

- Rose, R. J. (1982). Haematological changes associated with endurance exercise. *Vet. Rec.* **110**, 175–177.
- Rose, R. J., Purdue, R. A. and Hensley, W. (1977). Plasma biochemistry alterations in horses during endurance riding. *Equine Vet. J.* **9**, 122–126.
- Rose, R. J., Arnold, Kristin, S., Church, Sally and Paris, R. (1980). Plasma and sweat electrolyte concentrations in the horse during long distance exercise. *Equine Vet. J.* **12**, 19–22.
- Snow, D. H., Kerr, M. G., Nimmo, M. A. and Abbott, E. M. (1982). Alterations in blood, sweat, urine and muscle composition during prolonged exercise in the horse. *Vet. Rec.* **110**, 377–384.

# Plasma Enzyme Activities in Endurance Horses

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## Summary

*Plasma activities of creatine kinase (CK) and aspartate aminotransferase (AST) were measured in 70 horses before and after competitive endurance rides. Both pre-ride levels and the magnitude of the increases during the competitions were extremely variable and were not related to subjective assessments of degree of fatigue. The same enzymes were measured in four horses which took part in a controlled (16 to 18 km/h) 80 km ride on two occasions each. Measurements in these horses were continued for six months after the rides. Again, neither pre-ride enzyme activities nor the magnitude of the increases during the rides were related to observed degree of fatigue. Two horses showed elevated and fluctuating enzyme levels during the following months although no clinical muscle problems were seen. It is suggested that elevated plasma CK and AST activities in endurance horses may be a common occurrence and that they should not be interpreted as an adverse indication unless clinical evidence of muscle damage is also present.*

## Introduction

The assessment of the state of 'fitness' of horses in training and the state of 'fatigue' of horses during and after competition is a very subjective matter, particularly where endurance horses are concerned. Many sets of endurance competition regulations require veterinary judges to assess individual horses for fitness and fatigue by means of subjective tests, and as disputes occasionally arise, various attempts have been made to produce a scientifically objective method of grading a horse's performance.

The most common grading method involves scoring horses according to heart and respiratory rates, but when Littlewort and Hickman (1969) evaluated horses in a three-day event competition, they found one form of this system to be of no value. However, Rose *et al.* (1977) did find significant differences in several biochemical parameters between horses with heart rates above and below 60/min. after a 100 km ride.

It is well known that plasma activities of various enzymes, particularly of creatine kinase (CK) and aspartate aminotransferase (AST), increase following muscle damage or strenuous muscular exercise. Murakami and Takagi (1974) investigated these enzymes in

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endurance-trained horses and suggested that the increase in CK during exercise might indicate the 'severity of exercise', while AST might be an index of overtraining.

This study examines plasma CK and AST both in competing endurance horses and in horses undergoing a controlled 80 km endurance trial and relates these findings to a subjective assessment of the horses' performance.

### *Materials and Methods*

#### *Experiment 1*

Blood samples were collected from 70 endurance horses (50 separate individuals, 10 of which were sampled on more than one occasion) before and after competitive long-distance rides of 40 to 160 km. The animals' ages ranged from 5 to 19 years and a wide variety of breeds and types was represented. In the 80 km rides the speeds ranged from 9 km/h to 20 km/h.

#### *Experiment 2*

Four Thoroughbred geldings, aged between 6 and 11 years, were ridden at a constant speed of 16 to 18 km/h for either 80 km or until withdrawal due to fatigue or, in one instance, due to lameness. Each horse underwent this procedure on two occasions. Blood samples were collected before, during and after these rides. A more detailed description of the conditions of this experiment has been published elsewhere (Snow *et al.*, 1982).

#### *Blood sampling*

Blood was collected into heparinised plastic syringes which were stored in ice until centrifugation. The plasma was then stored at  $-20^{\circ}\text{C}$  until analysis.

#### *Plasma analysis*

Plasma activities of CK and AST were measured by reaction rate analysis at  $37^{\circ}\text{C}$  (Boehringer kits nos. 124 184 and 124 443, respectively).

#### *Assessment of fatigue*

*Experiment 1.* Horses were subjectively assigned to the three grades:

1. *Good*: top class performer, little sign of fatigue.
2. *Moderate*: average performer, not unduly fatigued.
3. *Poor*: insufficiently fit horse showing obvious signs of fatigue.

