified Warmblood, DWB = Dutch Warmblood, HA = Hanoverian, WBxTB = Warmblood cross Thoroughbred, WBx = Warmblood cross, HO = Holsteiner, FR = Friesian, OL = Oldenburg, Draught x = Draught cross, TRAK = Trakehner, WE = Westphalian, GE = Gelderlander, LI = Lippizaner, SWB = Swedish Warmblood, CWB = Canadian Warmblood.

**TABLE 2: Gender distribution for Warmblood horses**

Gender	Group 1*		Group 2		Control horses
	PSSM	Non-PSSM	PSSM	Non-PSSM	
Gelding	45 (67%)	28 (65%)	20 (66%)	8 (62%)	21 (53%)
Mare	22 (33%)	10 (23%)	12 (38%)	5 (38%)	19 (46%)
Stallion	0†	5 (2%)	0	0	0
Total	67	43	32	13	40 (100%)

\*Gender not available for 22 horses in *Group 1*. †Significantly different from non-PSSM group.

owners in *Group 1*. The 13 horses (29%) without PSSM in *Group 2* were diagnosed with neurogenic muscle atrophy (n = 1), RER (n = 1), nonspecific myopathy (n = 3) and no muscle biopsy abnormalities (n = 8).

### Serum CK and AST

There were no significant differences in CK and AST activities reported for PSSM and non-PSSM horses in *Group 1*. Serum enzyme activities were available for 21/72 (29%) PSSM horses. The median CK activity for these horses was 286 u/l (range 147–27,344 u/l) and median AST 320 u/l (range 211–5823 u/l). In non-PSSM horses, serum CK and AST activities were available for 17/60 and 15/60 horses, respectively. Median activity for CK was 385 u/l (range 93–442,000 u/l) and AST 321 u/l (range 153–7650 u/l) in non-PSSM horses. CK activity was above 400 u/l in 8/21 PSSM and 7/17 non-PSSM horses and AST was above 400 u/l in 7/21 and 7/17 PSSM and non-PSSM horses, respectively.

### Breed

In the *Group 1*, there were 12 specific Warmblood breeds identified along with 27 horses identified as a Warmblood without specifying a breed (nonspecific Warmblood), 5 horses that were draught crosses and 10 Warmblood crosses (Table 1). Of the 72 horses with PSSM, the breeds most highly represented were nonspecific Warmbloods, Hanoverians, Dutch Warmbloods and Warmblood crosses, which was similar to the breeds represented in the non-PSSM category. The breed distribution was similar in *Groups 1* and 2, and the control group (Table 1).

### Gender

No gender was stated for 22 (17%) horses in *Group 1*. When comparing PSSM to non-PSSM horses, there were significantly more stallions in the non-PSSM group; however, no differences were found between proportions of mares and geldings (Table 2). The distribution of males and females was approximately equal among the 5 RER horses, (2 mares, 2 geldings, one stallion, 2 unknown gender). The majority of horses with muscle atrophy were male (4 geldings, 2 stallions, one unknown gender). Of the 14 horses with nonspecific myopathic findings 8 were mares, 4 were geldings, one was a stallion and one was of unknown gender. Of the 32 horses with no abnormal biopsy findings there were 18 geldings, one stallion and 13 were of unknown gender. The gender distribution of the *Group 2* was similar between the PSSM and non-PSSM horses and was not statistically different from the control horses (Table 2).

