

- Lucke, J. N. and Hall, G. M. (1980). A biochemical study of the Arab Horse Society's marathon race. *Vet. Rec.* **107**, 523–525.
- Metivier, G., Poortmans, J., Vanroux, R. and Gauthier, R. (1980). Serum glutamic oxaloacetic acid transaminase changes during exercise of various intensities in trained athletes. *J. Sports Med.* **20**, 152–157.
- Milne, D. W. (1974). Blood gases, acid–base balance and electrolyte and enzyme changes in exercising horses. *J. S. Afr. Vet. Ass.* **45**, 345–353.
- Rose, R. J., Arnold, K. S., Church, S. and Paris, R. (1980a). Plasma and sweat electrolyte concentrations in the horse during long distance exercise. *Equine Vet. J.* **12**, 19–22.
- Rose, R. J., Ilkiw, J. E., Arnold, K. S., Backhouse, J. W. and Sampson, D. (1980b). Plasma biochemistry in the horse during 3-day event competition. *Equine Vet. J.* **12**, 132–136.
- Schwartz, M. K., Bethune, V. G., Fleisher, M., Pennaconia, G., Menedez-Botet, C. J. and Lehman, D. (1974). Chemical and clinical evaluation of the continuous flow analyzer 'SMAC'. *Clin. Chem.* **20**, 1062–1070.
- 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.
- Snow, D. H. and Mackenzie, G. (1977). Some metabolic effects of maximal exercise in the horse and adaptations with training. *Equine Vet. J.* **9**, 134–140.
- Sréter, F. A. (1959). The effect of systematic training on plasma electrolytes, haematocrit values and blood sugar in Thoroughbred racehorses. *Can. J. Biochem. Physiol.* **37**, 273–283.
- Takagi, S. and Sakurai, N. (1971). Changes in glucose, pyruvate and lactate in blood of horses at rest and during exercise. *Exp. Rep. Equine Hlth Lab.* **8**, 100–109.
- Traver, D. S., Coffman, J. R., Moore, J. N., Salem, C. A., Garner, H. E., Johnson, H. H. and Tritschler, L. G. (1976). Urine clearance ratios as a diagnostic aid in equine metabolic disease. *Proc. Am. Ass. Equine Practns* **22**, 177–183.

# Haematology and Blood Biochemistry of Horses during a 210 km Endurance Ride

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## Summary

*Various haematological analyses were performed on daily pre-ride and post-ride blood samples collected from 20 randomly sampled horses participating in the South African National Endurance Ride of 1981. The ride is an annual three-day event during which distances of 80 km, 80 km and 50 km are covered over the three days respectively.*

*The values of the majority of parameters increased during the ride on each of the three days and returned to approximately the pre-ride values overnight. The blood glucose decreased during the ride and also returned to the pre-ride values overnight. An exception was the plasma urea concentration which showed a cumulative increase during the three days. Only minor changes occurred in the concentrations of the plasma cations.*

*The horses were ridden faster on the first day of the ride and the alterations in the blood constituents were more marked on this day than on the two subsequent days.*

*The greater alterations in the concentration of blood constituents observed in less fit horses ridden at average speeds exceeding 19 km/h suggest that they were more stressed than the fit or more slowly ridden horses.*

## Introduction

Endurance riding has gained popularity in South Africa since 1974. Local competitive rides are normally one-day events over distances of 80 km and exceptionally over distances of 160 km. During July each year, a national ride is organised in the central part of the country at a small town called Fauresmith. This is a three-day event over a total distance of 210 km of which 80 km are covered on the first day, a further 80 km on the second day and the final 50 km on the third day. Approximately 70 to 90 horses are entered annually, with approximately 70% succeeding in completing the ride.

Strict veterinary control is exercised by a panel of veterinarians at the various check points and on the route. All competitors are compelled to rest their horses for half an hour at the first check point, 30 km from the start, and for one hour at the second check point (on the first two days), a further 30 km away. Apart from a general examination for habitus, lameness and possible injuries, pulse and respiratory rates are determined for each horse 20 minutes after arrival at each check point and at the end of each day's ride.

