# Prevalence and demographic characteristics of exertional rhabdomyolysis in horses in Australia

F. L. COLE, D. J. MELLOR, D. R. HODGSON, S. W. J. REID

**The proportion of the horses, of both sexes and of different ages, breeds and levels of activity, owned by a stratified random sample of Australian owners, which had suffered one or more episodes of exertional rhabdomyolysis during the previous 12 months was determined. The proportion in the general population was 1·9 per cent, and horses which exercised were significantly more likely to have experienced the condition than horses which did not. There were significant differences between the sexes and between certain breeds and activity groups in the proportions of horses affected.**

EXERTIONAL rhabdomyolysis or exercise-induced myopathy is the most common muscle disorder that affects athletic horses (Freestone and Carlson 1991). Its clinical signs can vary from stiffness of gait and pain on palpation of muscles after exercise in mild cases, to myoglobinuria, recumbency and death in severe cases (Hodgson 1993).

The aetiopathogenesis of the condition is complex and the biochemical and pathophysiological changes leading to the clinical signs are poorly understood. Several causes and risk factors have been proposed to explain why an individual horse may suffer an episode or repeated episodes. They include a dietary excess of carbohydrates (Valentine and others 1998, MacLeay and others 1999a, b), a day of rest before exercise or other variations in exercise routine (Frauenfelder and others 1986, MacLeay and others 1999a), vitamin E deficiency (Roneus and Hakkarainen 1985, Petersson and others 1991,) being young (Frauenfelder and others 1986, Harris 1991), stress (MacLeay and others 1999a, c), being female (Harris 1991, MacLeay and others 1999a), hypothyroidism (Waldron-Mease 1979), electrolyte imbalance (Harris and Colles 1988, Harris and Snow 1991), defects in metabolism (Valberg and others 1993a, 1997, Valentine and others 1997), and dysfunction in muscle contraction and calcium regulation (Beech and Lindborg 1993, Hodgson 1993, Lentz and others 1999a, b, Ward and others 2000).

As a result of the failure to find a unifying cause or satisfactory treatment for exertional rhabdomyolysis, it has been proposed that the condition may be due to several different underlying muscle diseases that induce similar clinical signs (Lentz and others 1999a, Valberg and others 1999). Particular myopathies in horses that show clinical signs consistent with exertional rhabdomyolysis have recently been identified in certain breeds of horses, including a polysaccharide storage myopathy in quarter horses (Valberg and others 1996, 1997, 1999) and some draught breeds (Valentine and others 1997), and a NADH reductase deficiency in an Arabian horse (Valberg and others 1997). In thoroughbreds, the clinical signs have been suggested to be due to a heritable defect in calcium regulation (Lentz and others 1999b, MacLeay and others 1999a), and other studies have demonstrated a familial basis for the disease in quarter horses (Valberg and others 1996) and standardbreds (Collinder and others 1997).

In view of the complicated, multifactorial nature of the condition, it is unlikely that the cause(s) will be identified solely by laboratory-based research involving a small number of affected horses. Multifactorial diseases require a population-based approach if the risk factors are to be successfully identified (Reeves 1997). There have been quantitative studies of the condition in the UK and the USA (Harris 1991, MacLeay and others 1999a, McGowan and others 2002a, b). In the UK, a retrospective analysis of laboratory data found that female horses were more likely to be affected than males (Harris 1991). In racehorses in training, the incidence over one racing season has been estimated to be 4·9 per cent in the USA (MacLeay and others 1999a) and 6·7 per cent in the UK (McGowan and others 2002a). These studies also reported that females and horses assessed as being nervous or very nervous were significantly more likely to be affected. In the USA, lameness was also a significant risk factor. The incidence in polo horses in the USA and the UK has been reported to be 7·3 per cent (McGowan and others 2002b). Although they were not specifically designed to investigate the condition, other epidemiological studies have indicated that exertional rhabdomyolysis is a common cause of disability in athletic horses. In a study of wastage in thoroughbred racehorses in the UK, 11·4 per cent of 314 two- to four-year-old thoroughbreds had had one or more episodes of the condition (Jeffcott and others 1982), whereas less than 1 per cent of pleasure horses in Scotland were estimated to have been affected (Mellor and others 2001). Whether this lower prevalence was due to usage, breed or geographical differences is unclear. The prevalence in a population of premier thoroughbreds in Sydney was estimated to be 6 per cent (Bailey and others 1999).

There is no other population-based information about the prevalence of exertional rhabdomyolysis among racehorses in Australia, and its prevalence in all other breed and activity groups of horses is unknown. As a result of this absence of information, compounded by the multifactorial nature and physiological complexity of the condition, it continues to affect horses repeatedly (Bailey and others 1999) despite many methods having been used in attempts to treat it. In order to reduce the occurrence and recurrence of exertional rhabdomyolysis in horses in Australia, detailed population-based data are required.

