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Effect of a simulate show jumping competition on the blood gas profile of horses trained for show jumping

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Abstract: The aim of the present study was to evaluate the changes in the blood gas profile of jumpers after warm up and after a show jumping competition. For this purpose, 10 Sella Italiana geldings, 7 years old and clinically healthy, were used. The horses were trained to take part in show jumping competitions. Blood samples were collected at rest, after the warm up, immediately after the exercise, and 45 min after the end of exercise. Standard bicarbonate concentration (SBC), hydrogen carbonate ion (HCO_3^-), total carbon dioxide (TCO_2), oxygen capacity (O_2Cap), oxygen content (O_2Ct), base excess of the blood (BE-b), base excess of extracellular fluid (BE-ecf), pH, partial pressure of carbon dioxide (PCO_2), partial pressure of oxygen (PO_2), oxygen saturation (SO_2), hematocrit (Hct), hemoglobin (Hb) and lactate were determined. Moreover, the heart rate (HR) of each subject was assessed by means of a cardio-frequency meter. One-way repeated measures analysis of variance (ANOVA) showed a statistically significant effect of sampling time on all of the parameters studied ($P < 0.05$). These findings showed the importance of the warm up and a long recovery on acid-base balance in jumpers, underlining the importance of the warm up in order to improve the body response in buffer capacity during show jumping events. The observed changes in the acid-base balance can be helpful in assessing the metabolic and respiratory changes in horses during training and competition but further studies should be conducted examining various training schedules and recovery times in order to better define the response of the jumper.

Key words: Acid-base status, blood gas analysis, show jumper, training, warm up

Introduction

The acid-base status, as the background of the vital processes, is indicative of systemic, metabolic, and functional health and is crucial for systemic homeostasis (1). Different studies have evidenced that exercise-induced stress is accompanied by a preponderance of the anaerobic pathway for energy production and indices of metabolic acidosis (1-3). Exercise is associated with changes in the acid-base balance that are well documented in horses both during and after exercise (4-8). The horse appears capable of greatly increasing the oxygen-carrying capacity of its blood when exercising, due primarily to its ability to greatly increase hematocrit via splenic contraction (9). Horses use HCO_3^- to buffer the metabolic acidosis and to increase muscle cell pH resulting from intense exercise. In an aqueous solution, carbon dioxide largely exists as carbonic acid, which dissociates into H^+ and HCO_3^- ions in transportation (10). Acid-base disturbances during exercise result when ventilation is not matched with metabolism and metabolic acidosis results from

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high workloads producing significant amounts of anaerobic metabolism and lactic acid (9). High intensity exercise on the part of the horse produces more dilute sweat than low-intensity prolonged exercise (4). Evidence from human studies suggests that some athletes, especially those highly trained, may undergo arterial desaturation and that in these situations ventilatory factors may limit oxygen transfer and thus performance level (11). For this reason, a great importance is attributed to the warm up. Its role is to adjust the body to transition from rest to exercise and thereby gain the benefits of enhanced performance by improving muscle oxygenation and causing the spleen to contract (9). If exercise intensity during the warm up is too high, significant lactate accumulation will be present at the onset of performance exercise (9). On the basis of that, the aim of the present study was to evaluate the changes in the blood gas profile of the jumper after warm up and after a show jumping competition.

Materials and methods

The present study involved a laboratory component and a veterinary clinic component, both of which were conducted at the University of Messina's School of Veterinary Medicine. Protocols of animal husbandry and experimentation were reviewed and approved in accordance with the standards recommended by the Guide for the Care and Use of Laboratory Animals and by Directive 86/609 CEE.

The study was carried out in the spring in Sicily (Italy) using 10 Sella Italiana geldings, 7 years old, with a body weight 420 ± 15 kg; the horses were all obtained from the same horse training center. All horses were kept in individual boxes under a natural photoperiod and natural indoor temperature (18-20 °C). The horses were fed a standard ration, in amounts calculated according to the natural requirements assessed by Institut National de la Richerche Agronomique (INRA) specifications (12), at 0800, 1200, and 1700 each day. The ration consisted of hay (first cut meadow hay, sun cured, late cut, 8 kg/horse per day, 6.9% crude protein on average) and a mixture of cereals (oats and barley, 50% each, about 3.5 kg/horse per day). The composition of the mixture of cereals was as follows: dry matter 87%; moisture 13%; horse digestible protein (MADC) 9.1% on dry matter; crude protein 12.1% on dry matter; crude fiber 20.7% on dry matter; ether extract 3.4% on dry matter; UFC/kg dry matter 0.80. Water was available ad libitum.

