

# Heart Rate, Hematological and Serum Biochemical Responses to Show Jumping

P. LEKEUX, T. ART, A. LINDEN, D. DESMECHT and H. AMORY

*Equine Sports Medicine Unit, Faculty of Veterinary Medicine, University of Liège, Bât B42, Sart Tilman, B-4000 Liège, Belgium*

**ABSTRACT.** Changes in heart rate (HR), plasma lactate (LA) and some other blood parameters were studied in 16 healthy show jumping horses participating in the Belgian Junior Championship. Venous blood was collected from each horse before and immediately after competing and was analysed for packed cell volume (PCV), LA, plasma cortisol, blood glucose (GLU), total plasma protein bicarbonate ions and serum levels of lactate dehydrogenase, creatine kinase, aspartate aminotransferase and gamma glutamyl transferase (GGT). A HR recorder placed under the saddle continuously recorded HR from the warm-up to 5 min after the course in 10 horses. Show jumping induced a significant increase in all parameters, except GLU, which decreased significantly, and GGT which remained unchanged. Resting values of LA and HR were  $0.43 \pm 0.05$  mmol l<sup>-1</sup> and  $44.7 \pm 2.9$  beats min<sup>-1</sup> respectively. Post-exercise LA reached a mean value of  $8.7 \pm 0.5$  mmol l<sup>-1</sup>, while HR rose to a peak of  $189.2 \pm 3.5$  beats min<sup>-1</sup> during the course. The results of the present study demonstrated that, although the speed and duration of such an exercise are low, show jumping represents severe exertion which requires some anaerobic metabolism.

*Key words:* Exercise physiology; horses; show jumping.

## INTRODUCTION

A knowledge of the physiology of the exercise performed by a horse for a specific competition is necessary to help in devising an adequate training programme. Numerous studies have contributed to a better understanding of the physiological and biochemical changes during racing, endurance and three-day event competitions.<sup>18,19,22,25</sup> From this understanding, a pattern is emerging which could provide a basis for improving the management, training programmes, evaluation of performance potential and assessment of the pathological processes induced by exercise.

As there are no reports on the physiological effects of show jumping competition, this study was undertaken to monitor heart rate (HR), plasma lactate and cortisol, and other blood biochemical parameters during a competition.

## MATERIAL AND METHOD

Sixteen show jumping horses, Belgian Saddlebred aged from 6 to 12 years, competing in the Belgian Junior Championship were used in this study. All were clinically healthy. They were investigated during an outdoor event consisting of a 560 m course, with fourteen 140 cm high fences. The horses were warmed up for varying periods from 10 to 35 min. The warm-up exercise consisted of walk and trot, with short periods of canter and jumping to 6 obstacles. The competition was scored by knockdowns and time on the course. The weather was dry and sunny (temperature 24°C; relative humidity 70%; barometric pressure 750 mmHg) and the ground was flat and grassed.

Blood samples were collected at rest, 24 hours before the competition (i.e. between 8.30 and 10.30 a.m.), and 2 min after the completion of the course. Blood was taken

from the jugular vein using 20 gauge needles (Terumo) and 3 vacuum collecting tubes (Terumo), i.e. 1 silicone coated (10 ml), 1 containing sodium heparin and sodium moniodoacetate (3 ml) and 1 EDTA K<sup>+</sup> coated (3 ml). Blood in the first tube was allowed to clot. The second tube was immediately centrifuged (20 min at 14 000 G). The third sample was immediately analysed for packed cell volume (PCV) by the microhaematocrit method and afterwards was centrifuged (20 min at 14 000 G). After separation, plasma from the second tube was stored at 18°C and analysed within 24 hours for glucose (GLU) and lactate (LA). Plasma from the third tube was frozen at -20°C and assayed for plasma cortisol concentration within one month of collection. The sera were stored at 4°C and were analysed within 24 hours for total plasma protein albumin (TPP), bicarbonate (HCO<sub>3</sub><sup>-</sup>) serum activities of plasma lactate dehydrogenase (LDH), creatine kinase (CK), aspartate amino transferase (AST) and gamma glutamyl transferase (GGT).

Blood glucose was determined by the GOD-PAP colorimetric method (Cat. No. 166391, Boehringer) and LA by the enzymatic U.V. spectrometric method (Cat. No. 149993, Boehringer). Serum activities of CK, AST, GGT and LDH were measured by reaction rate analyses at pH 7.0 and 37°C using the U.V. method (Boehringer). Total plasma protein was determined by the Biuret method (Boehringer) and HCO<sub>3</sub><sup>-</sup> by enzymatic procedure (Boehringer).