Horses found to be in a satisfactory condition and with pulse rates below 70 and respiratory rates below 40 per minute may continue the ride after the rest period. Those not conforming to these standards are examined again ten minutes later and, if within the limits, allowed to continue the ride, but if not, they are disqualified.

The winning time has improved over the years from 11 hours 1 minute in 1974 to 8 hours 38 minutes (405 m/min or 24.3 km/h) in 1982 over the same course.

The results of various blood analyses on horses competing in 80 km, 100 km and 160 km rides have been reported by various authors in the past (Carlson and Mansmann, 1974; Snow and Mackenzie, 1977; Rose *et al.*, 1977; Lucke and Hall, 1978; Rose *et al.*, 1979; Dybdal *et al.*, 1980; Lucke and Hall, 1980; Rose *et al.*, 1980; Rose 1982). Probably the most comprehensive study on changes occurring in endurance horses has been performed by Snow *et al.* (1982) under experimental conditions. Although minor differences may exist between the results, a reasonably clear picture can be formed from these articles of the mean haematological and biochemical changes that occur in horses performing endurance exercise. However, means do not always satisfy, as great differences between individual horses may occur. For example, the blood glucose concentration increased to 189% of the pre-ride value in one horse, while decreasing to 16% of the pre-ride level in another during the same ride (Grosskopf, unpublished data). For this reason attempts were made to group the horses according to speed and subjective fitness evaluations and to compare the haematological changes among such groups.

This paper is the first report on the haematological findings of horses subjected to three successive days of competitive endurance riding.

### *Materials and Methods*

Jugular blood samples of approximately 15 ml were collected from the horses of co-operative riders and placed into vacuum tubes containing lithium-heparin and oxalate/fluoride anticoagulants. The samples were taken at different stages of the 1981 South African National Endurance Ride.

Samples were collected from 20 selected horses. Each of these was bled on departure each morning and immediately on return in the afternoon. On the third day, an additional sample was taken from each horse exactly 20 minutes after arrival. Fortunately only 3 of these 20 horses were withdrawn or disqualified during the ride so that a complete picture of 17 horses over the three days could be obtained.

The heparinised blood samples were used for the following analyses: haematocrit, haemoglobin, total plasma proteins, plasma electrolytes, plasma creatine kinase, plasma cortisol and plasma urea. The fluoride/oxalated samples were used for the blood glucose and plasma lactate determinations.

The following analytical methods were employed:

*Haematocrit:* Microhaematocrit centrifugation.

*Total plasma proteins:* Goldberg refractometer.

*Plasma electrolytes:* Automated atomic absorption spectrophotometry (Varian Techton AA 275)

*Plasma creatine kinase (CK):* Enzymatic UV-spectrophotometric method using the Boehringer Mannheim assay kit. The very high levels had to be performed after dilution of the plasma and are not claimed to be accurate.

*Plasma cortisol*: A double antibody radio-immunoassay using the method and reagents as supplied by Diagnostic Products Corporation.

*Plasma urea*: Enzymatic UV-spectrophotometric method using the Boehringer Mannheim assay kit.

*Blood glucose*: The GOD-Perid colorimetric method using the Boehringer Mannheim assay kit.

*Plasma lactate*: The enzymatic UV-spectrophotometric method using the Boehringer Mannheim assay kit.

A temporary laboratory was set up at the stables from which the horses departed and to which they returned each day. Haematocrit and total plasma proteins were determined immediately after sampling. The remainder of the samples were simultaneously centrifuged, and the plasma was stored at  $-15^{\circ}\text{C}$  until it was possible to analyse the samples at the home laboratory during the following week. Maximum storage periods which would not materially affect the result were determined beforehand, and all analyses were performed well within these limits.

Plasma samples that appeared to be haemolysed were noted. Some of these were subjected to spectrophotometric analysis in an attempt to distinguish between haemoglobin and myoglobin. Both were found to be present in all samples examined, but because their absorption spectra overlap it was not possible to express the findings quantitatively.

