Venous hemogasometry of equines finalists in 90 km endurance races[1]

Cinthia B.S. Dumont[2], Camila A.O. Bello[2], André R.C.B. Vianna[2], Roberta F. Godoy[2] and Eduardo M.M. Lima[2]

ABSTRACT.- Dumont C.B.S., Bello C.A.O., Vianna A.R.C.B., Godoy R.F. & Lima E.M.M. 2014. **Venous hemogasometry of equines finalists in 90 km endurance races.** *Pesquisa Veterinária Brasileira 34(6):589-592*. Departamento de Anatomia Veterinária, Faculdade de Agronomia e Medicina Veterinária, Universidade de Brasília, ICC Ala Sul, Campus Darcy Ribeiro, Cx. Postal 4508, Brasília, DF 70760-701, Brazil. E-mail: limaemm@unb.br

Front of exercise, the organic systems may suffer water-electrolyte and acid-base imbalances, particularly in the case of blood gases, demonstrating variations from different causes, whether respiratory and/or metabolic. Understanding the physiological adaptations to exercise is essential in the search for the optimum performance. In this way, this study measured the venous blood gases (pO_2, pCO_2), as well as the oxygen saturation ($SatO_2$) in healthy equines, Arabian horses finalists in 90km endurance races. A total of fourteen Arabian horses were evaluated, nine males and five females, between six and 12 years old, finalists in 90km endurance races. There was a significant reduction in pO_2, pCO_2 and $SatO_2$ after the exercise, however, the values remained within the normality range, and did not change the athletic performance of the animals, indicating a temporary alteration, assuming thus a character of physiological response to the exercise performed. The equines, finalists in 90 Km endurance races, demonstrated efficient ventilatory process, without any alterations in the athletic performance, being adapted to the type of exercise imposed.

INDEX TERMS: Arabian horse, blood gas, endurance.

RESUMO.- [**Hemogasometria venosa de equinos finalistas de provas de enduro de 90 km.**] Diante do exercício, os sistemas orgânicos podem sofrer desequilíbrios hidroeletrolíticos e ácido-base, especialmente em se tratando dos gases sanguíneos, demonstrando variações decorrentes de diferentes causas, sejam elas respiratórias e ou metabólicas. O entendimento das adaptações fisiológicas que ocorrem em resposta ao exercício é de fundamental importância na busca do ótimo desempenho. Desta forma buscou-se mensurar os gases sanguíneos venosos (pO2, pCO2), bem como, a saturação de oxigênio (SatO2) em equinos saudáveis, Puro Sangue Árabe finalistas de competições de enduro de 90 km. Foram avaliados 14 equinos Puro Sangue Árabe (PSA), nove machos e cinco fêmeas, com seis a 12 anos de idade, finalistas em provas de enduro de 90 km. Houve redução significativa da pO2, pCO2 e SatO2 após o exercício, entretanto os valores se mantiveram dentro da normalidade, não alterando o desempenho atlético dos animais, indicando alterações transitória e caracterizando um caráter de resposta fisiológica ao exercício realizado. Os equinos, finalistas em provas de 90 Km, demonstraram processo ventilatório eficiente, sem quaisquer alterações no desempenho atlético e portanto estando adaptados ao tipo de exercício imposto.

TERMOS DE INDEXAÇÃO: Cavalo Árabe, gases sanguíneos, enduro.

INTRODUCTION

Front of exercise, the organic systems may suffer water--electrolyte and acid-base imbalances (Ribeiro-Filho et al. 2007, Dumont et al. 2012), particularly in the case of blood gases and their products. Thus, signaling variations deriving from different causes, whether respiratory and/or metabolic (Di Filippo et al. 2009).

The pulmonary function basically plays two main actions: blood oxygenation and alveolar ventilation, consi-

[1] Received on December 15, 2013.
Accepted for publication on March 21, 2014.