**TABLE 3: Clinical signs on presentation reported for Warmblood horses diagnosed with PSSM and those not diagnosed with PSSM in Group 2**

Clinical sign	PSSM (n = 32)	Non-PSSM† (n = 13)	Total (n = 45)
<b>Gait abnormality</b>	18 (56%)	6 (46%)	24 (53%)
Reluctance to move forwards	12	4	
Inability to engage hindquarters	10	4	
Inability to work in an outline/collected	2	3	
Inability to work in circles	2	3	
Stringhalt type gait	1	0	
<b>*Tying-up**</b>	5 (16%)	3 (23%)	8 (18%)
<b>Muscle atrophy</b>	5	2	7 (16%)
Atrophy and weakness	3	1	
Atrophy without weakness	2	1	
<b>Muscle fasciculations</b>	5 (16%)	1 (8%)	6 (13%)
<b>Shivers signs</b>	8	3	11 (24%)
Tail hike	2	0	
Difficulty lifting hindlimbs or backing up	3	1	
Hindlimb abduction	3	2	

\*Firm muscles, pain, stiffness, sweating, muscle twitching. Some horses had >1 clinical sign on presentation. †Non-PSSM horses were diagnosed with RER (n = 1), atrophy (n = 1), nonspecific myopathy (n = 3) and no abnormalities (n = 8) on histological examination.

#### Temperament

In total for Group 2, 34 Warmbloods were described as calm, 5 had an intermediate and 6 a nervous temperament, which was similar to control horses (28 calm, 6 intermediate, 6 nervous).

#### Age

Mean age of horses in Group 1 was  $7.9 \pm 4.5$  years. There was no difference in age of horses with PSSM ( $8.8 \pm 4.6$  years), compared to horses not diagnosed with PSSM ( $7.5 \pm 3.9$  years). Findings were similar in Group 2 with a mean age  $9.1 \pm 5.4$  years (PSSM  $9.9 \pm 5.8$  years, non-PSSM group  $7.0 \pm 3.9$  years) and mean age of control horses  $10.0 \pm 6.6$  years. Time in owner's possession was on average  $5.3 \pm 3.4$  years for Group 2, which was not different from controls ( $5.2 \pm 4.5$  years). The mean age of onset of clinical signs determined from Group 2 did not differ between PSSM horses ( $6.8 \pm 6.0$  years; range 0.5–23 years) and non-PSSM horses  $5.6 \pm 2.6$  (range; 2–11 years).

#### Primary clinical sign at presentation

The most common clinical signs identified in Group 1 were gait abnormality 42/132 (32%), 'tying-up' 29/132 (22%), shivers 26/117 (22%), muscle fasciculations 23/132 (17%) and muscle atrophy 13/132 (10%). The presence or absence of shivers could not be assessed in 15 horses based on an inadequate description of clinical signs.

In horses with PSSM, a gait abnormality was present in 25/72 (35%), which was not different from non-PSSM horses, 17/60 (28%). 'Tying-up' was evident in 18/72 (25%) PSSM horses, which was not different from non-PSSM horses 11/60 (18%). Muscle fasciculations were evident in a similar proportion of PSSM (14/72, 19%) and non-PSSM horses (9/60, 15%). Shivers was present in 15% of both PSSM (11/62) and non-PSSM (9/60) horses. Muscle atrophy was present in 5/72 (7%) of horses diagnosed with PSSM not different from 8/60 (13%) non-PSSM horses.

The distribution of clinical signs within the horses in Group 2 was similar to those reported in Group 1 (Table 3). The common

**TABLE 4: Muscle groups affected in Warmbloods in Group 2**

Muscle group	PSSM (n = 32)	Non-PSSM (n = 13)	Total (%) (n = 45)
Hindlimb	28 (88%)	9 (69%)	37 (82%)
Back	11 (24%)	5 (38%)	16 (36%)
Forelimb	8 (25%)	4 (31%)	12 (27%)
Croup	2 (6%)	2 (15%)	4 (9%)
Tail	2 (6%)	2 (15%)	4 (9%)
Abdomen	1 (3%)	3 (23%)	4 (9%)

Horses may have had more than one muscle group affected.

gait abnormalities reported by owners included a reluctance to move forward and engage their hindquarters under saddle, difficulty backing and difficulty to pick up hind feet manually. These signs were reported in both PSSM and non-PSSM horses (Table 3). The most common muscle groups affected by a myopathy involved the back and hindlimbs in both PSSM and non-PSSM horses (Table 4). Myoglobinuria was reported in only 3 of 45 horses. There did not appear to be any association with respiratory infections as 4 horses in both Group 2 and control group had a history of respiratory infection in the 3 years preceding a muscle biopsy.