This paper describes a questionnaire-based investigation designed to estimate the prevalence of exertional rhabdomyolysis among different types of horses in Australia; it is an initial step in a larger investigation of the epidemiology of the condition in Australian horses. In this preliminary study, univariable analyses were applied to identify the demographic characteristics that were associated with the condition, so that these characteristics could be further investigated by the analysis of more comprehensive data obtained later.

## MATERIALS AND METHODS

### Study design and sample population

The study was a cross-sectional, postal questionnaire-based study of Australian horse owners and trainers.

*Veterinary Record* (2004) **155,** 625-630

**F. L. Cole**, BVSc,
**D. R. Hodgson**, BVSc, PhD, DipACVIM, FACSM, MACVSC,
Faculty of Veterinary Science, University of Sydney, Werombi Road, Camden, NSW 2570, Australia
**D. J. Mellor**, BVMS, PhD, MRCVS,
**S. W. J. Reid,** BVMS, PhD, DipECVPH, FRSE, MRCVS,
Veterinary Informatics and Epidemiology, Department of Veterinary Clinical Studies, University of Glasgow Veterinary School, Bearsden, Glasgow G61 1QH

The Australian Equine Veterinary Association (AEVA) was considered to be the largest and most concentrated source of veterinarians working with horses in Australia. To ensure that sufficient numbers of owners and veterinarians were recruited for this and further studies, all AEVA practices were contacted by post and telephone. The veterinarians were invited to consent to their clients receiving a questionnaire about exertional rhabdomyolysis; the practices were contacted by telephone up to three times for this purpose.

Forty-eight of the 449 practices contacted supplied the addresses of approximately 20,000 horse owners. A stratified random sample of these owners, proportional to the size of each practice, was entered into a database (Microsoft Access). The required sample size was calculated so that the prevalence of the condition could be estimated with a desired level of accuracy and a desired measure of confidence. The number of horses required to estimate the period prevalence (defined as the proportion of horses affected one or more times during the previous 12 months) in a large population with a 95 per cent confidence interval was calculated using the formula:

$$\text{Number of horses} = \frac{3{\cdot}84 \times P_{exp} \times (100 - P_{exp})}{d^2}$$

where $P_{exp}$ is the expected percentage prevalence and d is the desired absolute precision (Thrusfield 1995); $P_{exp}$ was set at 7 per cent (Bailey and others 1999) and d was set at 2 per cent, giving a required number of 625 horses. Assuming a 50 per cent response rate (Dillman 2000) this figure was doubled to 1250. A survey of veterinary practices in Scotland and northern England found that the median number of horses owned by clients was 2·0 (Mellor and others 2001), but in the present study the veterinarians did not indicate how many horses each of their clients owned. To ensure that data about sufficient horses were collected, it was assumed that each owner had one horse. In the interest of maintaining the commitment of the veterinarians who had contributed clients to the study and were to be involved in the future case-control study, the number of questionnaires sent to each was rounded up to the nearest 10; a smaller number could have led some practitioners to believe that their clients were of little significance to the overall study. As a result, a revised sample size of 1540 questionnaires was obtained. A cover letter, one page in length, was enclosed with each questionnaire to explain the objectives of the study and to invite the owners to complete the questionnaire and participate in further studies.

### The questionnaire

In order to avoid a biased response that might affect the estimation of the prevalence of the condition, a general questionnaire was designed; it is available on request from the corresponding author. No case definition of exertional rhabdomyolysis was provided, because of the desire to limit the potential selection bias that might occur if owners were made aware of the specific interest of the study. The condition was referred to as 'tying-up', the term used and recognised by horse owners. This was a potential source of misclassification, but recent research has shown that there is good agreement between diagnosis of the condition by owners and trainers and its biochemical diagnosis (McGowan and others 2002b). No definitions of each health problem were provided because they would have made the second section of the questionnaire confusing and long, and might have affected the response. The questionnaire was designed to fit on one double-sided standard A4 page, which when folded in half produced an A5-sized booklet. The booklet had a title page, two pages of questions, and an optional section on the back page where owners could volunteer to participate in future studies. Open-ended questions were used to request information on the breed, age, sex and primary use of each horse owned. Information covering a variety of common health problems, including tying-up, was collected by means of a semi-open-ended question, the owners being asked to indicate whether each of their horses had experienced any of the conditions listed one or more times during the past 12 months. The questionnaire was pretested among a group of veterinary colleagues and horse owners who would not be involved in the full study. They were asked to read the cover letter and complete the questionnaire, to comment on both documents, and to indicate how long it took them to complete the questionnaire. The questionnaire was then refined in accordance with their comments. The final questionnaire was sent with a reply-paid envelope to the sample group and followed by two subsequent mailings, one month apart, a modified version of the total design method for questionnaire research (Christley and others 2000, Dillman 2000).