[2] Departamento de Anatomia Veterinária, Faculdade de Agronomia e Medicina Veterinária, Universidade de Brasília (UnB), ICC Ala Sul, Campus Darcy Ribeiro, Cx. Postal 4508, Brasília, DF 70760-701, Brazil. *Corresponding author: limaemm@unb.br

dering the partial oxygen pressure (pO2) as evaluation parameter of pulmonary oxygenation, as well as the partial pressure of carbon dioxide (pCO_2) for the pulmonary ventilation, being these last two inversely proportional. Therefore, it was considered that the increase or decrease in these parameters may indicate hypoventilation and hyperventilation. In this context, occurs hypoxemia induced by exercise in equine and humans, because the increase in the respiratory rate and decrease in the time of erythrocyte transit through pulmonary capillaries due to increased heart rate are mechanisms which compromise and worsen the gas diffusion through the alveolar-capillary membrane.

Understanding the physiological adaptations which occur in response to exercise is of fundamental importance in seeking the optimum performance. In this way, it was sought to measure the venous blood gases (pO_2, pCO_2), as well as the oxygen saturation ($SatO_2$) in healthy equines, Arabian horses, finalists in 90km endurance races.

MATERIALS AND METHODS

In this study we used 14 horses, nine males and five females, Arabian aged six to 12 years old, subjected to endurance training and participants of regional endurance championship of the Equestrian Federation of Brasília in the mode of 90 km. The races occurred in July, August, October and December 2009, covering the dry period with relative humidity of around 43% (April-September) and the rainy period with relative humidity of approximately 57% (October-March), with average temperature of 25ºC. The study was approved by the Ethics Committee on Animal Use of the University of Brasília under the protocol # 88-2009.

Animals were given different types of food and electrolyte supplements before and after the race. The health of the animals was proven by clinical and hematological evaluation, using an automatic cell counter (Abacus Júnior Vet®, Diagon, Ltda).

For blood gas analysis, 1.6ml blood from the external jugular vein was collected anaerobically (0.75x25mm, 22G, BD Preset Eclipse®). Samples were taken before (M0) and immediately after (MF) the exercise, being then identified and stored in ice bath (Lisboa et al. 2001) for a maximum period of 30 minutes until processing. By means of the automatic analyzer of gases, electrolytes and total hemoglobin (Analyzer of Blood Gas, Electrolyte, Hemoglobin, Hematocrit and O_2 saturation (OMNI C® Roche Diagnóstica, Brazil), it was obtained the partial pressure of oxygen pO_2 (v); partial pressure of carbon dioxide pCO_2 (v) and oxygen saturation SaO_2 (v).

The evaluation before the exercise (M0) took place in the horse farm, in days previously established, avoiding exercising the animals, by conducting a thorough clinical examination and measurement of body weight (MGR 3000 scale Toledo®). The evaluation after the exercise (MF) occurred at the place of the race, by the end of the last ring of the competition, soon after the official veterinary inspection according to methodology abovementioned.

Parameters obtained before and after the exercise were subjected to the Kolmogorov-Smirnov normality test, and compared by applying the paired t-test for parametric data, and Wilcoxon test for non-parametric data, considering significant when $P \leq 0.05$ (Table 2).

RESULTS AND DISCUSSION

The study on blood gas parameters is essential for understanding physiological responses of horses properly trained and fit for high performance sports. The results of clinical and hematological evaluation carried out before the exercise (M0) (Table 1) confirmed the health of all animals that completed the 90Km endurance race, within the reference values.

With the analysis of pO_2, pCO_2 and $SatO_2$, it was observed that all variables were slightly reduced compared with before the exercise (Table 2).

Values of pO_2 were lower than described for Arabian horses (Silva 2008), with minimum limit below physiological standards, 37 to 56 mmHg (Watanabe et al 2006). In the studied animals, the reduction was 10.08% (p=0.044), after the exercise (Table 2, Fig.1b), coinciding with that found in horses competitors of 60 Km-endurance races (Di Filipo et al. 2009) and differing from observed for jumping horses (Aguilera-Tejero et al. 2000). During intense exercises, the marked increase of cardiac output led to a reduction in the capillary transit time, compromising the oxygen equilibrium time, preventing the alveolar-capillary diffusion, resulting in hypoxemia (Wilkins et al. 2001). A fact proven when induced the hypervolemia in an attempt to reduce the hypoxemia, i.e., during periods of moderate to intense exercises the pO2 has reduced in approximately 15 mmHg (Tennent-Brown et al. 2006). This suggested that the difference between the types of exercise explains the divergent and varied values found by these authors.