Prior to the study, show jumpers underwent standard training which consisted of fitness training 6 days per week with a rest day on Sunday. For show jumpers, training lasted about 1 h each day and included walking, trotting, galloping and obstacle jumping. Training and general animal care were performed by professional staff not associated with the research team. Before the start of the study, all of the subjects underwent a rectal temperature evaluation, heart examination, respiratory auscultations, and routine hematology and plasma biochemistry analyses while at rest. Hematological parameters were assessed by means of the multiparametric automatic analyzer for hematology (HecoVet, SEAC, Firenze, Italy) and biochemical parameters were analyzed with commercially available kits by means of a UV spectrophotometer (model Slim SEAC, Firenze, Italy). Only clinically healthy animals were used in the study.

Before the simulate show jumping competition, all of the horses underwent a warm up of 15 min including pacing, trotting, galloping, and 6 jumps (with fence heights of 1.00-1.40 m). The simulate show jumping competition consisted of a 350 m distance with 6 oxers, 7 simple fences, and 1 triple combination (oxer, vertical, and vertical). The maximum height of the fences was 1.40 m and the average speed was 350 m/min.

Heart rate was monitored continuously during the trial and during the recovery period, with a cardio-frequency meter (Polar Equine Transmitter) applied to horses in the box before the saddling procedure. The data were downloaded to a personal computer for analysis by Polar Equine 4.0 software. Blood samples were collected by jugular venipuncture at 4 different sampling times: at rest, after the warm up, immediately after the exercise, and 45 min after the end of exercise. The blood samples were analyzed by a selective ion analyzer (Stat Profile pHOx Analyzer, GEPA, Nova Biomedical Corp., USA). The following parameters were assessed: standard bicarbonate concentration (SBC), hydrogen carbonate ion (HCO_3^-), total carbon dioxide (TCO_2), oxygen capacity (O_2Cap), oxygen

content (O_2Ct), base excess of the blood (BE-b), base excess of extracellular fluid (BE-ecf), pH (direct ISE), partial pressure of carbon dioxide (PCO_2, Severinghaus method), partial pressure of oxygen (PO_2, amperometric method), oxygen saturation (SO_2), hematocrit (Hct), and hemoglobin (Hb, combination of conductivity and photometric measurements). For each test, the operating temperature of the analyzer was set according to each horse's rectal temperature recorded during sampling (mean temperature ± SEM: 37.5 ± 0.50 °C). On site, blood lactate analysis was conducted using a dry chemistry device (Accusport, Boehringer, Mannheim, Germany), which provided the results within 1 min of the start of the analysis. One-way repeated measures analysis of variance (ANOVA) was applied to evaluate the effect of sampling time on blood gas parameters. The Newman-Keuls test was applied for post hoc comparison. A P value < 0.05 was considered statistically significant. All data were analyzed using the Statistica 7.5 software package (Stat Soft Inc., USA).

Results

The pattern of the mean values (± SD) along with the statistical significances of blood lactate and heart rate at rest, after the warm up, immediately after the exercise, and during the recovery period (45 min) is shown in Figure 1 as obtained from the jumpers.

ANOVA showed a statistically significant effect of sampling time on SBC ($P < 0.0001$; $F_{(3;27)} = 2.93$); HCO_3^- ($P < 0.0001$; $F_{(3;27)} = 3.30$); TCO_2 ($P < 0.0001$; $F_{(3;27)} = 24.15$); O_2Cap ($P < 0.0001$; $F_{(3;27)} = 15.19$); O_2Ct ($P < 0.02$; $F_{(3;27)} = 15.19$); BE-b ($P < 0.0001$; $F_{(3;27)} = 24.60$); BE-ecf ($P < 0.0001$; $F_{(3;27)} = 65.26$); PCO_2 ($P < 0.0001$; $F_{(3;27)} = 27.14$); PO_2 ($P < 0.005$; $F_{(3;27)} = 5.54$); SO_2 ($P < 0.0001$; $F_{(3;27)} = 13.09$); pH ($P < 0.006$; $F_{(3;27)} = 5.10$); Hct ($P < 0.0001$;$F_{(3;27)} = 16.31$); and Hb ($P < 0.0001$; $F_{(3;27)} = 13.23$).

Figures 2 and 3 show the pattern (mean ± SEM) and the statistical significances of the blood parameters obtained from jumpers during the experimental period.