**TABLE 1: Numbers and percentages, with 95 per cent confidence intervals (CIs), of 3901 exercising and non-exercising horses reported to have experienced one or more episodes of exertional rhabdomyolysis during the previous 12 months**

| | Number of horses | Number (%) of horses affected | 95 per cent CI of percentage |
|---|---|---|---|
| All horses | 3901 | 76 (1·9) | 1·5-2·4 |
| Horses over one year old | 3346 | 76 (2·3) | 1·8-2·8 |
| Exercising horses (>1 year) | 2144 | 72 (3·4) | 2·6-4·1 |
| Non-exercising horses (>1 year) | 1202 | 4 (0·3) | 0·0-0·7 |

### Data management

The data in the responses were entered into a database, checked for errors and analysed statistically by using appropriate software (Microsoft Excel and Minitab). The period prevalence was calculated as the percentage of the total population or sector of the population that had experienced one or more episodes of 'tying-up' during the previous 12 months. The significance of the differences between the period prevalence of the condition among different breeds and activity groups was assessed by a chi-squared test, and an odds ratio (OR) was used to measure the univariable association between certain demographic characteristics and the prevalence of the condition. A Mann-Whitney U test was used to compare the ages of the horses which had or had not suffered the condition. Statistical significance was set at $P<0{\cdot}05$ for all the tests.

## RESULTS

### Response rate

Approximately 10 per cent of the questionnaires were received marked 'return to sender'. Of the 1372 questionnaires delivered to the horse owners 688 were returned, a 50 per cent response rate, and they gave information about 4015 horses. There were complete records for 3901 (97 per cent) of these horses, and only these complete records were used for the statistical analysis.

### Exercising and non-exercising horses

Horses described by their owners as used only for 'breeding', or 'pet', 'paddock', 'resting' or 'retired', were considered as non-exercising. The percentage prevalences of owner-reported tying-up in the exercising and non-exercising horses over one year of age, and in the whole population, are shown in Table 1, together with the 95 per cent confidence intervals (CIs) of these percentages. The exercising horses had a significantly higher prevalence of the condition than the non-exercising

**TABLE 2: Numbers and percentages, with 95 per cent confidence intervals (CIs), of 2144 exercising horses reported to be engaged in different primary activities**

| Activity | Number (%) of horses | 95 per cent CI of percentage |
|---|---|---|
| Carriage/coach/draught | 22 (1·0) | 0·6-1·5 |
| Dressage | 168 (7·8) | 6·7-9·0 |
| Endurance | 29 (1·4) | 0·9-1·8 |
| Eventing | 81 (3·8) | 3·0-4·6 |
| Pleasure | 523 (24·4) | 22·6-26·2 |
| Polo | 74 (3·5) | 2·7-4·2 |
| Pony club/riding school | 157 (7·3) | 6·2-8·4 |
| Racing | 579 (27·0) | 25·1-28·9 |
| Rodeo events | 59 (2·8) | 2·1-3·4 |
| Showing | 107 (5·0) | 4·1-5·9 |
| Showjumping | 57 (2·7) | 2·0-3·3 |
| Stockwork | 247 (11·5) | 10·2-12·9 |
| Western | 19 (0·9) | 0·5-1·3 |
| Miscellaneous | 22 (1·0) | 0·6-1·5 |
| Total | 2144 (100) | |

**TABLE 3: Numbers and percentages, with 95 per cent confidence intervals (CIs), of horses of different breeds among 2144 exercising horses**

| Breed (including first crosses) | Number (%) of horses | 95 per cent CI of percentage |
|---|---|---|
| Appaloosa | 43 (2·0) | 1·4-2·6 |
| Arab | 201 (9·4) | 8·1-10·6 |
| Australian riding or stud pony | 95 (4·4) | 3·6-5·3 |
| Australian stock horse | 321 (15·0) | 13·5-16·5 |
| Draught | 35 (1·6) | 1·1-2·2 |
| Quarter horse | 187 (8·7) | 7·5-9·9 |
| Standardbred | 146 (6·8) | 5·7-7·9 |
| Shetland/miniature | 45 (2·1) | 1·5-2·7 |
| Thoroughbred | 803 (37·5) | 35·4-39·5 |
| Warmblood | 84 (3·9) | 3·1-4·7 |
| Welsh mountain pony | 67 (3·1) | 2·4-3·9 |
| Miscellaneous | 117 (5·5) | 4·5-6·4 |
| Total | 2144 (100) | |

horses (P<0·0001). Further analyses were restricted to the 2144 exercising horses over one year of age.