The activity in which the horse was involved at the time clinical signs developed was similar between PSSM and non-PSSM horses, with the majority of horses being ridden (17 PSSM; 8 non-PSSM) or hand walked (5 PSSM; 0 non-PSSM). Other less frequent activities included: standing (2 PSSM, 2 non-PSSM), backing up (3 PSSM, 0 non-PSSM), moving off (2 PSSM; 0 non-PSSM), out on pasture (2 PSSM, 0 non-PSSM) or unknown (1 PSSM; 2 non-PSSM).

#### Use of horse

In Group 2 and the control group of horses, respectively, the use of horse was similar: dressage (20, 22 horses), hunter/jumpers (12, 9), pleasure riding (5), 3-day eventing (4, 1) and other uses (4, 4) under saddle. The distribution was similar for PSSM and non-PSSM horses, respectively, dressage (15, 5 horses), hunter/jumpers (10, 2), pleasure riding (3, 2) 3-day eventing (2, 2) and other uses (2, 2).

#### Turnout and exercise regime prior to muscle biopsy diagnosis

Time for turnout was similar between horses in Group 2 and the control group, respectively: 0 h: (2, 2 horses); 1–3 h: (8, 5); 4–8 h: (6, 14); 9–12 h: (16, 14); 13–24 h: (10, 5); unknown: (3, 1). The size of pasture was small for both Group 1 and the control group, respectively, <0.4 ha: (21, 13 horses); 0.4–0.8 ha: (8, 14); 1.2–2 ha: (7, 9); >2.4 ha: (3, 3); unknown: (5, 1). The amount of exercise was also similar between follow-up and control groups, respectively, no work: (4, 6 horses); light work: (23, 15); moderate work: (16, 16); heavy work: (2, 3).

#### Diet prior to muscle biopsy diagnosis

Similar types of hay were fed to horses in Group 2 and the control group, respectively; grass hay base (24, 29 horses); grass/alfalfa mix (15, 9), pure alfalfa hay (6, 2). More horses in the Group 2 were fed a sweet feed/grain based concentrate (Category 1) prior to muscle biopsy diagnosis (28/45; 62%) than horses in the

control group (12/40; 30%). More control horses, 27/40 (68%) were fed a diet containing a fat supplement (*Category 2*) compared to *Group 2* 14/45 (31%). No horses in either group were fed a low starch fat supplemented commercial diet (*Category 3*) initially. A small number of horses in both groups were not being fed any grain (*Category 4*) prior to muscle biopsy diagnosis (3 and 1, respectively).

#### *Management of Group 2 after muscle biopsy diagnosis*

*Compliance level:* Following muscle biopsy diagnosis, 2/45 horses were fed a *Category 1* diet, 19/45 *Category 2*, 22/45 *Category 3* and 2/45 horses no grain (*Category 4*). Sixty-two percent of horse owners (28/45) were compliant with our recommendations, such that they fed a *Category 2* or *3* diet and provided regular exercise and turnout. Twenty-seven percent (12/45) complied only with dietary recommendations, 3/45 (7%) only provided regular exercise and made no dietary changes, and 2/45 (4%) made no recommended changes to their diet or exercise regimes.

*Improvement:* Overall 24/45 (53%) of owners reported that horses improved in the follow-up survey. Of these 24, 9 were fed *Category 2* diets and 15 *Category 3* diets. Of the horses that complied with diet and exercise recommendations, a significantly greater number of horses 19/28 (68%) reported improvement, whereas only 5/17 (29%) reported improvement when either diet (5/12), exercise (0/3) or no changes (0/2) were made. Of the PSSM horses that complied with diet and exercise, 15/21 (71%) improved whereas only 4/19 (21%) reported improvement when either diet or exercise was changed. Of the 11 horses with shivers, 8 had PSSM and 3 had no abnormalities on muscle biopsy. Improvement was reported in 5/11 horses (45%), 4 of which had PSSM. None of the shivers that did not fully comply with recommendations reported improvement.