The mean values obtained for every parameter were subjected to the following statistical analyses:

1. A one-way analysis of variance to determine the significance of the differences between the pre-ride values on the three different days.
2. A one-way analysis of variance to determine the significance of the effect of the ride, i.e. the differences between the pre-ride and post-ride values.
3. An analysis of variance to determine the significance of the recovery during the first 20 minutes after the ride on the last day, i.e. the differences between the immediately post-ride values and the values 20 minutes later and
4. The differences between the initial pre-ride values and the values obtained after the 20 minute recovery period.

For the purpose of an analysis of the results, comparisons were drawn between fast/fit, fast/less fit, slow/fit and slow/less fit horses on the three different days of the ride.

The average speed of each horse on each of the three days was taken as the criterion for fast or slow. Horses averaging more than 317 m/min (19 km/h) were classified as fast and those below 317 m/min as slow. Fitness was determined according to a formula used by the veterinary panel of the Endurance Ride Association of South Africa and on the reports of the two course veterinarians. The formula is the following: riding time in half hours for a three-day ride (or in ten-minute periods for a one-day event) plus the mean pulse rate at each check point taken 20 minutes after arrival plus the mean respiratory rate at each check point also counted 20 minutes after arrival. The lowest value indicates the fittest horse. On this basis, 9 of the 20 experimental horses were classified as fit and 11 as less fit. With one exception, all horses remained in the same fitness category for statistical purposes throughout. The exception was one horse (no. 35) whose rider, contrary to the advice of the course veterinarians, tried to keep up with a faster horse on the first two days. On the last day she rode alone, and the general condition of the horse improved so much that it was no longer logical to keep it in the less fit group. On the first

TABLE 1. Daily mean values, with standard deviations, of eleven haematological parameters prior to and immediately after the rides and 20 minutes after the ride on the final day.

| Parameter   | Day 1         |               | Day 2         |               | Day 3         |               | Statistical significance*  |
|---|---------------|---------------|---------------|---------------|---------------|---------------|--|
|   | Pre-ride      | Post-ride     | Pre-ride      | Post-ride     | Pre-ride      | Post-ride     |  |
|   | Mean          | SD            | Mean          | SD            | Mean          | SD            |  |
| Haematocrit (/l)                                      | 0.401 ± 0.041 | 0.516 ± 0.055 | 0.418 ± 0.028 | 0.493 ± 0.036 | 0.416 ± 0.047 | 0.478 ± 0.032 | a <sup>o</sup> b <sup>o</sup> *c <sup>o</sup> d <sup>o</sup> **  |
| Total plasma proteins (g/l)                           | 67.5 ± 3.3    | 76.2 ± 5.7    | 64.2 ± 4.9    | 72.3 ± 4.7    | 63.2 ± 4.3    | 68.9 ± 4.4    | a <sup>o</sup> *b <sup>o</sup> *c <sup>o</sup> d <sup>o</sup> ** |
| Blood glucose (mmol/l)                                | 3.8 ± 0.7     | 3.0 ± 0.9     | 4.0 ± 0.8     | 2.3 ± 0.9     | 3.9 ± 0.7     | 2.9 ± 0.9     | a <sup>o</sup> b <sup>o</sup> *c <sup>o</sup> d <sup>o</sup> *   |
| Plasma lactate (mmol/l)                               | 0.8 ± 0.3     | 2.2 ± 0.9     | 0.9 ± 0.3     | 1.7 ± 0.6     | 1.1 ± 0.4     | 1.8 ± 1.1     | a <sup>o</sup> *b <sup>o</sup> *c <sup>o</sup> d <sup>o</sup> ** |
| Plasma urica (mmol/l)                                 | 5.5 ± 1.0     | 8.0 ± 2.4     | 8.6 ± 2.1     | 10.6 ± 2.6    | 10.2 ± 3.2    | 10.7 ± 2.5    | a <sup>o</sup> *b <sup>o</sup> *c <sup>o</sup> d <sup>o</sup> ** |
| Plasma creatine kinase (log units/l)                  | 1.74 ± 0.99   | 3.28 ± 1.12   | 2.74 ± 0.88   | 3.06 ± 0.73   | 2.39 ± 0.92   | 2.78 ± 0.61   | a <sup>o</sup> *b <sup>o</sup> *c <sup>o</sup> d <sup>o</sup> ** |
| Plasma creatine kinase (7 horses with rhabdomyolysis) | 2.29 ± 1.21   | 4.51 ± 0.47   | 3.71 ± 0.42   | 3.84 ± 0.32   | 3.23 ± 0.50   | 3.30 ± 0.44   | —  |
| Plasma creatine kinase (13 horses)                    | 1.42 ± 0.70   | 2.49 ± 0.63   | 2.31 ± 0.51   | 2.64 ± 0.51   | 1.88 ± 0.72   | 2.47 ± 0.47   | —  |
| Plasma sodium (mmol/l)                                | 139 ± 3.4     | 139 ± 5.4     | 139 ± 4.5     | 139 ± 5.4     | 139 ± 4.4     | 139 ± 5.5     | a <sup>o</sup> b <sup>o</sup> *c <sup>o</sup> d <sup>o</sup> *   |
| Plasma potassium (mmol/l)                             | 3.3 ± 0.6     | 4.2 ± 1.9     | 4.4 ± 1.9     | 3.9 ± 0.5     | 3.9 ± 0.5     | 4.2 ± 0.9     | a <sup>o</sup> *b <sup>o</sup> *c <sup>o</sup> d <sup>o</sup> *  |
| Plasma calcium (mmol/l)                               | 3.1 ± 0.1     | 3.0 ± 0.3     | 3.0 ± 0.1     | 2.8 ± 0.2     | 2.9 ± 0.2     | 2.7 ± 0.2     | a <sup>o</sup> *b <sup>o</sup> *c <sup>o</sup> d <sup>o</sup> ** |
| Plasma magnesium (mmol/l)                             | 0.8 ± 0.1     | 0.9 ± 0.1     | 0.8 ± 0.1     | 0.9 ± 0.1     | 0.8 ± 0.1     | 0.9 ± 0.1     | a <sup>o</sup> b <sup>o</sup> *c <sup>o</sup> d <sup>o</sup> *   |
| Plasma cortisol (nmol/l)                              | 148 ± 58      | 461 ± 189     | 173 ± 61      | 377 ± 159     | 172 ± 65      | 309 ± 131     | a <sup>o</sup> b <sup>o</sup> *c <sup>o</sup> d <sup>o</sup> **  |
| Number of horses sampled                              | 20            | 19            | 17            | 17            | 17            | 17            |  |