### Demographic characteristics

Table 2 lists the primary activities of the exercising horses, Table 3 lists their breeds and Table 4 shows the distribution of the sexes. Their ages ranged from two to 35 years and were not normally distributed; their median age was 7·0 years and their mean age was 8·9 years.

### Types of horses that had been affected during the previous 12 months

Table 5 shows the prevalence of tying-up among horses of different breeds, Table 6 shows its prevalence among horses with different primary activities, and Table 7 shows the prevalence in male and female horses. In view of the low prevalence of the condition in the whole population the smaller breed and activity groups were amalgamated into 'other' categories. Table 8 shows that there were significant differences in the prevalence of the condition among the activity groups (P<0·0001) and the different breeds (P=0·002). Table 8 also shows the odds ratios of univariable comparisons between these groups. The horses that experienced tying-up ranged from two to 22 years of age. The ages of the horses which did and did not experience the condition were not significantly different; the estimated median age of both groups was 7·0 years.

## DISCUSSION

This is the first cross-sectional, questionnaire-based study of exertional rhabdomyolysis in Australia. Other questionnaire-based studies of the condition have been carried out in the USA (MacLeay and others 1999a) and the UK (McGowan and others 2002a, b), but this study was different because it included horses of many different breeds and horses engaged in many different activities, so that comparisons could be made between the prevalence of the condition in horses of different activity types and different breeds.

However, the extent to which the results of the survey may be applicable to the entire horse population in Australia is limited, because the response rate to the questionnaire was only 50 per cent and the population includes only horses whose owners have used a veterinarian in the past. The response rate was lower than the 72 per cent recorded in a similar questionnaire-based study of equine veterinarians in Australia (Christley and others 2000). The response rate to the questionnaire may have been lower because of its broader target audience and by the fact that, owing to privacy restrictions and variations in the data supplied by the veterinary practices, it was not possible to administer it by telephone or, in some cases, to use the owner's first name (Dillman 2000). As with all questionnaire-based research, it must be considered that the horse owners who responded may have been different in some way from those who did not. Bias was also introduced into the study because the veterinarians had volunteered to take part.

There may be substantial clustering of horses among veterinary practices and among owners, which may increase the standard error of the estimates for the prevalence of the condition in different sectors of the population, and widen the confidence limits. However, this potential source of error would have been minimised by the large number of horses investigated. It was not possible to sample all the owners from each practice and, instead, a stratified random sample of the owners, proportional to the size of each practice, was selected, to ensure that each practice was represented, rather than to investigate differences between practices. A stratified analysis would not have been appropriate because only 48 out of a possible 449 strata were represented. The analyses were

**TABLE 4: Numbers and percentages, with 95 per cent confidence intervals (CIs), of horses of different sexes among 2144 exercising horses**

| Sex | Number (%) | 95 per cent CI of percentage |
|---|---|---|
| Female | 847 (39·5) | 37·4-41·6 |
| Male | 1297 (60·5) | 58·4-62·6 |
| Gelding | 1228 (57·3) | 55·2-59·4 |
| Stallion | 69 (3·2) | 2·5-4·0 |

**TABLE 5: Numbers and percentages of horses, with 95 per cent confidence intervals (CIs), of horses of different breeds that were reported to have experienced one or more episodes of exertional rhabdomyolysis during the previous 12 months**

| Breed (including first crosses) | Number of horses | Number (%) affected | 95 per cent CI of percentage |
|---|---|---|---|
| Welsh mountain pony | 67 | 1 (1·5) | – |
| Warmblood | 65 | 2 (3·1) | – |
| Quarter horse | 187 | 4 (2·1) | 0·1-4·2 |
| Arab | 201 | 7 (3·5) | 0·9-6·0 |
| Standardbred | 146 | 7 (4·8) | 1·3-8·3 |
| Australian stock horse | 321 | 14 (4·4) | 2·1-6·6 |
| Thoroughbred | 803 | 37 (4·6) | 3·2-6·1 |