#### **Discussion**

There are very few cases in the literature that describe myopathies in Warmblood horses. (Harris 1991; Valentine *et al.* 1998; Cole *et al.* 2004) This may be explained by the fact that most of these previous reports specifically looked for signs of exertional rhabdomyolysis and, in the present study, <40% of horses had serum CK and AST activities >400 u/l and only 22% presented for 'tying-up'. The most common reason that Warmblood horses presented to veterinarians with a strong suspicion of a myopathy was reluctance to move forward and perform collection, or inability to back smoothly without momentarily pausing with the limb flexed and elevated (shivers). Therefore, previous studies may have underestimated the prevalence of myopathies in Warmblood horses, which appear to be of such concern to owners in the present study that they sought veterinary consultation and muscle biopsy. The present study evaluated 132 Warmblood horses and these were categorised into 4 disease diagnoses or no apparent myopathy. Even with this substantial number, the small number in the non-PSSM category limited power to detect differences. Therefore diagnoses were evaluated statistically only as PSSM or non-PSSM.

In general, Warmblood horses were older at presentation than has previously been reported for Quarter Horses (Firshman *et al.* 2003) and Thoroughbreds (MacLeay *et al.* 1999) with myopathies. This may be a reflection of perceived slower maturity rates of Warmbloods and the fact that intense collected work that

would illicit clinical signs is not usually initiated until a later age. Although Thoroughbred mares develop exertional myopathies more commonly than geldings, geldings appeared to be prevalent in the group of Warmbloods presenting for a myopathy. Since statistical comparisons did not find a significant difference in gender distribution between the control group and *Group 2*, there does not appear to be a significant effect of gender on the development of a muscle disorder in Warmbloods.

The most common histopathological diagnosis in Warmbloods was PSSM with 72/132 horses diagnosed by muscle biopsy. This is similar to findings in draught horses (Valentine *et al.* 2001a,b; McCue *et al.* 2006) and Quarter Horses (McCue *et al.* 2006) but, in contrast to Thoroughbreds (McCue *et al.* 2006), where RER is the most common disorder seen. The diagnostic criteria used to establish a diagnosis of PSSM was divided into *Grade 1* and *Grade 2* to ensure that the diagnosis could be evaluated using varying diagnostic specificity and sensitivity. *Grade 1* biopsies have less specificity for PSSM than *Grade 2*, but higher sensitivity (Firshman *et al.* 2005, 2006). Since *Grade 2* biopsies represented 60% of the Warmbloods with PSSM in the present study it appears that even using the most stringent diagnostic criteria, PSSM is highly prevalent amongst Warmblood horses that present for evaluation of gait abnormalities, shivers or 'tying-up'. The high prevalence of PSSM in Warmbloods in this study compared to previous studies (Harris 1991; Valentine *et al.* 2001a; Cole *et al.* 2004) may be a reflection of the larger number of horses sampled and the broader application of the muscle biopsy technique in North America compared to Europe.

In Quarter Horses, PSSM is inherited and there appear to be specific bloodlines affected (Valberg *et al.* 1996; De La Corte *et al.* 2002). A wide range of European Warmblood breeds and American Warmbloods were diagnosed with PSSM in the present study and this breed distribution was similar to that of horses not diagnosed with PSSM and to control horses. Many Warmblood breeds are derived from selective breeding stock of German, French, Dutch and British descent; which evolved by crossing light breeds and 'cold blooded' draught lines (Edwards 1993). PSSM is highly prevalent in draught horses (Valentine *et al.* 2001a; Firshman *et al.* 2005; Valentine and Cooper 2005; McCue *et al.* 2006), and it may be that PSSM in Warmbloods originates from the incorporation of draught horse bloodlines early in the development of a variety of Warmblood breeds. It appears difficult to restrict PSSM to specific Warmblood bloodlines, perhaps because these breeds do not have closed studbooks and introduce a variety of breeds to improve their phenotype and performance traits (Edwards 1993).

