Cation-anionic and acid base status of Quarter Horse in vaquejada training

Status cátion-aniônico e ácido base de Quarto de Milha em treinamento de vaquejada

Received: 05-04-2024 | Accepted: 08-05-2024 | Published: 14-05-2024

ABSTRACT

The cation-anionic and acid base status were assessed and compared among pull and helper Quarter Horses in three times (T) in vaquejada training: before (T0) and immediately after three sprints (T1), one hour after the end of the sprints (T2). At each time blood samples were collected for gasometry, plasma and serological analyses, and the differences were calculated of strong ions (SID), anion gap (AG) and weak ions (Atot). Sodium, potassium, chloride and Atot did not vary among the times or between the groups. In T1, ionized calcium (iCa), pH, HCO3-, pCO2, CBase and SID decreased in the groups, but not between them, while the lactate and AG increased in both the groups, and the lactate was higher in the pull horse group. Only iCa and lactate remained, respectively, lower and higher in T2, compared to T0. It was concluded that the exercise caused hypocalcemia, hyperlactatemia and metabolic acidosis in both groups, however, a greater lactic acidosis in the pulling, characterizing that in this group the anerobic metabolism was of higher intensity.

Keywords: Exercise; Ions; Acidosis; Equine; Vaquejada.
RESUMO

O status cátion-aniônico e ácido básico foram avaliados e comparados entre Quarto-de-Milha de puxada e esteira (auxiliar), em três tempos (T) de um treinamento de vaquejada: antes (T0) e imediatamente após três percorridas (T1), e uma hora após percorridas (T2). Em cada tempo foram realizados exame físico e coleta de sangue para gasometria, análises plasmáticas e sorológicas, e cálculos das diferenças de íons fortes (DIF), do anion gap (AG) e de íons fracos (Atot). Sódio, potássio, cloreto, e Atot não variaram entre os tempos ou entre os grupos. Em T1, houve redução do cálcio ionizado (iCa), pH, HCO₃⁻, pCO₂, CBase e DIF nos grupos, mas não entre estes, enquanto o lactato e o AG aumentaram em ambos os grupos, sendo maiores no grupo puxada. Apenas o iCa e o lactato permaneceram, respectivamente, menores e maiores no T2 em relação ao T0. Concluiu-se que o exercício ocasionou hipocalcemia, hiperlactatemia e uma acidose metabólica em ambos os grupos, porém, uma acidose lática maior no grupo puxada, caracterizando que neste grupo o metabolismo anaeróbio foi de maior intensidade.


INTRODUCTION

Physical exercise makes high demands on the athlete horse metabolism in equestrian sports, making them susceptible to cardiovascular, respiratory and thermoregulatory instabilities. To better adapt the horses to these demands, suitable and continuous trainings are required (TITOTTO et al., 2023), supported by results from physical and laboratorial examinations, including those that indicate electrolytic alterations and the acid base balance in the body (GOMES et al., 2020b).

In horse sports where there is high intensity and short duration exercise, the organism intensifies anaerobic mechanisms, mainly the anaerobic glucose (BARBOSA et al., 2016), due to the need for rapid production and uptake of energy to give energetic support to the musculce work (VERMEULEN et al., 2017). Vaquejada is among the sports where anaerobic mechanisms are needed by the horses’ organism. In Brazil, this a frequent event and its circuits are officialized by the Associação Brasileira de Criadores de Cavalos Quarto de Milha (ABQM), a breed that is outstanding in the sport, because its muscle fibers have low oxidative capacity and high glycolytic capacity (LOPES et al., 2009, RODRIGUES et al., 2016).

In the vaquejada, two sets of mounted cowboys riding “pull” horses and “helper” horses follow a course on a sand track with the aim of aligning a steer between them so that the cowboy helper horse can help the cowboy pull horse. The pull horse cowboy is responsible for pulling the steer down in a marked area on the track (ABVAQ, 2016).
Because they are considered different athletes, the preparation of pull and helper horses should be based on adequate physical and nutritional programs that are specific to each one, resulting in better performance and well-being (COELHO et al., 2021).

Although vaquejada is common in Brazil, there are few reports in the literature on the physiological results or the acid base of vaquejada horses. Considering that it is important to obtain results that express the metabolic responses of these animals that may help in guiding their athletic preparation for the sport, the objective of the present study was to assess the physiological parameters, cation-anionic and acid base status in healthy quarter horses, in a simulated vaquejada training.