*Experiment 2.* On both occasions each horse was assigned to one of four grades:

1. Withdrawn early due to lameness, not fatigued.
2. Completed 80 km and appeared able to continue at the 16 km/h pace.
3. Completed 80 km but appeared unable to continue.
4. Withdrawn early due to fatigue as manifested by extreme unwillingness to continue at 16 km/h.

### *Results*

#### *Experiment 1: competitive endurance rides*

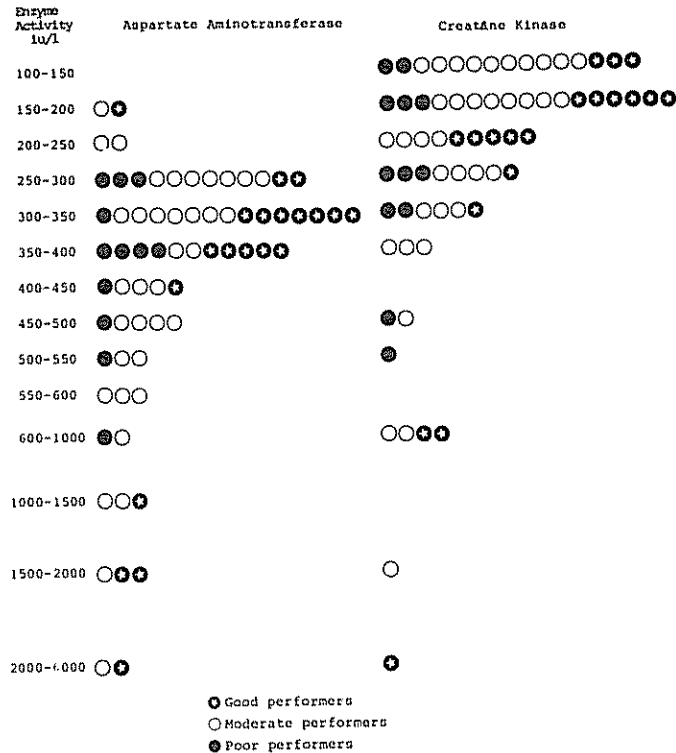
##### *A. Resting plasma enzyme activities*

The plasma levels of CK and AST in the samples taken before the starts of the events are shown in Fig. 1. Although most of the values lie in or around what would generally be

considered to be the 'normal range', several horses had extremely high plasma enzyme levels before the competition started. It can be seen that the horses with the particularly high resting enzyme levels were not those which were obviously poor performers.

There was a tendency for horses with particularly elevated resting AST levels (greater than 1000 iu/l) to have higher than average resting CK levels also, but this was not invariably the case.

FIGURE 1. Resting plasma enzyme levels in endurance-trained horses.



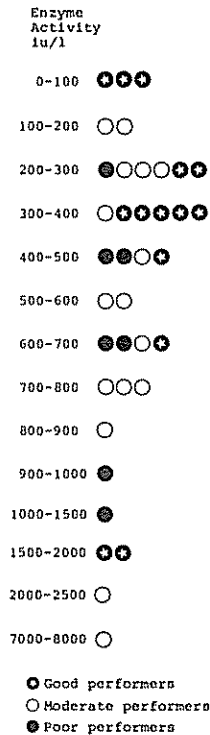
B. Increases in enzyme activities during competition

With the exception of the individual in the 160 km ride discussed below, all the increases in AST during exercise were small; almost all were under 100 iu/l and very few over 200 iu/l.

The increases in plasma CK during exercise are shown in Fig. 2. To eliminate the variation due to the distance covered, only horses which completed an 80 km ride are included. Again, there was no consistent correlation between large increases in plasma CK activity and poor performance. One of the four horses with the greatest CK increases had high resting CK and AST levels. Another horse, although showing normal resting enzyme levels on this occasion, was the same individual whose enzyme changes in the 160 km ride are discussed below, but the other two were moderate or good performers whose resting enzyme levels were not elevated.

During the 160 km ride the increases in plasma CK were generally somewhat higher than during the 80 km rides, and again there was no obvious correlation between increases in enzyme levels and performance. One individual showed particularly bizarre patterns of changes in plasma enzyme activities, the details of which are shown in Fig. 3. This horse had no history of muscular problems and showed no particular ill effects of the ride. The veterinary judges awarded this horse the prize for the best condition on the day following the ride.