**TABLE 6: Numbers and percentages, with 95 per cent confidence intervals (CIs), of horses engaged in different primary activities that were reported to have experienced one or more episodes of exertional rhabdomyolysis during the previous 12 months**

| Activity | Number of horses | Number (%) affected | 95 per cent CI of percentage |
|---|---|---|---|
| Western | 19 | 1 (5·3) | – |
| Eventing | 80 | 2 (2·5) | – |
| Showing | 107 | 2 (1·9) | – |
| Showjumping | 57 | 3 (5·3) | – |
| Dressage | 168 | 4 (2·4) | 0·1-4·7 |
| Pony club/riding school | 157 | 4 (2·5) | 0·1-5·0 |
| Rodeo | 59 | 4 (6·8) | 0·4-13·2 |
| Pleasure | 523 | 5 (1·0) | 0·1-1·8 |
| Stockwork | 247 | 6 (2·4) | 0·5-4·3 |
| Polo | 74 | 10 (13·5) | 5·7-21·3 |
| Racing | 579 | 31 (5·4) | 3·5-7·2 |

**TABLE 7: Numbers and percentages, with 95 per cent confidence intervals (CIs), of horses of different sexes in the exercising horse population**

| Sex | Number of horses | Number (%) affected | 95 per cent CI of percentage |
|---|---|---|---|
| Female | 847 | 36 (4·3) | 2·9-5·6 |
| Male | 1297 | 36 (2·8) | 1·9-3·7 |
| Gelding | 1228 | 36 (2·9) | 2·0-3·9 |
| Stallion | 69 | 0 | – |

therefore not performed in a stratified manner, but the population of horses was treated as a simple random sample; as a result, the estimates of the prevalence of the condition are more conservative. Another limitation of the study is that it relied on the horses' owners to diagnose the condition and report it, with the risk that some cases may have been misdiagnosed. However, in a similar study in the UK and the USA there was 100 per cent agreement between the biochemical diagnosis of the condition and owner-reported episodes in nine polo horses (McGowan and others 2002b).

The prevalence of the condition reported by the owners during the course of a year in horses over the age of one year was 1·9 per cent (95 per cent CI 1·5 to 2·4 per cent). It is considered to be an exercise-induced condition, and the prevalence was significantly higher among the exercising horses than among the non-exercising horses. Using the odds ratio (OR) as an approximate indication of relative risk, the exercising horses were estimated to be 10·4 times more likely to suffer an episode of exertional rhabdomyolysis than non-exercising horses (95 per cent CI 3·8 to 28·6 per cent). As a result, the further analyses and discussion concern only the exercising horses. It is possible that this group of horses may have had a less severe or a chronic form of the condition, because they had not been forced to retire from activity.

Fourteen types of activity were reported by the horses' owners, and the condition was reported to occur in horses in 11 of them (Tables 2, 6). The prevalence of the condition in the exercising horses was 3·4 per cent (95 per cent CI 2·6 to 4·1 per cent). Other studies have reported the prevalence and incidence of the condition in particular groups of horses (Bailey and others 1999, MacLeay and others 1999a, Mellor and others 2001, McGowan and others 2002a, b). In Scotland, the prevalence of the condition in pleasure horses was reported to be 1 per cent (Mellor and others 2001), which is similar to the prevalence of 1·0 per cent (95 per cent CI 0·1 to 1·8 per cent) calculated for the pleasure horses in the present study. In the USA and UK, respectively, the incidences of the condition in racehorses over one racing season were 4·9 and 6·7 per cent (MacLeay and others 1999a, McGowan and others 2002a), similar to the 5·4 per cent (95 per cent CI 3·5 to 7·2 per cent) of the racehorses in this study which suffered an attack during the year. This figure indicates the minimum incidence rate because the owners reported only whether their horses had experienced an episode during the previous 12 months, but not whether they had had more than one episode. The figure is also similar to the 6 per cent reported in a study of the wastage rate in a cohort of racehorses in Sydney (Bailey and others 1999); this study involved a premier group of racing horses, whereas the present investigation included rural and metropolitan racehorses at more varied levels of competition and performance. Another questionnaire-based study of owners in the UK and the USA reported that over one season the incidence of the condition in polo horses was 7·3 per cent (McGowan and others 2002b). In the present investigation the prevalence in polo horses was 13·5 per cent; however, this higher rate had a wide 95 per cent CI (5·7 to 21·3 per cent), possibly because there were only 74 polo horses, and the true prevalence may be closer to that reported in other studies.

Horses have been reported to suffer episodes of exertional rhabdomyolysis after various types and intensities of exercise (Frauenfelder and others 1986, Valberg and others 1993b). In this study, using racehorses as a reference category, horses used for pleasure were significantly less likely to experience the condition (OR=0·2, 95 per cent CI 0·1 to 0·4), whereas polo horses were more likely to experience it (OR=2·8, 95 per cent CI 1·3 to 5·9), suggesting that horses undergoing more intense exercise are more likely to experience the condition. Racing and polo could also excite horses more than quieter activities such as pleasure riding, and nervousness has been implicated in the aetiology of the condition (MacLeay and others 1999a, McGowan and others 2002a, b). More complex, multivariable analyses would be required to assess the effect of activity on the incidence and prevalence, and determine whether activity has an effect over and above the effects of other potential risk factors, such as breed, sex, age, diet, rest, temperament and fitness (Frauenfelder and others 1986, Harris 1991, MacLeay and others 1999a, Valberg and others 1999).