MATERIAL AND METHODS

The experiment was carried out on two consecutive mornings in a vaquejada park, located in the municipality of São Luís, Maranhão state, Brazil, Latitude: 2° 31’ 51” South, Longitude: 44° 18’ 24” West and 3.66 m altitude. The sprints started on the first day at 8h45min, at 28°C temperature and 93% relative air humidity, and ended at 12h15min, with 31°C temperature and 64% relative air humidity. On the next day, the sprints started at 8h25h, at 27°C temperature and 94% relative air humidity and ended at 12h35min, at 30°C temperature and 66% relative air humidity.

A total of 12 quarter mile breed horses were used, eight males and four females, 389 to 462 kilograms (kg) body weight, aged from seven years three months to eleven years eight months. Six horses made up a set with the cowboy in the pull function (six males) and six in the helper function (two males and four females), and three pull and three helper horses were used on each one of the two consecutive days. All the horses were already adapted to vaquejada competition, in good health conditions according to the normal limits of the parameters: mucosa coloring and moisture, capillary refill time, skin turgor, heart and respiratory frequencies, rectal temperature, normal miction and defecation, normal hemogram, leucogram, total plasma proteins (TPP) and fibrinogens. No horse had presented colic in the previous 60 days and no horse presented lameness at the time of the selection examination for the study.

The animals were kept in individual masonry stalls ranging from 16.0 and 18.0 m² in size. The horses´ diet was based on conditions of moderate degree exercise, directed for approximate intake of 3% dry matter/day, as they were in training and were not in a competition period. Tifton (Cynodon spp.) hay as bulk was placed in the stall in hay baskets twice a day (6h00min and 17h30min), with free access in 24h, in a total of
approximately 0.5 kg bulk/100 kg body weight/day. As supplementation, pelleted commercial concentrate was supplied containing a minimum 120 g kg$^{-1}$ crude protein and 3.400 kcal kg$^{-1}$ digestible energy (Equivita vaquejada – Integral Mix), in a total of approximately 1% body weight/day, divided in three daily meals at 6:00h, 13h30 p.m. and 18h30min. Another supplement supplied was mineral salt (Coequi plus© – Tortuga): 100g/day, in an individual salt cellar in the stall. Water was supplied ad libitum, in individual water dispensers in the stalls.

The assessment times (T) of the physical parameters and sample collections for laboratory tests of the horses were: T0 (fifteen minutes before starting to warm up the horse for 10 minutes before the first sprint, with the horse still unsaddled); T1 (immediately after the three sprints); and T2 (1h after T1, with the animals resting in stalls, but without water or feed). Between the T0 collection and the first sprint, the horse was conditioned with a gentle warm-up by trotting for 10 minutes. T2, after the third sprint, occurred with the horses in their stall without food. No horse received water or any liquid from 20 minutes before T0 and until T2. Immediately after T2, water was made available ad libitum in the stall drinking fountain.

Blood samples were collected from anaerobic blood via anaerobic – after cleaning the skin with a small ball of cotton wool soaked in iodine alcohol at 2% – by puncturing the external jugular vein with a 30 x 7 needle in a 3 ml disposable plastic syringe, previously heparinized. After collection, a small quantity of the horse’s blood was immediately placed individually in a cartridge model CG8+ in the gasometry device (I-STAT – Abaxis Brasil) to obtain the following parameters: hydrogen potential (pH), plasma bicarbonate concentration (HCO$_3^-$), carbon dioxide partial pressure (pCO$_2$), titer base concentration (cBase), and concentrations ([  ] of sodium (Na$^+$), potassium (K$^+$) and ionized calcium (iCa$^{2+}$).

Blood samples were collected, after cleaning the skin, by puncturing the jugular vein, and placed in a flask containing sodium fluoride to obtain plasma (vacuum sealed siliconized flask – 4.0 ml – sodium fluoride – Vacuette), in a siliconized flask without anticoagulant to obtain serum (vacuum sealed siliconized flask – 4.0 ml without anticoagulant – Vacuette). The serum and plasma aliquots were kept frozen at -20 °C until laboratory analysis, in the Clinical Pathology Laboratory at the State University of Maranhão (UEMA), state of Maranhão, Brazil. In these samples, the serum chloride and plasma lactate were measured in an automatic biochemical multi analyzer (Chermray 120 full Automatic Biochemical Analyzer – Rayto, China). After obtaining the ion values, the
differences among strong ions (DIF) were calculated using the formula: 
\[ \text{SID (mMol L}^{-1}\text{)} = ([\text{Na}^+] + [\text{K}^+] - ([\text{Cl}^-] + [\text{Lac}^-]) \]. 
The lactate ([Lac^-]) was included in the SID calculation since during the mechanism of intense anaerobiosis in exercise, lactate can accumulate at high concentrations in the muscle fibers and blood, therefore it should not be omitted from the SID calculation (LINDINGER, 2004). The anion gap (AG) was calculated by the formula: 
\[ \text{AG (mMol L}^{-1}\text{)} = ([\text{Na}^+] + [\text{K}^+] - ([\text{Cl}^-] + [\text{HCO}_3^-]) \] (CONSTABLE, 2000).