Table 1. Hematological values obtained for Arabian horses, finalists of a 90 km endurance race, before and after exercise. Brasília, 2012

Parameters	Before the exercise (M0)	After the exercise (MF)	Reference Values
HR (bpm)	34.71±3.5	51.78±6.08	35±5[a]
RT (°C)	36.9±0.4	38±0.6	37.5±38.5[b]
Weight (kg)	377±23.64	369.85±26.63*	390±25.4[a]
Ht (%)	37.29±3.29	45.9±7.08*	39±1[a]
TPP (g/dL)	7.1±0.24	7.6±0.59*	6.0±8.5[b]
Platelets (mm3)	156714.29±38698.89	202000±45802.30	100000±600000[b]
Leukocytes (mm3)	8712.86±1616.54	14971.43±2297.30	8490.00±2280.00[a]

Values followed by * in the same row are significantly different (p<0.05) by the paired t-test, in the evaluations before and after the exercise. HR = heart rate, bpm = beats per minute, RT = rectal temperature, °C = degrees centigrade, Ht = hematocrit, PPT = total plasma protein, g/dL = grams per deciliter. a Ferraz et al. 2009, b Thomassian 2005.

Table 2. Blood gas values obtained Arabian horses, finalists of a 90 km endurance race, before and after exercise. Brasília, 2012

Parameters	Before the exercise (M0)	After the exercise (MF)	Reference Values (Silva, 2008)
pH	7.40±0.23	7.41±0.31	7.30
pO2(v) (mmHg)	41.7 ± 6.4	37.5 ± 3.7*	53.64±1.52
pCO2(v) (mmHg)	47.5 ± 2.8	43.1 ± 2.3*	37.61±0.40
SatO2(v) (%)	77 ± 6.4	71.9 ± 5.6*	73.70±0.64

Values followed by * in the same row are significantly different (p<0.05) by the paired t-test, in the evaluations before and after the exercise. °C: degrees centigrade, mmHg: millimeters of mercury, pH: potential of hydrogen, pO2(v): venous partial pressure of oxygen, pCO2(v): venous partial pressure of carbon dioxide, SatO2(v): venous oxygen saturation.

Animals used in endurance tests, Arabian horses, have presented hyperventilation due to the more efficient adaptation to prolonged compared with other breeds, characterizing a gradual increase in arterial and reduced venous pO2 throughout the exercise (Taylor et al. 1998), corroborating thus the results for animal finalists in 90 km-races.

The hematocrit (Ht) and the concentration of plasma protein (PPT) have increased after the 90 km-endurance exercise (Table 1), suggesting a dehydration according to substantial losses of fluid during this type of activity (Robert et al. 2010). The increase in hematocrit along with plasma pO_2 influences the transport of oxygen per unit of blood volume, and its availability is essential for efficient production of ATP during the resistance exercise (Hoffman et al. 2002). Thus the positive association between speed with variables related to the transport of oxygen can improve the performance of endurance horses. However the inverse can also occur, i.e., the increase in hematocrit has no effect in the pO_2 increase, suggesting that this parameter had been influenced by dehydration and not by splenic contraction, characterizing a relative increase, which was confirmed by the PPT concentration, a parameter safer than Ht for determining the degree of dehydration due to the splenic contraction during the exercise (Dumont et al. 2012). Therefore, using these two parameters together has appropriately assisted in the determination of the factor that actually contributed to quantify the water loss and hence the pO_2.

After the end of the exercise, the pCO_2 has reduced by 9.26% in its concentration before the exercise (p<0.001), maintaining values higher than found for Arabian horses (Silva 2008) (Table 2, Figure 1b), differing from data presented by horses that ran 60km, when the increase in this parameter was related to the acidification of plasma by the increased production of carbonic acid in an attempt to correct the metabolic alkalosis in long-term submaximal exercise (Di Filipo et al. 2009). Thus, it was verified that animals evaluated have not developed metabolic alkalosis, confirming that they were trained and adapted to the type of exercise imposed.