\* a = difference between pre-ride values of the three days.

b = difference between pre-ride and post-ride values.

c = difference between day 3 post-ride value and 20 min. post-ride value.

d = difference between day 1 pre-ride value and 20 min. post-ride value.

o = no significant difference (p > 0.05); \* = significant at p < 0.05; \*\* = significant at p < 0.01.

day only one horse was classified as slow/fit, and on the third day none of the less fit horses exceeded 19 km/h, and therefore there was no fast/less fit group on the final day.

The differences between the daily pre-ride and post-ride values of each parameter were determined for each horse. Analyses of variance were then performed on these differences between the four groups to determine the statistical significance.

### *Results and Discussion*

The mean changes in the haematological values are presented in Table 1. The statistical significance of these changes is indicated in the right-hand column.

Seven of the 20 experimental horses showed signs of stiffness, and two were reported to have passed red-stained urine on the first day of the ride. Of these, two had to be disqualified for not being able to recover sufficiently at the first and second check points respectively. A third horse had to be withdrawn on the first day because of lameness. In retrospect it was quite obvious that the seven horses were suffering from a rhabdomyolytic syndrome precipitated by sudden work after three days with insufficient exercise.

The plasma of all the affected horses had a red to reddish-brown discolouration after the first day's ride and contained exceptionally high levels of creatine kinase, as indicated by the results in Table 1.

It is evident from Table 1 that the mean values of a number of the parameters, notably haematocrit, total plasma proteins, plasma lactate, plasma creatine kinase and plasma cortisol, increased during the ride on each of the three successive days and, with the exception of CK, decreased overnight to levels not much in excess of the pre-ride levels. In fact, the haematocrit and total plasma proteins nearly returned to their pre-ride values within 20 minutes after the ride, indicating that severe dehydration did not take place. This is contrary to previous experience (Grosskopf, unpublished results) where dehydration used to be a major problem. The riders have since accepted the advice to water their horses more frequently, if possible every 5 km, so that dehydration is no longer a problem on cool days (maximum temperature below 20°C).