The plasma bicarbonate concentration ([HCO_3^-]) obtained in the hemogasometry was used in the anion gap calculation. The total plasma weak acid concentration ([Atot]) was calculated by multiplying the total protein by 2.24: 
\[ \text{Atot (dL}^{-1}\text{)} = \text{TTP (g)} \times 2.24 \] (CONSTABLE, 1997).

The means and standard deviations of the variables were calculated. For analyzes between times in the same group, the data were submitted to ANOVA and the Tukey test, and at the same time between groups, to the Student's t-test, both with 5% probability. The analyzes were carried out using the statistical analysis program 9.4/2015 (Statistical Analysis System Institute - SAS Institute, SAS/STAT, USA).

The research was approved by the Ethics in Animal Experimentation Commission of the Veterinary Medicine Course at the Maranhão State University, Brazil – UEMA, protocol number 10/2016.

RESULTS AND DISCUSSION

All the horses tolerated the activity well and there was no abnormal performance in any animal before, during or after the carrying out the exercise session. The physical parameters of the horses before the exercise were within the limits of normality, according to Speirs (1999).

There was no difference for sodium in the groups or between the groups at the time points evaluated (P>0.05) (Table 1). Non-significant variations for this cation were also observed in Quarter Horses after high intensity short duration exercise in barrel race training (GOMES et al., 2019; GOMES et al., 2020b), after concluding athletic test in the double lasso sport (COELHO et al., 2011), and the authors considered that it was due to the previous conditioning of the horses to the exercise, that could contribute to a small sodium loss in the sweat with concomitant maintenance of the sodium levels in the blood, because homeostasis of sodium in the blood is very important in maintaining blood osmolarity, since sodium is the most abundant component in the plasma. Prado et al. (2019) reported that the hypothalamus-hypophysis-adrenal axle influences the renal
sodium homeostasis by increasing mineralocorticoid synthesis and by acting on the mineralocorticoids and glucocorticoid receptors in the kidneys. In this process, cortisol plays a fundamental role, because it stimulates the renal transport processes attributed to the renin-angiotensin-aldosterone system (SRAA), and the high sodium concentration during exercise helps to maintain the stability of its concentration in the blood. Thus, it is possible that significant loss of this electrolyte may occur by sweating when the exercise is very prolonged, causing alteration in the body sodium.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Equine</th>
<th>Evaluation time</th>
<th>T0</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium (mMol L⁻¹)</td>
<td>Pull</td>
<td>130.00 ± 5.96</td>
<td>133.00</td>
<td>130.20 ± 1.92</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Helper</td>
<td>129.40 ± 3.78</td>
<td>136.60</td>
<td>135.60 ± 6.54</td>
<td></td>
</tr>
<tr>
<td>Potassium (mMol L⁻¹)</td>
<td>Pull</td>
<td>3.38 ± 0.28</td>
<td>3.43</td>
<td>3.29 ± 0.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Helper</td>
<td>3.22 ± 0.16</td>
<td>3.25</td>
<td>3.23 ± 0.59</td>
<td></td>
</tr>
<tr>
<td>Chloride (mMol L⁻¹)</td>
<td>Pull</td>
<td>95.00 ± 4.64</td>
<td>97.00</td>
<td>98.80 ± 2.17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Helper</td>
<td>98.00 ± 4.94</td>
<td>97.80</td>
<td>95.60 ± 3.21</td>
<td></td>
</tr>
<tr>
<td>Ionized Calcium (mMol L⁻¹)</td>
<td>Pull</td>
<td>1.66 ± 0.03</td>
<td>1.45</td>
<td>1.50 ± 0.03</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Helper</td>
<td>1.63 ± 0.06</td>
<td>1.47</td>
<td>1.46 ± 0.03</td>
<td></td>
</tr>
</tbody>
</table>

T0: before the start of training; T1: immediately after three runs; T2: 1h after T1. Different uppercase letters in the same line indicate different values from each other (P<0.05) by Tukey’s test. Different lowercase letters in the same column indicate different values from each other (P<0.05) by Student’s t-test.