Plasma cortisol concentrations were determined by a radioimmunoassay technique. The assay detection limit was 6.62 nmol l<sup>-1</sup> and the cross reactivity of the antiserum to other steroids has been previously described.<sup>11</sup>

In 10 of the 16 horses, HR was recorded by means of a commercial HR recording system (Horse Tester PEH 200). The accuracy of the system used in this study was checked by comparing the HR recorded with those obtained by a telemetric recording of the electrocardiogram. The recorder was used to

store the number of heart beats during consecutive periods of 5 seconds; after the recording, the stored data were displayed using a computerised read out unit.

The horse tester recording system was placed under the saddle 10–15 min before the course and HR was continuously recorded from the moment the rider started or continued the warm-up until 5 min after the end of the course. Performance, i.e. time for completion of the course, fault and refusal, of each horse was carefully noted.

Results are given as mean ± SEM. The values of the blood parameters post-exercise were compared to the resting values by a one-way analysis of variance. The changes in HR were also statistically analysed by a one-way analysis of variance.

## RESULTS

Six horses performed a clear round, four finished with 1 fault and six with 2 faults. The pace of the horses was regular and there was no refusals. The average time taken to complete the course was 84.27 ± 1.45 seconds; the mean speed was thus 398 ± 5 m min<sup>-1</sup>.

There were significant increases ( $p < 0.001$ ) in PCV from 0.352 ± 0.012 l l<sup>-1</sup> to 0.494 ± 0.015 l l<sup>-1</sup> and in TPP from 64 ± 1 to 71 ± 1 g l<sup>-1</sup>. Post-exercise LA concentration reached a mean value of 8.7 ± 0.5 mmol l<sup>-1</sup>; GLU showed a significant decrease between the rest (5.47 ± 0.15 mmol l<sup>-1</sup>) and the post-exercise period (4.84 ± 0.21 mmol l<sup>-1</sup>) while plasma cortisol increased significantly from 67.62 to 118.68 nmol l<sup>-1</sup> (Fig. 1). Lastly, HCO<sub>3</sub><sup>-</sup> was significantly lower after the show jumping, changing from 23.4 ± 0.5 to 18.3 ± 0.8 mmol l<sup>-1</sup>.

An increase in all plasma enzyme activities is demonstrated in Fig. 2. This tendency was moderate but significant ( $p < 0.01$ ) for AST and LDH, and marked for CK ( $p < 0.001$ ). The mean value of GGT at rest was 6.8 ± 0.3 IU l<sup>-1</sup>. This value did not increase significantly after the completion of the trial (7.9 ± 0.5 IU l<sup>-1</sup>).

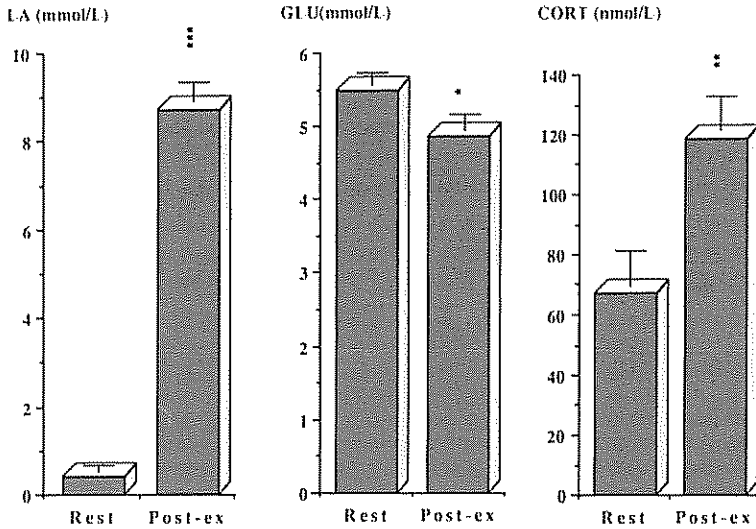


Fig 1. Plasma lactate (LA), blood glucose (GLU) and plasma cortisol (CORT) at rest and after (Post-ex) the completion of a show jumping competition. Mean  $\pm$  SEM ( $n=16$ ). \* Significantly different from rest values with  $p<0.05$ ; \*\*  $p<0.01$ ; \*\*\*  $p<0.001$

The mean values of HR at rest and at different times during recording are shown in Fig. 3. The horses had a mean HR of  $96.5 \pm 5.3$  beats  $\text{min}^{-1}$  in the warm-up period. Heart rate showed a progressive and significant increase from the start of the course to the end ( $179.4 \pm 3.9$  to  $189.2 \pm 3.5$  beats  $\text{min}^{-1}$ ). During the recovery, HR fell to  $106.4 \pm 5.0$  beats  $\text{min}^{-1}$  after 2 min and to  $75.2 \pm 6.4$  beats  $\text{min}^{-1}$  after 5 min.