Discussion

The analyzed blood gas parameters are subject to change after exercise due to the variations that occur in the acid-base status as determined by the kind of energetic process involved with the muscle energy supply (13). Both aerobic and anaerobic metabolism are involved in energy production, with the balance between them depending on the fitness of the horse, the size and number of fences, the length of the track, and the horse's speed on the course (14). It

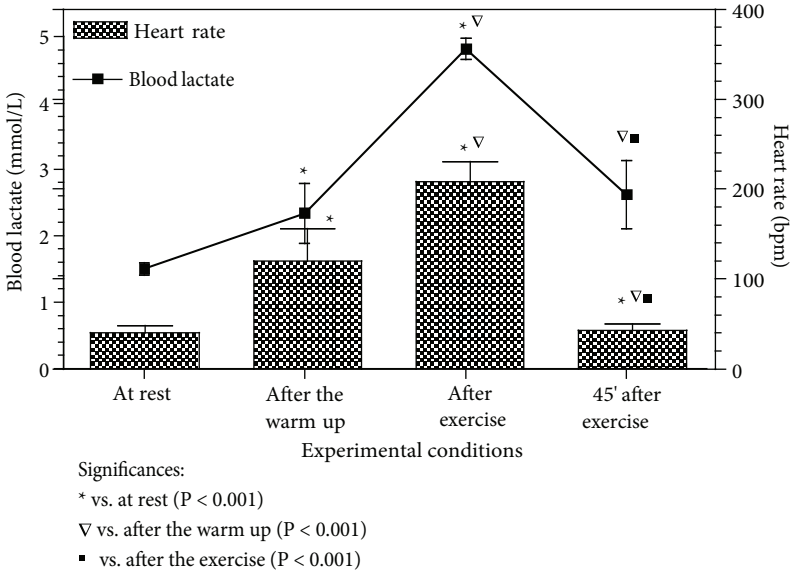


Figure 1. Blood lactate and heart rate during a simulated show jumping competition.