There were 13 breeds represented in the population of exercising horses. Exertional rhabdomyolysis affects horses of

**TABLE 8: Odds ratios, with 95 per cent confidence intervals (CIs), derived from univariable comparisons of the risk of horses of different breeds, primary activities and sexes of having been reported to have experienced one or more episodes of exertional rhabdomyolysis during the previous 12 months**

| | Number affected | Number not affected | Odds ratio | 95 per cent CI of odds ratio |
|---|---|---|---|---|
| All horses | | | | |
| Non-exercising | 4 | 1198 | 1·0 | – |
| Exercising | 72 | 2072 | 10·8 | 3·8-28·6 |
| Exercising horses | | | | |
| Activity | | | | |
| Racing (reference category) | 31 | 548 | 1·0 | – |
| Polo | 10 | 64 | 2·8 | 1·3-5·9 |
| Stockwork | 6 | 241 | 0·4 | 0·2-1·1 |
| Pleasure | 5 | 518 | 0·2 | 0·1-0·4 |
| Other | 20 | 701 | 0·5 | 0·3-0·9 |
| Breed | | | | |
| Thoroughbred (reference category) | 37 | 766 | 1·0 | – |
| Australian stock horse | 14 | 307 | 0·9 | 0·5-1·8 |
| Standardbred | 7 | 139 | 1·0 | 0·5-2·4 |
| Arab | 7 | 194 | 0·7 | 0·3-1·7 |
| Other | 7 | 666 | 0·2 | 0·1-0·5 |
| Sex | | | | |
| Male (reference category) | 36 | 1261 | 1·0 | – |
| Female | 36 | 811 | 1·6 | 1·0-2·5 |
| Male racehorses (reference category) | 10 | 319 | 1·0 | – |
| Female racehorses | 29 | 229 | 2·9 | 1·4-6·3 |

several breeds (Harris 1991) and several of the 13 breeds were reported to have experienced it, including warmbloods, quarter horses, Arabs, standardbreds, Australian stockhorses, thoroughbreds and one Welsh pony. It has been suggested that in thoroughbreds, quarter horses and standardbreds the condition is heritable (Valberg and others 1996, Collinder and others 1997, MacLeay and others 1999b). Recent research suggests that there are different underlying causes for the condition in different breeds, because thoroughbreds and quarter horses with similar clinical signs have been shown to have different underlying abnormalities (Valberg and others 1999). In this study, the thoroughbreds were more likely to have had the condition than most other horses (OR=0·2, 95 per cent CI 0·1 to 0·4), though in some other breed groups the analyses were limited by small numbers. However, this may be due to the activity of the thoroughbreds, as 55·6 per cent of them (447 of 803) were reported as being used primarily for racing.

Exertional rhabdomyolysis has often been reported to be more common in females than males, and fillies have been shown to have greater fluctuations in muscle enzyme activities during race training (Frauenfelder and others 1986, Harris 1991, MacLeay and others 1999a). In this study, sex was not significantly associated with the condition in the exercising population over one year of age, although the females' OR of 1·6 (95 per cent CI 1·0 to 2·5) suggests that they tend to experience it more than males. Female horses were found to be significantly more likely to experience the condition in an epidemiological study of racetracks in the USA and the UK (MacLeay and others 1999a, McGowan and others 2002a), and in the present study female racehorses were almost three times more likely (OR=2·9, 95 per cent CI 1·4 to 6·3) to experience it than male racehorses. It is possible that the horse's sex affects the occurrence of the disease differently in horses of different breeds, ages or types of usage, as is suggested by the differences observed in the effect of sex on the condition in the exercising population and the racehorses in this study. In a study of thoroughbreds, the condition was associated with sex (MacLeay and others 1999a), but in a study of polo horses (McGowan and others 2002b) there was no association.

Exertional rhabdomyolysis has been reported to occur in horses of a range of ages, from foals to horses more than 15 years old (Harris 1991). In this study it occurred in horses ranging from two to 22 years of age; horses less than a year old were excluded because their exercise status would have been uncertain. The condition has been associated with younger racehorses (MacLeay and others 1999a) and in younger horses in a retrospective, laboratory-based study (Harris 1991), but age was not a significant factor in the occurrence of the disease in polo horses in the UK and the USA (McGowan and others 2002b). In the present study the condition was not significantly associated with the ages of the exercising horses, but this result should be interpreted with caution in view of the differences in sex, breed and activity, and the age at which horses typically begin their different activities.