An unexpected cumulative increase in the mean plasma urea concentration was encountered over the three days. Lucke and Hall (1980) ascribed the increase to reduced renal perfusion, but the fact that it did not decrease overnight suggests that it originated from increased gluconeogenesis and deamination of amino acids. This has also been suggested by Snow *et al.* (1982). Similarly, a continuous small decrease in the mean plasma calcium concentration was noted over the three days which was also not reversed overnight.

The mean blood glucose level decreased on each day of the ride but returned more or less to its pre-ride level overnight. An insignificant increase (approximately 10% of the post-ride level) was recovered within 20 minutes after the ride.

The mean plasma sodium concentration remained absolutely constant throughout the ride. A small decrease (from 139 to 137 mmol/l) occurred within the first 20 minutes after the ride. This could have been due to the replenishment of water. The mean potassium concentration in the plasma increased during the ride on the first day, further increased overnight, decreased during the ride on the second day and then remained constant until the next day when it increased a little during the ride and dropped back to its pre-ride level within 20 minutes after the ride. Plasma magnesium concentrations showed a

similar small increase (approximately 16% of the pre-ride level) during each day of the ride and returned to normal overnight.

In general, these findings agree with those of other authors, although there seems to be no general agreement on the changes in the concentrations of electrolytes during the

TABLE 2. The mean differences (and standard deviations) between the daily pre-ride and immediately post-ride values of a number of haematological parameters in four groups of endurance horses.

| Parameter                     | Day | Fast/fit |       | Fast/less fit |       | Slow/fit |       | Slow/less fit |       |
|-------------------------------|-----|----------|-------|---------------|-------|----------|-------|---------------|-------|
|                               |     | Diff.    | SD    | Diff.         | SD    | Diff.    | SD    | Diff.         | SD    |
| Haematocrit (l/l)             | 1   | +0.078   | 0.054 | +0.155        | 0.082 | +0.055   | —     | 0             | 0.021 |
|                               | 2   | +0.065   | 0.030 | +0.106        | 0.022 | +0.047   | 0.042 | +0.077        | 0.014 |
|                               | 3   | +0.085   | 0.033 | —             | —     | +0.057   | 0.021 | +0.048        | 0.050 |
| Plasma protein (g/l)          | 1   | +5.4     | 2.3   | +11.0         | 5.7   | +1.0     | —     | +12.5         | 0     |
|                               | 2   | +9.8     | 5.0   | +10.7         | 1.9   | +5.9     | 4.5   | +7.6          | 1.6   |
|                               | 3   | +6.4     | 2.5   | —             | —     | +4.6     | 1.3   | +5.0          | 2.0   |
| Glucose (mmol/l)              | 1   | -0.42    | 0.73  | -1.20         | 0.99  | -1.90    | —     | -0.54         | 0.40  |
|                               | 2   | -1.42    | 0.26  | -2.30         | 0.36  | -1.09    | 0.36  | -1.32         | 0.79  |
|                               | 3   | -0.81    | 0.57  | —             | —     | -1.12    | 0.21  | -1.03         | 0.49  |
| Lactate (mmol/l)              | 1   | +1.49    | 0.61  | +1.83         | 0.95  | +0.32    | —     | +0.90         | 0.57  |
|                               | 2   | +0.96    | 0.57  | +1.25         | 1.14  | +0.89    | 0.29  | +0.42         | 0.49  |
|                               | 3   | +1.16    | 1.76  | —             | —     | +0.86    | 0.82  | +0.30         | 0.76  |
| Urea (mmol/l)                 | 1   | +2.0     | 1.35  | +2.7          | 2.97  | +1.7     | —     | +4.0          | 1.63  |
|                               | 2   | +1.8     | 0.41  | +1.9          | 0.59  | +1.9     | 0.85  | +3.1          | 1.13  |
|                               | 3   | +0.7     | 0.60  | —             | —     | +0.5     | 1.05  | +1.1          | 0.74  |
| Creatine kinase (log units/l) | 1   | +3.25    | 0.90  | +3.32         | 1.21  | +2.17    | —     | +2.21         | 1.25  |
|                               | 2   | +2.81    | 0.36  | +2.91         | 0.40  | +2.43    | 0.55  | +2.39         | 0.73  |
|                               | 3   | +2.37    | 0.26  | —             | —     | +1.97    | 0.31  | +2.58         | 0.49  |
| Sodium (mmol/l)               | 1   | +2       | 6.7   | -1            | 3.9   | +9       | —     | +2            | 0.7   |
|                               | 2   | +3       | 6.7   | 0             | 2.2   | 0        | 4.5   | -3            | 4.5   |
|                               | 3   | +2       | 2.9   | —             | —     | +3       | 7.8   | -1            | 5.6   |
| Potassium (mmol/l)            | 1   | +0.56    | 0.98  | +1.15         | 2.32  | +0.03    | —     | +1.78         | 2.32  |
|                               | 2   | +0.16    | 0.32  | +0.25         | 0.72  | +0.07    | 0.45  | -0.17         | 0.79  |
|                               | 3   | +0.06    | 0.57  | —             | —     | -0.04    | 0.35  | +0.47         | 1.13  |
| Calcium (mmol/l)              | 1   | -0.04    | 0.11  | -0.20         | 0.32  | -0.20    | —     | -0.04         | 0.02  |
|                               | 2   | -0.06    | 0.15  | -0.18         | 0.08  | -0.13    | 0.11  | -0.30         | 0.15  |
|                               | 3   | -0.18    | 0.22  | —             | —     | -0.23    | 0.13  | -0.36         | 0.17  |
| Magnesium (mmol/l)            | 1   | +0.09    | 0.06  | +0.17         | 0.17  | +0.06    | —     | +0.22         | 0.08  |
|                               | 2   | +0.11    | 0.12  | +0.17         | 0.09  | +0.13    | 0.03  | +0.17         | 0.07  |
|                               | 3   | +0.07    | 0.09  | —             | —     | +0.07    | 0.10  | +0.11         | 0.10  |
| Cortisol (nmol/l)             | 1   | +229     | 132   | +403          | 87    | +103     | —     | +417          | 265   |
|                               | 2   | +151     | 71    | +378          | 48    | +163     | 33    | +146          | 82    |
|                               | 3   | +200     | 139   | —             | —     | +13      | 136   | +141          | 85    |