Due to the limitations in study design and small number of horses in some categories, it was difficult to determine if management practices had a strong influence on development of PSSM in Warmbloods. The control horses frequently had the same owner as horses with a muscular disorder, which resulted in *Group 2* and control horses being managed similarly. There were few identifiable differences in temperament, turnout, exercise regimes or diet between control horses, PSSM horses and non-PSSM horses. One exception to this was that, prior to diagnosis, more horses with myopathies were fed a high starch diet and more control horses were fed a fat supplemented diet. This could, in part, be a result of horse owners choosing to feed both *Group 2* and control horses the recommended fat supplemented diet once a diagnosis was established. A point of concern with regard to management of Warmbloods was the small size of turnout paddocks (<0.4 ha for 47% of horses) and limited

turnout time prior to our recommendations (<3 h for 22% of horses). Limited turnout appears to influence the incidence of rhabdomyolysis in horses with PSSM (De La Corte *et al.* 1999; Firshman *et al.* 2003) and may impact the development of clinical signs of a myopathy in Warmbloods.

All owners of horses were provided with the same written dietary and exercise recommendations. Regardless of diagnosis, this appeared to improve clinical signs in 68% of cases when full compliance with the recommendations was met and in 71% of horses with PSSM. The level of improvement decreased to 29% with partial compliance, emphasising the importance of changing both the diet and exercise regime for successful management of myopathies (Valberg *et al.* 1997; Firshman *et al.* 2003). Providing regular daily exercise, maximum turnout and a low starch diet are in general good management practices for horses such as Warmbloods, which are easy keepers (able to maintain an adequate bodyweight on minimal amounts of required feed), and may be one reason why most horses' performance improved regardless of diagnosis. The addition of a fat supplement has not been examined under controlled conditions in Warmbloods but has been shown to be beneficial in other breeds of horses with exertional myopathies (McKenzie *et al.* 2003; Ribeiro *et al.* 2004). Exceeding daily caloric requirements with excessive fat supplementation is, in the authors' view, inadvisable.

A lower treatment response of 45% was seen in Warmbloods with signs of shivers, which is characterised by progressive development of difficulty backing up, hindlimb flexion and abduction, difficulty lifting the hind feet, quivering and a tail hike (Baird *et al.* 2006). It is an age-old problem, described in draught breeds, Warmbloods and Warmblood crosses, the aetiology of which is unknown but suggested to be possibly genetic, traumatic, myopathic, infectious or neurological (Baird *et al.* 2006). From the present study it was clear that shivers is a significant problem in Warmbloods with approximately 20% of horses in Group 2 being affected. Previous reports have suggested that signs of shivers may be related to PSSM, (Valentine *et al.* 1999). However, a recent study in Belgian draught horses determined that the 2 conditions were common but unrelated disorders (Firshman *et al.* 2005). In the present study, about 50% of shivers horses had PSSM and these were largely the shivers cases that responded to treatment. It may be that when horses have both of these conditions, relieving the underlying signs of PSSM may improve signs of shivers. In horses without PSSM, diet and exercise recommendations were not effective in alleviating clinical signs of shivers.

In conclusion, a variety of Warmblood breeds are affected by myopathies including PSSM and RER. Clinical signs are often similar among myopathies and related to gait abnormalities in addition to overt exertional rhabdomyolysis. Low starch fat supplemented diets and regular exercise both appear to be important in the successful management of myopathies. Muscle biopsy evaluation may be a beneficial part of a clinical evaluation when examining Warmblood horses presenting for vague lameness, poor performance and gait abnormalities.

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