The prevalence of exertional rhabdomyolysis in the population of exercising horses was estimated to be 3·4 per cent. It affected a variety of Australian horses, of many different breeds, activity groups and ages. The more active groups, such as racehorses and polo horses, were more likely to be affected than pleasure horses. The horses' sex and age were not significantly associated with the condition but there was a tendency for females to be more affected than males. Overall the results show that its prevalence was different in different sectors of the horse population, and these differences may provide support for the theory that there are different underlying aetiologies for the condition in different groups of horses.

## References


BAILEY, C. J., ROSE, R. J., REID S. W. J. & HODGSON, D. R. (1999) Impact of injuries and disease on a cohort of two- and three-year-old thoroughbreds in training. *Veterinary Record* **45,** 487-493

BEECH, J. & LINDBORG, S. (1993) Caffeine contractures, twitch characteristics and the threshold for $Ca^{2+}$ -induced $Ca^{2+}$ release in skeletal muscle from horses with chronic intermittent rhabdomyolysis. *Research in Veterinary Science* **54,** 110-117

COLLINDER, E., LINDHOLM, A. & RASMUSON, M. (1997) Genetic markers in Standardbred trotters susceptible to the rhabdomyolysis syndrome. *Equine Veterinary Journal* **29,** 117-120

CHRISTLEY, R. M., ROSE, R. J., HODGSON, D. R., REID, S. W. J., EVANS, S., BAILEY, C. & HODGSON, J. L. (2000) Issues associated with the application to veterinarians of a mailed questionnaire regarding lower respiratory-tract disease in racehorses. *Preventive Veterinary Medicine* **46,** 161-170

DILLMAN, D. A. (2000) Mail and Internet Surveys: the Tailored Design Method. 2nd edn. New York, John Wiley and Sons

FRAUENFELDER, H. C., ROSSDALE, P. D. & RICKETTS, S. W. (1986) Changes in serum muscle enzyme levels associated with training schedules and stage of the oestrus cycle in Thoroughbred racehorses. *Equine Veterinary Journal* **18,** 371-374

FREESTONE, J. F. & CARLSON, G. P. (1991) Muscle disorders in the horse: a retrospective study. *Equine Veterinary Journal* **23,** 86-90

HARRIS, P. A. (1991) The equine rhabdomyolysis syndrome in the United Kingdom: epidemiological and clinical descriptive information. *British Veterinary Journal* **147,** 373-384

HARRIS, P. & COLLES, C. (1988) The use of creatinine clearance ratios in the prevention of equine rhabdomyolysis: report of four cases. *Equine Veterinary Journal* **20,** 459-463

HARRIS, P. A. & SNOW, D. H. (1991) Role of electrolyte imbalances in the pathophysiology of the equine rhabdomyolysis syndrome. In Equine Exercise Physiology 3. Eds S. Persson, A. Lindholm, L. B. Jeffcott. Davis, ICEEP Publications. pp 435-442

HODGSON, D. R. (1993) Exercise-associated myopathy: is calcium the culprit? *Equine Veterinary Journal* **25,** 1-3

JEFFCOTT, L. B., ROSSDALE, P. D., FREESTONE, J., FRANK, C. J. & TOWERS-CLARK, P. F. (1982) An assessment of wastage in thoroughbred racing from conception to four years of age. *Equine Veterinary Journal* **14,** 185-198

LENTZ, L. R., VALBERG, S. J., BALOG, E. M., MICKELSON, J. R. & GALLANT, E. M. (1999a) Abnormal regulation of muscle contraction in horses with recurrent exertional rhabdomyolysis. *American Journal of Veterinary Research* **60,** 992-999

LENTZ, L. R., VALBERG, S. J., MICKELSON, J. R. & GALLANT, E. M. (1999b) In vitro contractile responses and contracture testing of skeletal muscle from Quarter Horses with exertional rhabdomyolysis. *American Journal of Veterinary Research* **60,** 684-688

MACLEAY, J. M., SORUM, S. A., VALBERG, S. J., MARSH, W. E. & SORUM, M. D. (1999a) Epidemiologic analysis of factors influencing exertional rhabdomyolysis in thoroughbreds. *American Journal of Veterinary Research* **12,** 1562-1566

MACLEAY, J. M., VALBERG, S. J., PAGAN, J. D., DE LA CORTE, F., ROBERTS, J., BILLSTROM, J., MCGINNITY, J. & KAESE, H. (1999b) Effect of diet on Thoroughbred horses with recurrent exertional rhabdomyloysis performing a standardised exercise test. *Equine Veterinary Journal Supplement* **30,** 458-462