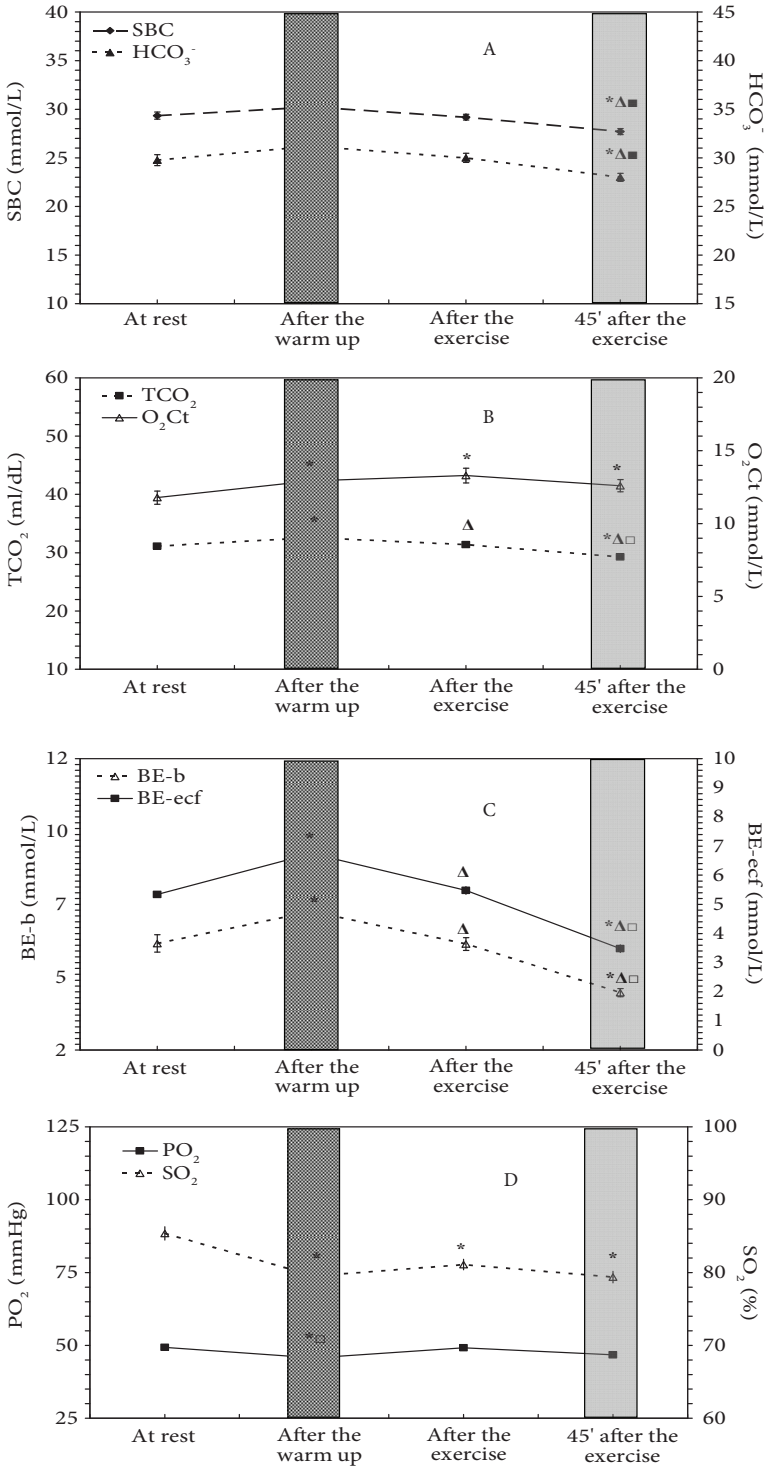
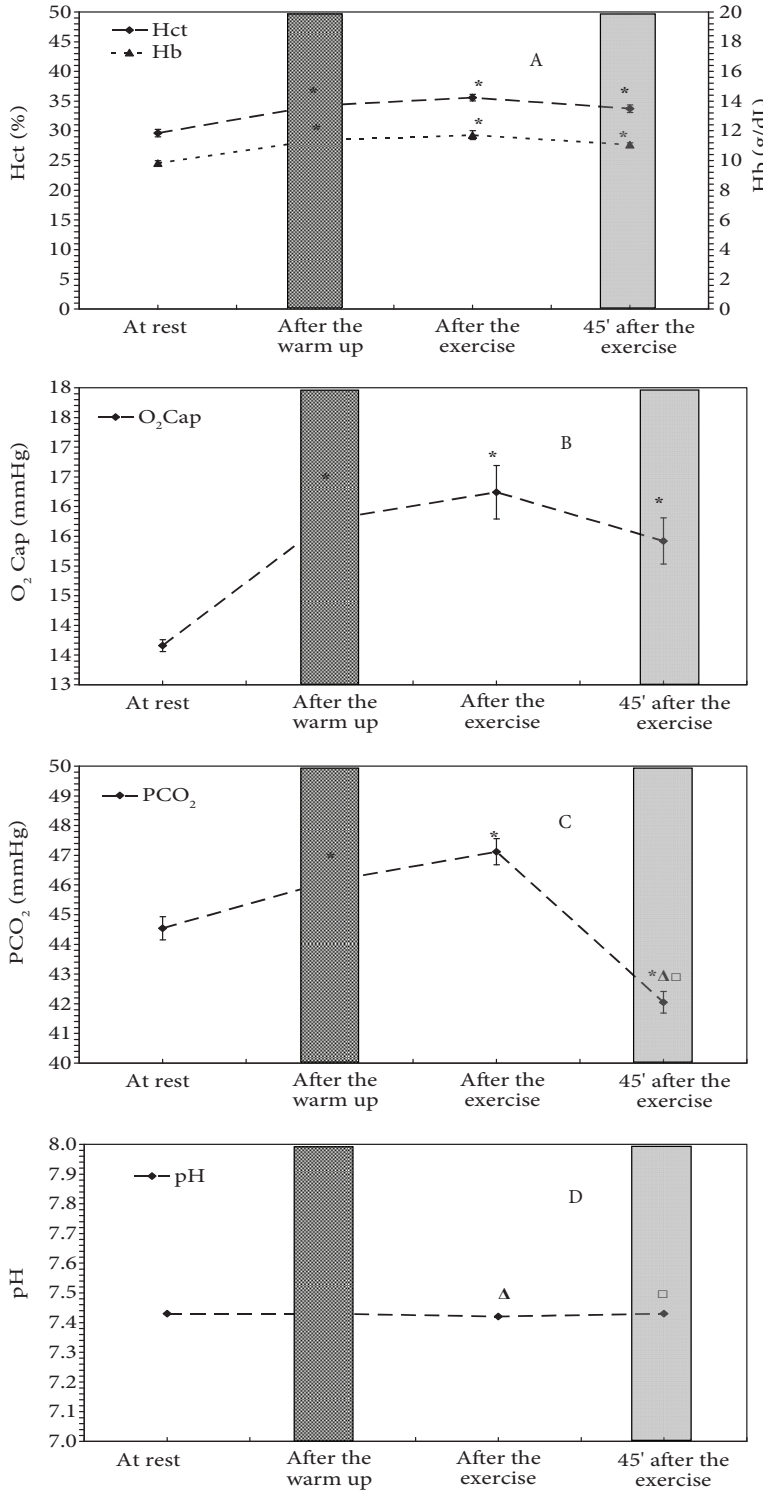


Figure 2. Blood gas parameters I (**A**: SBC and HCO_3^-; **B**: TCO_2 and O_2Ct; **C**: BE-b and BE-ecf; **D**: PO_2 and SO_2).