FIGURE 2. Magnitude of increase in plasma CK activity during competitive 80 km rides.



*Experiment 2: Controlled 80 km rides*

A. Assessment of fatigue

Each horse's performance on each of the experimental rides was graded according to the criteria for fatigue previously described. These grades are presented in Table 1.

B. Resting plasma enzyme activities

Before the first ride, plasma CK ranged from 127 to 177 iu/l and plasma AST from 217 to 450 iu/l. Before the second ride, CK ranged from 118 to 186 iu/l and AST from 236 to 912 iu/l. As in Experiment 1, there appeared to be no relationship between plasma enzyme activity before the ride and ride performance.

FIGURE 3. Changes in plasma CK and AST activities in one horse during and after a 160 km endurance ride. This horse was awarded the prize for good condition on the day following the event.

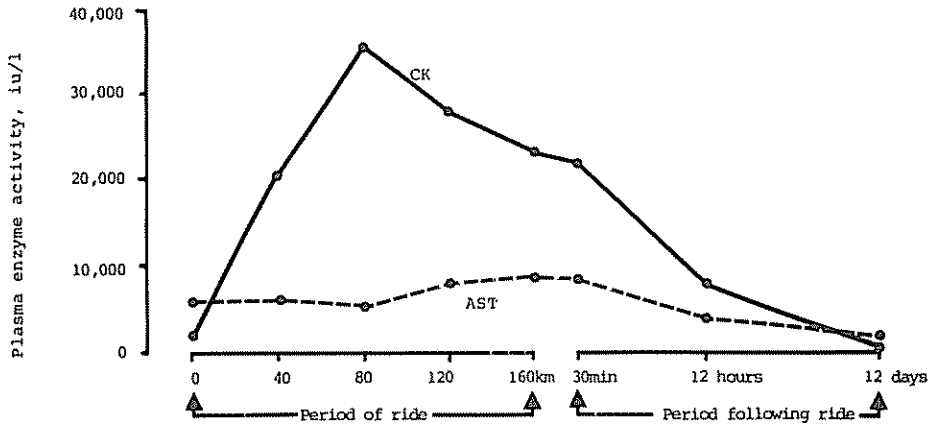


TABLE 1. Grade of fatigue assessed for each horse after both 80 km rides.

Horse	Grade of fatigue	
	Ride 1	Ride 2
1	2	1
2	3	3
3	3	2
4	4	4

C. Increases in enzyme activities during the 80 km rides

The increases in plasma enzyme activities during the rides are compared to the grade of fatigue for each horse in Fig. 4. It can be seen that the correlation between rise in plasma CK or AST activity and observed degree of fatigue is very poor.

D. Plasma enzyme activities following endurance training

The changes in plasma enzyme activities in two of the horses in the months following the two 80 km rides are shown in Fig. 5. The plasma enzyme levels of the other two horses returned to normal within a few days of each ride and remained there. After the second ride the endurance training was discontinued and the horses received only short periods of light exercise. On the days following the 80 km rides all the horses appeared stiff and tired, but otherwise there were no obvious ill effects associated with the rides.

Discussion

Most publications on the biochemical changes occurring in competing endurance horses deal with their data by presenting mean values from a group of animals. When an individual's results are presented they are usually either those of a particularly good performer (Lucke and Hall, 1980b) or a particularly poor performer (Lucke and Hall,

FIGURE 4. Increases in plasma CK and AST activities compared to degree of fatigue during the controlled 80 km rides.