rides. For example, some found the plasma sodium concentrations to rise (Rose *et al.*, 1977; Lucke and Hall, 1980; Snow *et al.*, 1982), others found it to decrease (Carlson and Mansmann, 1974; Rose *et al.*, 1980), while another (Lucke and Hall, 1978) found no difference between the pre-ride and post-ride values. Similarly, the above authors do not agree on the changes in plasma potassium and calcium. It appears that the prevailing environmental temperature and humidity and the degree of dehydration of the horses may be responsible for these discrepancies.

Despite the information that could be gained from the mean changes in the values of the different parameters, the problem of why certain horses become fatigued and others do not still remains to be clarified. It was therefore decided to compare the reactions of fit and less fit and fast and slow horses. Such comparisons are shown in Table 2. The parameters are discussed individually.

#### *Haematocrit*

As expected the haematocrits of the less fit horses ridden faster than 317 m/min (19 km/h) increased the most during the ride, while the fit, more slowly ridden horses showed the least increase. The differences between the fast/fit and fast/less fit, between the fast/fit and slow/fit, between the fast/less fit and slow/less fit and between the slow/fit and slow/less fit were all statistically significant at the 1% level.

The two horses disqualified for not recovering at check points on the first day had haematocrits of 0.65 l/l and 0.57 l/l at the time of disqualification. These were the highest and third highest values recorded during the ride.

Lucke and Hall (1980) do not regard haematocrit increases as reliable measures of dehydration. This viewpoint is supported. The haematocrits of the majority of horses returned to values very close to the pre-ride levels within 20 minutes after the ride. In such cases it was concluded that the increased haematocrits were mainly due to a reaction to the exercise and not to dehydration. On the other hand, when the higher haematocrit persists after exercise it might be a useful indication of the degree of dehydration.