## DISCUSSION

The results of this study showed that the completion of the entire jumping competition, including the warm-up period, induced marked changes in most of the parameters measured. A metabolic acidosis, i.e. a significant decrease in  $\text{HCO}_3^-$  concentration, was induced by the jumping exercise. This is associated with the substantial increase in LA observed. It was previously reported that

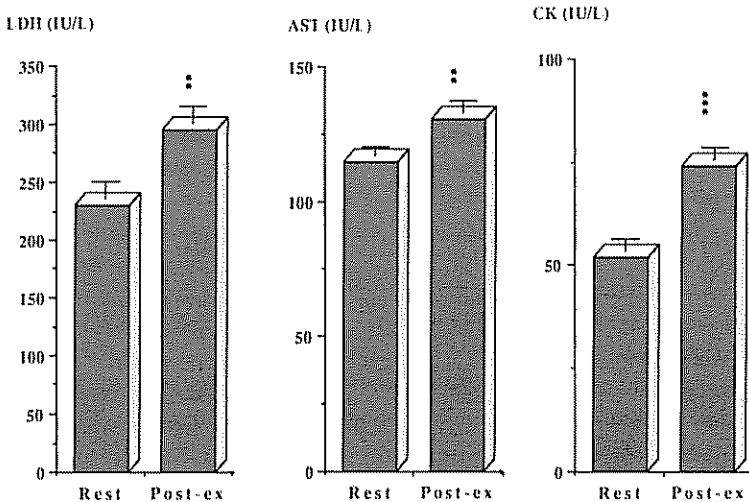


Fig 2. Serum enzyme activities of lactate dehydrogenase (LDH), aspartate aminotransferase (AST) and creatine kinase (CK) in 16 horses at rest and after (Post-ex) the completion of a show jumping competition. Mean  $\pm$  SEM ( $n=16$ ). \*\* Significantly different from rest values with  $p<0.01$ ; \*\*\*  $p<0.001$

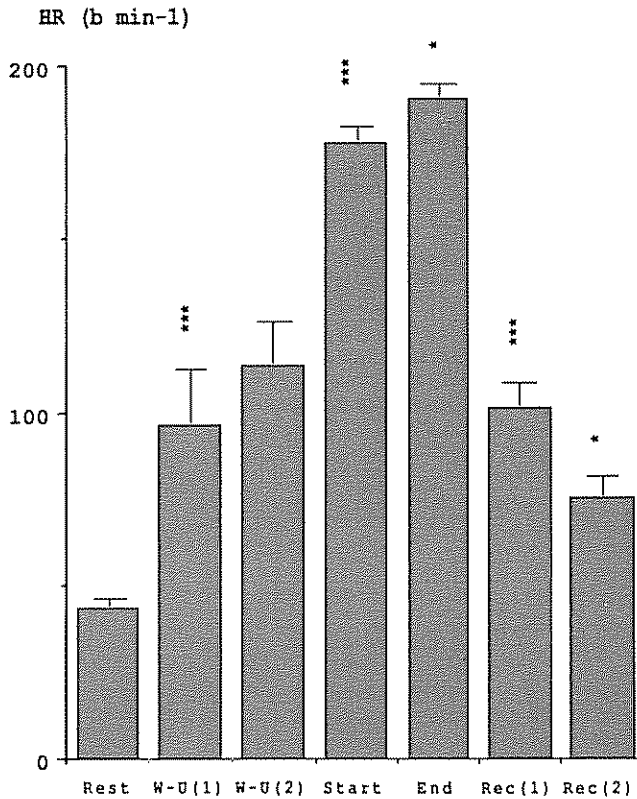


Fig 3 Mean HR values  $\pm$  SEM in 10 horses at rest, during the warm-up period [W-U (1)], just before the start [W-U (2)], at the start, at the end of the run, after 2 min recovery [Rec (1)] and 5 min recovery [Rec (2)]. \* Significantly different from preceding value with  $p < 0.05$ ; \*\*\*  $p < 0.001$ .

there were no changes in  $\text{HCO}_3^-$  or in LA after a moderate exercise ( $350 \text{ m min}^{-1}$  on the flat) and that workloads in excess of  $600 \text{ m min}^{-1}$  would be required to observe any changes in either parameter, even in the unconditioned horse.<sup>14</sup> The same observations were made concerning serum enzyme activities.<sup>15</sup> This suggests that the metabolic demand of the entire show jumping competition is similar to these of a run at  $600 \text{ m min}^{-1}$  on the flat.