The pCO_2 in this study was similar to observed in Arabian horses subjected to High-speed treadmill (Watanabe et al. 2006), for thoroughbred horses, simulating equestrian event of two to three days (Tennent-Brown et al. 2006), for thoroughbred horses subjected to exercise test on a treadmill (Kwoal et al. 2008) and polo horses in high

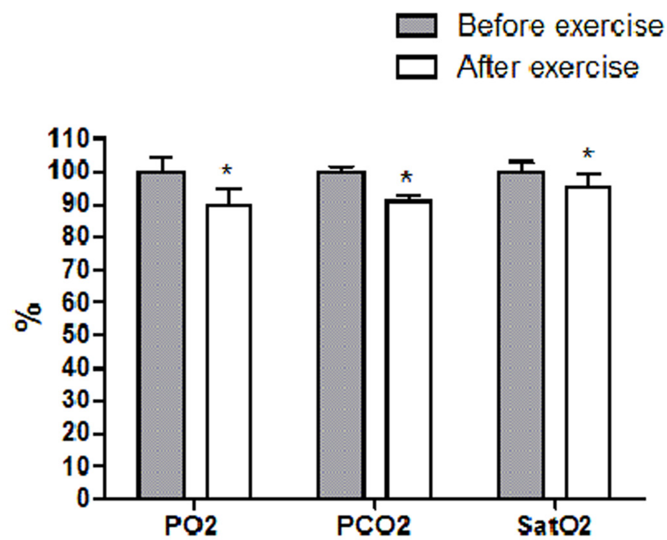

Fig.1. Percentage (%) of parameters pO2, pCO2 and SatO2 corrected with those measured before the exercise in horse finalists of 90 Km-endurance race. (*) indicates significant difference (P<0.05) before the exercise. pO_2: venous partial pressure of oxygen, pCO_2: venous partial pressure of carbon dioxide, $SatO_2$: venous oxygen saturation.

performance training (Ferraz et al. 2010). This suggested that the continuity of the exercise, possibly promote hypocapnia, as observed in Arabian horses (Taylor et al. 1995), once the hyperventilation process during high speed exercises could lead to a metabolic acidosis (Taylor et al. 1995), which suggests a drop in pCO_2 resulting from alveolar hyperventilation that could counteract and overcome the CO_2 produced by cell metabolism (Taylor et al. 1998, Tenente-Brown 2006). This condition is observed in situations of metabolic acidosis that physiologically adjusts the pH to the normality level, with lower intensity during the exercise (Ferraz et al., 2010).

Considering the oxygen saturation ($SatO_2$), this parameter followed the behavior of oxygen pressure, presenting a significant reduction of 6.62% (P<0.001), because its saturation in the hemoglobin is directly related to its partial pressure (Fenger et al. 2000; Tennent-Brown et al. 2006). In this way, it characterizes the effectiveness of diffusion of these gases in the blood of horses studied and ensures the good training of animals.

The pH remained within the reference range, between 7.34 and 7.43 (Watanabe et al 2006) and slightly higher than described by Silva (2008), reiterating the non-occurrence of metabolic acidosis, unlike the results found for high intensity exercises in thoroughbred horses undergoing supramaximal exercises (Bayly et al. 2006), in other words, the exercise intensity is probably related to the development of hypo-or hypercapnia.

CONCLUSIONS

The parameters were significantly reduced, but remained within the reference range, indicating that such alteration occurred temporarily, assuming a character of physiological response to the exercise performed.

The Pure Blood Arabian animals, finalists in 90 km races, showed an efficient ventilatory process, without any alterations in the athletic performance and thus being adapted to the type of exercise imposed.

REFERENCES

Aguilera-Tejero E., Estepa J.C., López I., Bas S., Mayer-Valor R. & Rodríguez M. 2000. Quantitative analysis of acid-base balance in show jumpers before and after exercise. Res. Vet. Sci. 68(2):103-108.

Bayly W.M., Kingston J.K., Brown J.A., Keegan R.D., Greene S.A. & Sides R.H. 2006. Changes in arterial, mixed venous and intraerythrocytic concentrations of ions in supramaximally exercising horses. Equine Vet. J. 36:294-297.