#### *Total plasma proteins*

As with the haematocrits, the increase in plasma protein concentration in the fast/less fit group appeared to be higher than in the other groups, but the differences between groups were not significant. The plasma protein concentration increased in every horse on each of the three days. This general increase has also been recorded by other authors, e.g. Carlson and Mansmann (1974), Rose *et al.* (1977), Rose *et al.* (1980), Lucke and Hall (1980) and Snow *et al.* (1982).

#### *Blood glucose*

The blood glucose concentrations decreased in all four groups of horses on all the days of the ride. This is in agreement with the findings of Rose *et al.* (1977), Lucke and Hall (1978), Dybdal *et al.* (1980) and Snow *et al.* (1982). The greatest drop was recorded in the fast/less fit group, while the decreases in the other groups were more or less of the same order. No significant differences between the groups could be demonstrated.

The lowest value (0.8 mmol/l) was found in horse no. 38 (fast/less fit group) at the end of the second day's ride.

#### *Plasma lactate*

The plasma lactate concentration increased during the ride in every horse that averaged more than 267 m/min (16 km/h) on that day. The increase was more pronounced in the two fast groups. Significant differences at the 5% level could be indicated between the fast/fit and slow/fit groups and between the fast/less fit and slow/less fit groups. The latter significant difference can possibly be ascribed to the fact that the riders of the less fit horses realized that they had to ride much more slowly on the last day if they wanted to complete the ride.

Snow and Mackenzie (1977) found greater lactate rises in untrained than in trained horses working aerobically over a distance of 22.4 km.

#### *Plasma creatine kinase (CK)*

Creatine kinase increases in the plasma with strenuous muscular exercise and reaches high concentrations after muscular damage. Extremely high CK values were encountered in seven of the horses after the first day's ride. Although only one of them presented the typical clinical symptoms of exertional rhabdomyolysis, six others were partly stiff on the first day but were allowed to continue. With the exception of two horses which were classified in the fast/fit group, the other five were grouped as fast/less fit on the first day. On the third day only three of the latter were still in the ride and these were all in the slow/less fit group.

If the horses with the extremely high CK values are disregarded, the CK values of the others all increased to a greater or lesser extent. They increased more in the less fit than in the fit groups. However, mainly because of the great deviations in the increases, the differences between the groups were not significant.

#### *Plasma cortisol*

Cortisol levels increased in all the horses with the exception of two on the last day (one of the two being the winner). Highly significant differences ( $p < 0.01$ ) in the changes in cortisol concentration could be demonstrated between the fast/fit and fast/less fit groups, between the fast/fit and slow/fit groups, between the fast/less fit and slow/less fit groups and between the slow/fit and slow/less fit groups.

#### *Plasma electrolytes*

The changes in plasma electrolytes during the ride have been discussed. No statistical differences could be demonstrated between the changes that occurred in the four different groups.

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## References

- Carlson, G. P. and Mansmann, R. A. (1974). Serum electrolyte and plasma protein alterations in horses used in endurance riding. *J. Am. Vet. Med. Ass.* **165**, 262–264.
- Dybdal, N. O., Gribble, D., Madigan, J. E. and Stabenfeldt, G. H. (1980). Alterations in plasma corticosteroids, insulin and selected metabolites in horses used in endurance rides. *Equine Vet. J.* **12**, 137–140.
- Lucke, J. N. and Hall, G. M. (1978). Biochemical changes in horses during a 50-mile endurance ride. *Vet. Rec.* **102**, 356–358.
- Lucke, J. N. and Hall, G. M. (1980). Long distance exercise in the horse: Golden Horseshoe Ride 1978. *Vet. Rec.* **106**, 405–407.
- 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 an endurance ride. *Equine Vet. J.* **9**, 122–126.
- Rose, R. J., Ilkiw, J. E. and Martin, I. C. A. (1979). Blood-gas, acid–base and haematological values in horses during an endurance ride. *Equine Vet. J.* **11**, 56–59.
- Rose, R. J., Arnold, K. S., Church, S. 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. and Mackenzie, G. (1977). Effect of training on some metabolic changes associated with submaximal endurance exercise in the horse. *Equine Vet. J.* **9**, 226–230.
- 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.