Cortisol levels are used to characterize adrenal activity and physiological stress. Large fluctuations in resting values throughout the day have been reported in horses.<sup>13</sup> However, variations due to circadian rhythm are limited by the fact that resting samples in this study were taken 24 hours before the competition between 8.30 a.m. and 10.30 a.m., which is the time of the highest plasma glucocorticoid values in the horse.<sup>11</sup> Exer-

cise-induced plasma cortisol changes have been reported previously in man,<sup>5</sup> dogs<sup>7</sup> and horses<sup>6,21,25</sup> but conflicting results exist which report either an increase or a decrease in the exercise-induced changes. Basically, moderate exercise causes little alteration in plasma cortisol concentration while strenuous and exhaustive exercise produces a marked increase.<sup>23</sup> The entire show jumping competition includes the warm-up and the event, and therefore represents an averaged 30 min period of mild work followed by 2 min of high intensity exercise. The 1.5-fold rise in cortisol level reported here is lower than the 3-fold rise following an endurance competition<sup>21</sup>—which is much longer—and the 2-fold rise after racing—which is more intense.<sup>20</sup> This is in agreement with the fact that plasma cortisol rise depends on duration and/or intensity of the exercise.<sup>25</sup>

In both man<sup>4</sup> and horse, varied effects of

exercise on levels of GLU have been reported, which depend largely on the intensity and duration of the exercise. GLU has been reported to increase following racing and three-day eventing and to fall with endurance exercise.<sup>18,19</sup> In the current study GLU remained essentially unchanged; this has also been observed in horses after a canter.<sup>1</sup>

The CK, LDH and AST activities increased significantly above resting values. It is documented that these enzymes activities can increase 5 to 24 hours after the end of exercise.<sup>2</sup> The increase in enzyme levels was expected, as similar findings have been reported in horses after varying short distance exercises<sup>2</sup> and endurance rides.<sup>18</sup> Several studies in man have also indicated that serum muscle enzymes rise after exercise.<sup>9</sup> The mechanism by which cellular enzymes are released into the bloodstream is still obscure. A transient change in cell membrane permeability or damage resulting in cell destruction and release of its content have been put forward to explain this phenomenon.<sup>2</sup>

The increase of PCV was less dramatic than that found after maximal exercise.<sup>10</sup> This may be due to an incomplete contraction of the spleen, which is probably associated with lower sympathetic activity at sub-maximal than at maximal workload.

Most of the jumping horses showed a progressive increase in HR from the start to the end of the course. This pattern has also been observed in horses exercised at high workloads, where HR approached a final plateau within 45 to 120 seconds.<sup>12,16</sup> This increase of HR in the latter stage of the course was attributed partly to fatigue and partly to the need for accelerating near the finish.<sup>8</sup> The same may be true in this study.

Heart rate and LA have been studied, reported and correlated as a function of speed.<sup>3,17,24</sup> The onset of LA accumulation has been defined as a threshold reached when a horse is running at 450–500 m min<sup>-1</sup>. At this speed, LA and HR are expected to rise above 4 mmol l<sup>-1</sup> and 180–200 beats min<sup>-1</sup> respectively.<sup>24,25</sup> The horses studied ran at an average speed of 398

m min<sup>-1</sup>. Clearly LA and HR were above the expected values for such a speed. This leads to the conclusion that the effort required in the jumping of a course of fences represents severe exercise, and invokes the use of anaerobic metabolism.

This study attempts to define the type of exercise performed by a horse during an entire show jumping competition. It appears that although the speed and duration of this kind of event are low, the energy contribution is provided not only by oxidative processes but also to a great extent through anaerobic metabolism. Therefore, if genetic, conformation, kinesiological aspect of locomotion and psychological motivation are vital factors in determining the performance of the elite jumping horse, the results of this study suggest that the training schedule is also important. Endurance training is necessary in the early preparation of a jumping horse to increase its stamina, but afterwards a power training, for example running uphill or working on an inclined treadmill, is also essential. It provides the stimulation and recruitment of fast contracting fibres, which are responsible for speed and power.