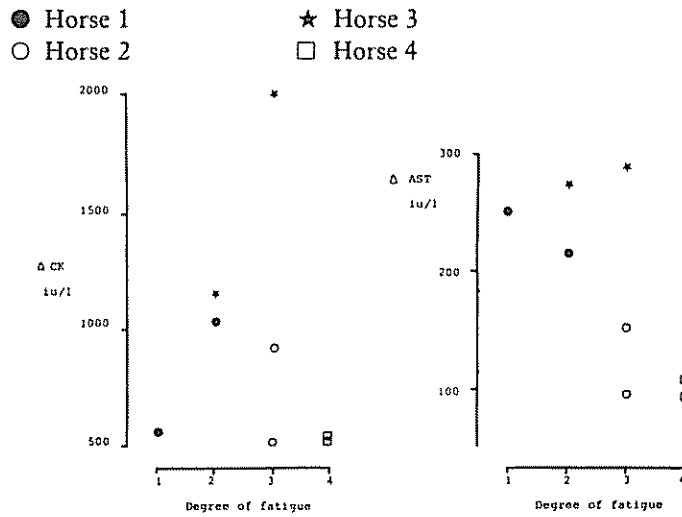
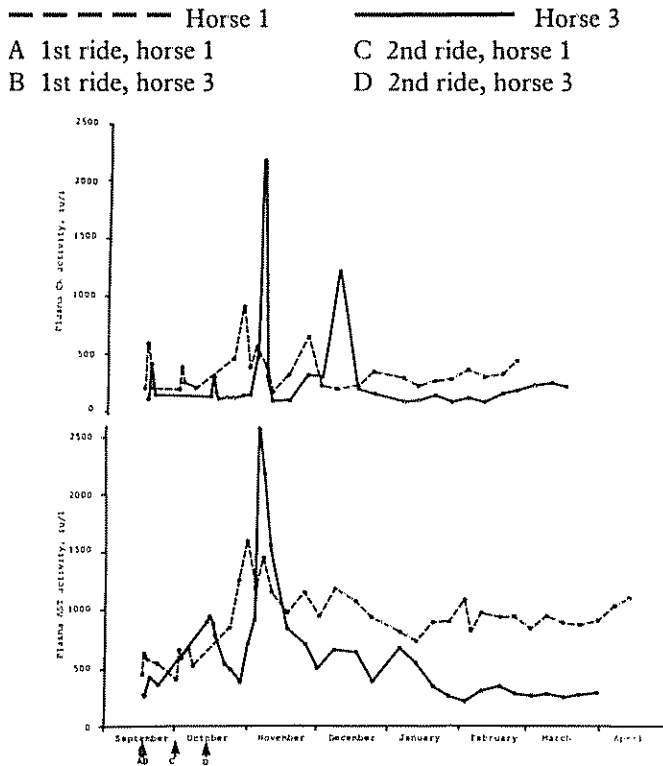


FIGURE 5. Changes in plasma CK and AST activities in two of the horses involved in the controlled 80 km rides during the six months following the rides.



1980a). Statistical treatment is undoubtedly of value in highlighting the general trends that occur, but it tends to obscure the wide range of values for many parameters obtained from perfectly normal horses.

Several authors have remarked on the extremely elevated plasma CK and AST levels seen in endurance horses which develop rhabdomyolysis (Hinton 1976; Carlson 1979; Fowler 1979). This has led to the assumption that elevated plasma enzyme levels are in themselves evidence of unfitness, excessive muscle trauma and poor performance, although Fregin (1979) reported horses which completed a 160 km ride with elevated CK values but with no clinical signs of muscle damage. Murakami and Takagi (1974) presented evidence that the magnitude of the increase in plasma CK during exercise was directly related to the exercise load, but other than this, no work has been done to relate enzyme changes to the degree of fitness or fatigue in endurance horses.

Entry numbers for British endurance events are not usually large, and attempts to select homogeneous groups of contestants usually result in groups being too small to give meaningful results. In any one event, variation will exist in sex, age, breed, state of training, rider motivation, rider experience, ride tactics and time taken, and terrain and weather conditions also vary between events. Because of this multiplicity of variables it was decided to consider each of the horses in this study individually, along with the subjective general assessment of its performance. This precludes rigorous statistical treatment of the results but prevents individual peculiarities from being lost within mean values. Performance scoring on the basis of heart and respiratory rates was not used because of the possibility of excited horses giving spurious results and because of the use of 'gamesmanship' tactics by a few competitors to obtain good heart rate scores.