Significances:
* vs. at rest ($P < 0.0001$)
Δ vs. after the warm up ($P < 0.0001$)
□ vs. after the exercise ($P < 0.0001$)

Figure 3. Blood gas parameters II (**A**: Hct and Hb; **B**: O_2Cap; **C**: PCO_2; **D**: pH).

has been previously demonstrated in human sport medicine that the warm up represents the initial step of the glycolysis occurring during exercise-induced hypoxia (15); furthermore, it is important to quantify analytically the workload of the exercise by monitoring heart rate and blood lactate, two traditional parameters used in the evaluation of horse performance (16,17). In particular, our results showed a significant increase in lactate concentration and some other blood gas parameters after the warm up when compared to the measurements taken at rest. Parameters such as SBC, HCO_3^-, BE-b, and BE-ecf change in relation to their buffer capacity because the warm up significantly influences the acid-base balance variables (15). During high intensity exercise, CO_2 is produced primarily as a result of hydrogen ions buffered by HCO_3^- because the extracellular acidosis resulting from exercise may depress muscle contraction and muscle glycogen utilization and provoke fatigue (18). Based on previous studies, we expected a decrease in HCO_3^- after the warm up, but the increase found in our values leads us to think that in trained horses the buffer capacity of the HCO_3^- and the base content overcompensate for the acidosis developed during a show jump (2-4,8,9). In fact, the HCO_3^- decreased after the exercise session and 45 min after the end of exercise. This could be explained by hyperventilation, which makes possible a massive elimination of CO_2 from the lungs so that the conversion of CO_2 into HCO_3^- cannot be accomplished (1,12). This was confirmed by a significant decrease in TCO_2 only during the recovery (45 min after the end of exercise). Moreover, a significant decrease in the bicarbonate concentration of blood usually signals an increase in H^+ in the blood (18). The contribution of bicarbonate to the acid-base balance in the muscle during exercise is mainly due to the marked reduction in muscle bicarbonate concentration when muscle pH falls (19). A portion of the muscle H^+ load is removed by metabolic and fixed physicochemical buffers and by the reduction in muscle bicarbonate concentrations while another portion leaves the cell in exchange with Na^+ or along with lactate through others transporters, thus increasing plasma lactate and H^+ concentrations. Bicarbonate ions act as a weak fixed physicochemical buffer in muscle, both because their concentration is low at rest and decreases in response to exercise and because their pK is much lower than muscle pH at rest or during exercise (19).

SO_2, which represents the percentage of blood saturated with oxygen, showed a different trend. The mean value of this parameter decreased during the warm up, but it tended to stabilize during the other experimental conditions. This demonstrates how the workload to which our horses were subjected was sufficient to induce oxygen consumption that remained constant after the show jump. Moreover, the oxygen saturation data demonstrated that our animals did not undergo hypoxia after exercise and compensated for the exercise effort during the recovery period. Hb and Hct showed a similar trend in relation to the spleen contractions that resulted in an increase of red blood cells; presumably this is due to the release of catecholamines, as previously demonstrated in show jumpers (20). A different trend was recorded for lactate during our experimental study. In fact, lactate concentration had an early initial increase during the warm up and peaked during the exercise. Lactate concentration was reduced during recovery but remained above the rest value. The 45 min recovery was sufficient to cause a decrease in lactate but was not enough to bring it down to the rest value. We think that lactate production during the warm up was low because of the activation of aerobic pathways and rose during the show jumping because of the activation of anaerobic pathways (4,21).

In conclusion, these findings show the importance of the warm up and a long recovery (45 min) on the acid-base balance in jumpers. The significant increase of blood buffers after the warm up compared to rest highlights the importance of the warm up to improve the body response in buffer capacity during the show jumping events. The observed changes in the acid-base balance can be helpful in assessing the metabolic and respiratory changes that occur in horses during training and competition but further studies should be conducted with a consideration of various training schedules and recovery times in order to better define the responses of jumpers.

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