MACLEAY, J. M., VALBERG, S. J., SORUM, S. A., SORUM, M. D., KASSUBE, T., SANTSCHI, E. M., MICKELSON, J. R. & GEYER, C. J. (1999c) Heritability of recurrent exertional rhabdomyolysis in Thoroughbred racehorses. *American Journal of Veterinary Research* **60,** 250-256

MCGOWAN, C. M., FORDHAM, T. & CHRISTLEY, R. M. (2002a) Incidence and risk factors for exertional rhabdomyolysis in Thoroughbred racehorses in the UK. *Veterinary Record* **151,** 623-626

MCGOWAN, C. M., POSNER, R. E. & CHRISTLEY, R. M. (2002b) Incidence of exertional rhabdomyolysis in polo horses in the USA and United Kingdom in the 1999/2000 racing season. *Veterinary Record* **150,** 535-537

MELLOR, D. J., LOVE, S., GETTINBY, G. & REID, S. W. J. (2001) Sentinel practice-based survey of the management and health of horses in northern Britain. *Veterinary Record* **149,** 417-423

PETERSSON, K. H., HINTZ, H. F., SCHRYVER, H. F. & COMBS, G. F., Jr (1991) The effect of vitamin E on membrane integrity during submaximal exercise. In Equine Exercise Physiology 3. Eds S. Persson, A. Lindholm, L. B. Jeffcott. Davis, ICEEP Publications. pp 315-322

REEVES, M. J. (1997) Equine epidemiology – still struggling to find a seat at the table. *Equine Veterinary Journal* **29,** 82-84

RONEUS, B. & HAKKARAINEN, J. (1985) Vitamin E in serum and skeletal

muscle tissue and blood glutathione peroxidase activity from horses with the azoturia-exertional rhabdomyolysis syndrome. *Acta Veterinaria Scandinavica* **26,** 425-427

THRUSFIELD, M. (1995) Surveys. In Veterinary Epidemiology. 2nd edn. London, Blackwell Science. pp 178-198

VALBERG, S. J., GEYER, C., SORUM, S. A. & CARDINET, G. H., III (1996) Familial basis of exertional rhabdomyolysis in Quarter Horse-related breeds. *American Journal of Veterinary Research* **57,** 286-290

VALBERG, S. J., HAAGENDAL, J. & LINDHOLM, A. (1993a) Blood chemistry and skeletal muscle metabolic response to exercise in horses with recurrent exertional rhabdomyolysis. *Equine Veterinary Journal* **25,** 17-22

VALBERG, S. J., JONSSON, L., LINDHOLM, A. & HOLMGREN, N. (1993b) Muscle histopathology and plasma aspartate aminotransferase, creatinine kinase and myoglobin changes with exercise in horses with recurrent exertional rhabdomyolysis. *Equine Veterinary Journal* **25,** 11-16

VALBERG, S. J., MACLEAY, J. M. & MICKELSON, J. R. (1997) Exertional rhabdomyolysis and polysaccharide storage myopathy in horses. *Compendium on Continuing Education for the Practicing Veterinarian* **19,** 1077-1086

VALBERG, S. J., MICKELSON, J. R., GALLANT, E. M., MACLEAY, J. M., LENTZ, L. & DE LA CORTE, F. (1999) Exertional rhabdomyolysis in Quarter Horses and Thoroughbreds: one syndrome, multiple aetiologies. *Equine Veterinary Journal Supplement* **30,** 533-538

VALENTINE, B. A., CREDILLE, K. M., LAVOIE, J. P., FATONE, S., GUARD, C., CUMMINGS, J. F. & COOPER, B. J. (1997) Severe polysaccharide storage myopathy in Belgian and Percheron draught horses. *Equine Veterinary Journal* **29,** 220-225

VALENTINE, B. A., HINTZ, H. F., FREELS, K. M., REYNOLDS, A. J. & THOMPSON, K. N. (1998) Dietary control of exertional rhabdomyolysis in horses. *Journal of the American Veterinary Medical Association* **212,** 1588-1593

WALDRON-MEASE, E. (1979) Hypothyroidism and myopathy in racing Thoroughbreds and Standardbreds. *Journal of Equine Medicine and Surgery* **3,** 123-128

WARD, T. L., VALBERG, S. J., GALLANT, E. M. & MICKELSON, J. R. (2000) Calcium regulation by skeletal muscle membranes of horses with recurrent exertional rhabdomyolysis. *American Journal of Veterinary Research* **60,** 242-246