Table 1 – Means and standard deviations of sodium, potassium, chloride and ionized calcium of Quarter Horses in vaquejada training

There was also no difference in the potassium concentration among times in either group or between groups at a same time (P>0.05), and the potassium values remained within the normal reference limits in all the times studied in both the groups (Table 1). Similarly, no variation was found in the potassium concentration in quarter horses after a barrel race sprint (GOMES et al., 2019) or two sprints of this sport (GOMES et al., 2020b), when the potassium concentration also remained within the normal limits. On the other hand, reduced potassium concentration in the blood (hypokalemia) was reported in horses that performed low intensity-long duration exercises in the endurance sport (FERNANDES and LARSON, 2000; Di FILIPPO et al., 2009).

The variation in serum potassium in relation to exercise may be because this cation is released by muscle cells proportionally to the exercise intensity and the concentration in the muscle. Furthermore, there is an efficacious recapturing mechanism for this
electrolyte in these cells by the action of the Na\(^+\)-K\(^-\) pump, that can quickly absorb its excess after interruption of the exercise (MURIEL, 2007; ASSENZA et al., 2014), that responds to low variation and quick potassium recovery after exercise in the horses in the present research.

There were no differences for chloride among the times or among the groups studied (P>0.05) (Table 1), and in all the times assessed the serum chloride means were within limits of normality. Considering that chloride is the most concentrated electrolyte in horse sweat, doing more intense exercises may cause more sweating and, consequently, bigger chloride losses in the sweat, reducing the serum concentration (LACERDA-NETO et al., 2003).

It is possible that the intensity of the exercise did not cause enough sweating to result in chloride loss in the sweat of the horses during the study, as happened in other research where the exercise was more intense. For example, Prado et al., (2019) detected chloride reduction in the blood (hypochloremia) in English Thoroughbreds, 30 minutes after speed racing (12 km h\(^{-1}\) for 30 min) and 60 minutes after the end of the exercise. Reduction in serum chloride was also observed in horses that did polo tests (MONTEIRO et al., 2018). However, Walker and Collins (2017) did not observe alteration in chloride in horses after 20 minutes trotting and immediately after a two minute of running. Therefore, close to the time at which the horses were submitted in the present study. However, it should also be considered that there are organic mechanisms that control the cation-anionic balance in organisms, regulating the chloride and sodium concentrations (MURIEL, 2007), with predominantly chloride excretion by the kidneys of the co-transporter K\(^+\)-Cl\(^-\) or by bicarbonate exchanges for chloride in the kidneys to maintain blood neutrality (McCUTCHEON and GEOR, 1998; FLAMINIO and RUSH, 1998).

The iCa\(^{++}\) was normal in T0 in both groups, but decreased in T1 (P<0.05), and further still in T2, and was lower than in T0 (P<0.05), but not significantly different in relation to T1 (P>0.05) (Table 1). There were no significant differences between the groups in any of the times (P>0.05) and the decreases in calcium reduction in groups in T1 and T2 were not so accentuated in relation to the normal reference values (Table 1). These results corroborate the study by Di Fillipo et al. (2009) who verified ionized calcium reduction in horses in endurance exercise. The most commonly found reasons for calcium reduction due to exercise is that there is calcium loss in the animal’s sweat due to the increased demands of the work. Furthermore, horses submitted to intense exercise have increased bone mass, therefore they have a greater need for calcium
Lactic acid is dissociated in H\(^+\) protons and lactate (FERGUSON et al., 2018). Lactate is the ionized form of lactic acid and exists as two stereoisomers: L-lactate and D-lactate. L-lactate is produced by the cell metabolism in mammal cells, and the isomeric increases in hyperlactatemia and lactic acidosis in horse patients, and is the form measured in the commercial lactate analyzer apparatus (ALLEN and HOLM, 2008). Thus, the plasma lactate concentration is commonly used to infer on the lactate acid concentration in the plasma (SANTOS, 2019). In the present study, the plasma lactate acid levels increased in T1 in both the groups reaching limits of hyperlactatemia (> 5 mMol L\(^{-1}\)). This occurred due to the predominant anaerobic metabolism in the high intensity-short duration exercise, when the increase in lactate is related to the increase in the protein metabolism and larger input of energy to the muscle submitted to physical stress (FERGUSON et al., 2018).