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#### REFERENCES

- 1 Anderson, M. G. (1975). The effects of exercise on blood metabolite levels in the horse. *Equine Vet. J.* 7, 27–33.

- 2 Anderson, M G (1975) The influence of exercise on serum enzyme levels in the horse *Equine Vet J* 7, 160-165.
- 3 Asheim, A, Knudsen, O, Lindholm, A, Rulcker, C and Saltin, B (1970) Heart rates and blood lactate concentrations of standardbred horses during training and racing *J Am Vet Med Assoc* 157, 304-312
- 4 Bergstrom, J, Guarnieri, G and Hultram, E (1971) Carbohydrate metabolism and electrolyte changes in human muscle tissue during heavy work *J Appl Physiol* 30, 122-125.
- 5 Davies, C T M and Few, J D (1973) Effects of exercise on adrenocortical function *J Appl Physiol* 35, 887-891.
- 6 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
- 7 Foss, M L, Bernard, R J and Tipton, C M. (1971) Free 11-hydroxycorticosteroid levels in working dogs as affected by exercise training *Endocrinology* 89, 96-104.
- 8 Hall, M C., Steel, J D and Stewart, G A (1976) Cardiac monitoring during exercise tests in the horse Part 2 Heart rate responses to exercise *Austr. Vet J* 52, 1-5
- 9 Halonen, P I and Konttinen, A (1962) Effect of physical exercise on some enzymes in the serum *Nature*, 193, 942
- 10 Irvine, C H G (1958). The blood picture in the race horse. I The normal erythrocyte and hemoglobin status—a dynamic concept *J Am Vet Med Assoc* 133, 97-101
- 11 James, V H T, Horner, M W., Moss, M S and Rippon, A E (1970) Adrenocortical function in the horse *J Endocr* 48, 319-335
- 12 Krzywanek, H, Wittke, G, Bayer, A and Borman, P (1970) The heart rates of thoroughbred horses during a race. *Equine Vet. J* 2, 115-117
- 13 Larsson, M, Edqvist, L -E, Ekman, L and Persson, S (1979) Plasma cortisol in the horse, diurnal rhythm and effects of exogenous ACTH *Acta Vet Scand* 20, 16-24.
- 14 Milne, D W (1974) Blood gases, acid-base balance and electrolyte and enzyme changes in exercising horses *Jl S Afr Vet Assoc* 45, 345-354
- 15 Milne, D W., Skarda, R T., Gabel, A A., Smith, L G and Ault, K (1976). Effects of training on biochemical values in Standardbred horses *Am J Vet Res* 37, 285-290
- 16 Persson, S G B (1967) On blood volume and working capacity in horses *Acta Vet Scand Suppl* 19, 1-189
- 17 Persson, S G B (1983) Evaluation of exercise tolerance and fitness in the performance horse *In* Snow, D H, Persson, S G B and Rose, R J (eds): *Equine Exercise Physiology*. Granta Editions, Cambridge, pp 441-457
- 18 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
- 19 Rose, R J, Ilkiw, J E, Arnold, K S, Backhouse, J W and Sampson, D (1980) Plasma biochemistry in the horse during 3-day event competition *Equine Vet J* 12, 132-136.
- 20 Rosedale, P D, Burguez, P N and Cash, R S G (1984) Changes in blood neutrophil/lymphocyte ratio related to adrenocortical function in the horse *Equine Vet. J.* 14, 293-298
- 21 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
- 22 Snow, D H, Mason, D K, Ricketts, S W and Douglas, T. A (1983) Post-race blood biochemistry in Thoroughbreds *In* Snow, D H, Persson, S G B and Rose, R J (eds): *Equine Exercise Physiology*. Granta Editions, Cambridge, pp 389-399
- 23 Tharp, G D (1975). The role of glucocorticoids in exercise *Med Sci Sports* 7, 6-11
- 24 Thornton, J, Essén-Gustavsson, B, McMiken, D. and Persson, S G B (1983) Effect of training and detraining on oxygen uptake, cardiac output, blood gas tensions, pH and lactate concentration during and after exercise in the horse *In* Snow, D. H., Persson, S G B and Rose, R J (eds): *Equine Exercise Physiology*. Granta Editions, Cambridge, pp 470-486
- 25 Valberg, S, Essén-Gustavsson B, Lindholm, A and Persson, S G B (1989) Blood chemistry and skeletal muscle metabolic responses during and after different speeds and durations of trotting *Equine Vet J* 21, 91-95.