The number of horses with elevated resting enzyme levels before endurance rides was a surprising finding. No consistent explanation could be advanced which would cover all the individuals concerned, as they belonged to different owners, represented several different breeds and competed at different levels of the sport. Although two horses with elevated pre-ride AST levels had some history of a previous muscle problem, these occurrences were too far in the past to have explained the enzyme levels found. None of the other horses had any previous clinical muscle problems. It is conceivable that these horses with high pre-ride enzyme activities were indeed overtrained or overstressed in some way, but if this was the case, it had no discernible effect on their performance or general health. One of these horses was a regular prize-winner during two seasons of competition. A much more likely explanation is provided by the findings of elevated and fluctuating CK and AST levels in two of the experimental horses in the period following the rides. The reasons for these findings are far from clear, but it is possible that they reflect some altered state of muscle metabolism caused by endurance exercise. The physiological or pathological process involved is unknown, as is the reason for only some horses being affected. However, in the absence of any definite link with poor performance or clinical muscle problems it would be unwise to assume that elevated enzyme levels are themselves indicative of anything untoward in an endurance horse.

The absence of any marked rise in AST after exercise in this study is consistent with the findings of Cardinet *et al.* (1967) who observed elevations in both CK and AST in cases of rhabdomyolysis but reported that the effect of exercise on plasma AST activity was inconsistent.

The interpretation of the increases in CK during the competitive rides is complicated

by the fact that those horses classed as poor performers tended to take a much longer time to complete the course than the good performers. The increase in duration of exercise might itself explain any tendency for the poor performers to have greater plasma CK increases. In the experimental horses which all travelled at the same speed, the magnitude of the CK increases appeared to be quite unrelated to the horses' performances. The peculiar pattern of plasma CK in the individual horse discussed in the 160 km ride could be explained by extreme exertion during the early stages, followed by quiet riding in the later stages, but this hardly accounts for a peak level of over 35000 iu/l. One of this horse's companions also showed a peak plasma CK (of 2500 iu/l) at 80 km, but two others which rode in the same group had regularly increasing CK levels throughout the 160 km. The results of this study suggest that in view of the number of apparently good performers with inexplicably large increases in plasma CK, it would be unwise to use the magnitude of increase in plasma CK to score a horse's performance.

### Acknowledgements

This study was supported by a grant from the Horserace Betting Levy Board, and Miss Kerr was a Horserace Betting Levy Board Veterinary Research Scholar. The authors are indebted to members of the Endurance Horse and Pony Society of Great Britain and to other riders who competed in events organized by the Society for permission to bleed their horses.

### References

- Cardinet, G. H., Littrell, J. F. and Freedland, R. A. (1967). Comparative investigations of serum creatine phosphokinase and glutamic-oxaloacetic transaminase activities in equine paralytic myoglobinuria. *Res. Vet. Sci.* **8**, 219–226.
- Carlson, G. P. (1979). Physiologic responses to endurance exercise. *Proc. Am. Ass. Equine Practnrs* **25**, 459–468.
- Fowler, M. E. (1979). Veterinary problems during endurance trail rides. *Proc. Am. Ass. Equine Practnrs* **25**, 469–478.
- Fregin, G. F. (1979). General discussion of physiologic observations recorded on 117 horses during 100 mile endurance rides. *Proc. Am. Ass. Equine Practnrs* **25**, 315–321.
- Hinton, M. (1976). Long distance horse riding and the problem of dehydration and rhabdomyolysis. *Vet. Ann.* **17**, 136–141.
- Littlewort, M. C. G. and Hickman, J. (1969). Analysis of a proposed test to assess fatigue in horses. *Equine Vet. J.* **1**, 231–237.
- Lucke, J. N. and Hall, G. M. (1980a). Further studies on the metabolic effects of long distance riding: Golden Horseshoe Ride 1979. *Equine Vet. J.* **12**, 189–192.
- Lucke, J. N. and Hall, G. M. (1980b). A biochemical study of the Arab Horse Society's marathon race. *Vet. Rec.* **107**, 523–525.
- Murakami, M. and Takagi, S. (1974). Effects of continuous long distance running exercise on plasma enzyme levels in horses. *Exp. Rep. Equine Hlth Lab.* **11**, 106–118.
- Rose, R. J., Purdue, R. A. and Hensley, W. (1977). Plasma biochemistry alterations in horses during an endurance ride. *Equine Vet. J.* **9**, 122–126.

Snow, D. H., Kerr, M. G., Nimmo, M. A. and Abbott, E. M. (1982). Alterations in blood, sweat, urine and muscle composition during prolonged exercise in the horse. *Vet. Rec.* **110**, 377–384.