In T2, in both the groups, the lactate decreased in relation to T1 (P<0.05), but still remained above the normal physiological limits and were significantly increased in relation to T0 (P>0.05) (Table 2). Hyperlactatemia can generate a transitory lactic acidosis in horses adapted to high intensity-short duration exercise, which decreases after rest (RODRIGUES et al., 2016; BINDA et al., 2016; GOMES et al., 2019) while it can damage muscle in athletes poorly conditioned to the exercise (VERMEULEN, 2017). For example, the results obtained here corroborate the finding by Hunka et al. (2018) who observed increase in blood lactate in pull and helper horses after one and two cycles of vaquejada exercise, respectively, with recovery in both groups in less than an hour after the end of the cycles.

There were differences between groups in relation to plasma lactate, being higher in the pull group at T1 (P<0.05) (Table 2). Similar results were obtained by Hunka et al. (2018) in Quarter Horses who carried out a field vaquejada test. The pulling group had a much higher lactate concentration after one cycle than that of the assist group after completing two cycles. Gomes et al. (2024) also found a greater increase in plasma lactate in pulling horses compared to assistants, at the end of vaquejada training. It is likely that the reason for the greater lactatemia in the pull horse is the greater effort to which it is subjected by its cowboy in the function of taking down the reins on the track, which means that anaerobic metabolism is more intense in horses that perform this function.
Acid base analysis by the of strong ion quantitative model considers the influence of the concentration of strong ions such as sodium (Na\(^+\)), potassium (K\(^+\)), chloride (Cl\(^-\)), and lactate (Lac\(^-\)), and the concentration of weak non-volatile buffer ions (Atot), mainly the plasma proteins. It gives a conceptual distinction between the dependent variables: pH and bicarbonate (HCO\(_3\)\(^-\)) and the independent variables: carbon dioxide pressure (pCO\(_2\)), difference of strong ions (SID) and weak anions (Atot). The main limitation in clinical practice to applying the strong ions model is the difficulty in obtaining precise values for DIF and Atot, because all the strong and weak ions in the plasma need to be identified and measured, which is very difficult to do. The SID and Atot calculation requires, therefore, measuring more plasma constituents, and the values derived can only be estimated. To estimate parameters by the SID, the following equation is used:

\[
\text{SID} = ([\text{Na}^+] + [\text{K}^+] - ([\text{Cl}^-] + [\text{Lac}^-])
\]


### Table 2 – Means and standard deviations of chloride, lactate, strong ions difference (SID), anion gap (AG) and weak anions (Atot) of Quarter Horses in vaquejada training

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Equine</th>
<th>Evaluation time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>T0</td>
</tr>
<tr>
<td>Lactato (mMol L(^{-1}))</td>
<td>Pull</td>
<td>0.66(^{\text{Ca}}) ± 0.13</td>
</tr>
<tr>
<td></td>
<td>Helper</td>
<td>0.64(^{\text{Ci}}) ± 0.09</td>
</tr>
<tr>
<td>SID (mMol L(^{-1}))</td>
<td>Pull</td>
<td>40.59(^{\text{Aa}}) ± 8.91</td>
</tr>
<tr>
<td></td>
<td>Helper</td>
<td>37.08(^{\text{Aa}}) ± 3.71</td>
</tr>
<tr>
<td>Anion Gap (mMol L(^{-1}))</td>
<td>Pull</td>
<td>14.95(^{\text{Ba}}) ± 7.00</td>
</tr>
<tr>
<td></td>
<td>Helper</td>
<td>10.60(^{\text{Ba}}) ± 7.61</td>
</tr>
<tr>
<td>Atot (mMol L(^{-1}))</td>
<td>Pull</td>
<td>15.59(^{\text{Aa}}) ± 0.97</td>
</tr>
<tr>
<td></td>
<td>Helper</td>
<td>15.05(^{\text{Aa}}) ± 0.75</td>
</tr>
</tbody>
</table>

T0: before the start of training; T1: immediately after three runs; T2: 1h after T1. Different uppercase letters in the same line indicate different values from each other (P<0.05) by Tukey’s test. Different lowercase letters in the same column indicate different values from each other (P<0.05) by Student’s t-test.