Di Filippo P.A., Gomide L.M.W., Orozco C.A.G., Giannocaro M.A., Martins C.B., Lacerda-Neto J.C. & Santana A.E. 2009. Alterações hemogasométricas e hidroeletrolíticas de cavalos da raça árabe durante prova de enduro de 60 km. Ciênc. Anim. Bras. 10:840-846.

Dumont C.B.S., Leite C.R., Moraes J.M., Alves R.O., Moreira M., Moscardini A.R.C., Godoy R.F. & Lima E.M.M. 2012. Osmolaridade, ânion gap, potencial hidrogeniônico e íons plasmáticos mensuráveis de equinos Puro Sangue Árabe finalistas em provas de enduro de 90 km. Pesq. Vet. Bras. 32(6):542-546.

Fenger C.K., Mckeever K.H., Hinchcliff K.W. & Kohn C.W. 2000. Determinants of oxygen delivery and hemoglobin saturation during incremental exercise in horses. Am. J. Vet. Res. 61:1325-1332.

Ferraz G.C., Soares O.A.B., Foz N.S.B., Pereira M.C. & Queiroz-Neto A. 2010. The workload and plasma íon concentration in a training match session of high-goal (elite) polo ponies. Equine Vet. J. 42(38):191-195.

Hoffman R.M., Hess T.M., Williams C.A., Kronfeld D.S., Griewe-Crandell K.M., Waldron J.E., Graham-Thiers P.M., Gay L.S., Splan R.K., Saker K.E. & Harris P.A. 2002 Speed associated with plasma pH, oxygen content, total protein and urea in an 80 km race. Equine Vet. J. 34:39-43.

Lisboa J.A.N., Benesi F.J., Maruta C.A., Mirandola R.M.S. & Teixeira C.M.C. 2001. Tempo de viabilidade de amostras de sangue venoso bovino destinadas ao exame hemogasométrico, quando mantidas sob conservação em água gelada. Ciência Rural 31(2):271-276.

Ribeiro Filho J.D., Abreu J.M.G., Alves G.H.S. & Dantas W.M.F. 2007. Hemogasometria em equinos com compactação experimental do cólon maior tratados com sene, fluidoterapia enteral e parenteral. Ciência Rural 37(3):755-761.

Robert C., Goachet A.G., Fraipont A., Votion D.M., Erck E.V. & Leclerc J.L. 2010. Hydration and electrolyte balance in horses during an endurance season. Equine Vet. J. 42(38):98-104.

Silva M.A.G., Martins C.B., Gomide L.M.W., Albernaz R.M., Queiroz-Neto A. & Lacerda-Neto J.C. 2009. Determinação de eletrólitos, gases sanguíneos, osmolalidade, hematócrito, hemoglobina, base titulável e anion gap no sangue venoso de equinos destreinados submetidos a exercício máximo e submáximo em esteira rolante silva. Arq. Bras. Med. Vet. Zootec. 61(5):1021-1027.

Taylor L.E., Ferrante P.L., Wilson J.A. & Kronfeld D.S. 1995. Arterial and mixed venous acid-base status and strong ion difference during repeated sprints. Equine Vet. J. 18:326-330.

Taylor L.E., Kronfeld D.S., Ferrante P.L., Wilson J.A. & Tiegs W. 1998. Blood-gas measurements adjusted for temperature at three sites during incremental exercise in the horse. J. Appl. Physiol. 85:1030-1036.

Tennent-Brown B.S., Goetz T.E., Manohar M., Hassan A.S., Freeman D.E., Bundy J.S. & Evans M.R. 2006. Pre-exercise hypervolemia is not detrimental to arterial oxygenation of horses performing a prolonged exercise protocol. Equine Vet J. 36:495-501.

Watanabe M.J., Thomassian A., Teixeira Neto F.J., Alves A.L.G., Hussni C.A. & Nicoletti J.L.M. 2006. Alterações do pH, da PO2 e da PCO2 arteriais e da concentração de lactato sanguíneo de cavalos da raça Árabe durante exercício em esteira de alta velocidade. Arq. Bras. Med. Vet. Zootec. 58(3):320-326.

Wilkins P.A., Gleed R.D., Krivitski N.M. & Dobson A. 2001. Extravascular lung water in the exercising horse. J. Appl. Physiol. 91:2442-2450.