Source: the authors (2024)

The SID values did not vary among the times per group (P>0.05) or between the groups by time (P>0.05) (Table 2). According to Lindinger (2004), SID values superior to the reference band (37 to 43 mMol L\(^{-1}\)), indicate metabolic alkalosis, while lower values indicate metabolic acidosis. In both groups, SID means were within normal reference limits at T0 and T2, but, decreased at T1. As the SID value is calculated using lactate, the change in its concentration influences its value. At T1, lactate concentration was increased in both groups (Table 1), which may have contributed to a SID close to the
minimum normal limits, characterizing metabolic acidosis due to hyperlactatemia. These results corroborate those obtained by Gomes et al. (2020a), studying horses subjected to high-intensity, short-duration exercise in the three-barrel equestrian modality.

In both groups, the AG increased in T1 (P<0.05), and in T2 it was restored to the T0, and was not different between the groups in the assessment times (P>0.05) (Table 2). These results corroborate with those by Silva et al. (2009) who also described increase in AG in horses immediately after maximum exercise that remained increased 30 minutes after the effort, and with findings by Gomes et al. (2020a) who also reported raised AG in Quarter Horses shortly after barrels race. It also corroborates the results obtained by Dumont et al. (2012), in horses after prolonged endurance physical exercise, and with those of Silva et al. (2009), in untrained horses subjected to maximum exercise on a treadmill.

The AG is defined as the difference between the non-measured plasma cation and the non-measured plasma anions. The AG is derived from the principle of electroneutrality. The AG acts as a measure of the accumulated acid, quantifying the changes in the composition of the plasma ions. The strong acids from the plasma dissociate completely in conjugated base and one proton (H⁺). The proton subsequently joins the buffer, creating a neutral element, while the conjugated base remains, characterizing the presence of acid element. The dissociation of strong acids alters the relative composition of the plasma anions, the buffer decreases and the conjugated base increases. Thus, increased quantities of the conjugated base are reflected in an increased AG increasing when the organic acid is strong, signaling the present of an organic metabolic acidosis (FIDKOWKI and HELSTROM, 2009) due to one or more non-measured strong anions in the plasma (CARLOTTI, 2012). The decrease in the pH < 7.3, with concomitant lactate > 5 mMol L⁻¹ and AG > 12 mEq L⁻¹, is indicative of metabolic acidosis (CHARJES and HEILMAN, 2005), a fact verified in the present study.

The term “weak” refers to the anionic acids and cation bases that are not totally dissociated in solution. The total concentration of weak acid (A<sub>tot</sub>) representes the sum of the acids and weak bases. Increase in A<sub>tot</sub> has an acidifying effect, with normal reference values between 13.6 and 18.5 mMol L⁻¹ (WALLER and LINDINGER, 2022). There were no differences in A<sub>tot</sub> among the times of each group (P>0.05) or between the groups at the same time (p>0.05), characterizing that there was no significant influence of weak acids on the acid base balance of the animals in the present study.
The traditional approach to assess the acid base state is concentrated on the relationship between pH, HCO\textsubscript{3}̄, and pCO\textsubscript{2}. The pCO\textsubscript{2} is considered an independent measure of the respiratory component of the acid base balance. If the change in the pH was due to changes in the HCO\textsubscript{3}̄, the mechanism for alteration is considered of metabolic origin (non-respiratory). In both the groups, the pH, HCO\textsubscript{3}̄, and pCO\textsubscript{2} decreased to below the values of normality in T1 (P<0.05), signaling the presence of metabolic (non-respiratory) acidosis. and were lower in relation to T0 and T2 that presented similar values within the limit of normality (P>0.05). There were no differences between pull horses and helper horses in any of the assessment times (P>0.05) (Table 3). These hemogasometric parameters normalized after one hour of rest.

### Table 3 – Means and standard deviations of pH (hydrogen potential), HCO\textsubscript{3}̄ (bicarbonate concentration), pCO\textsubscript{2} (partial pressure of carbon dioxide) and base coefficient (CBase) of Quarter Horse in vaquejada training

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Equine</th>
<th>Evaluation time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>T0</td>
</tr>
<tr>
<td>pH</td>
<td>Pull</td>
<td>7.38\textsuperscript{Aa} ± 0.02</td>
</tr>
<tr>
<td></td>
<td>Helper</td>
<td>7.38\textsuperscript{Aa} ± 0.02</td>
</tr>
<tr>
<td>HCO\textsubscript{3}̄ (mMol L\textsuperscript{-1})</td>
<td>Pull</td>
<td>26.24\textsuperscript{Aa} ± 2.29</td>
</tr>
<tr>
<td></td>
<td>Helper</td>
<td>26.84\textsuperscript{Aa} ± 0.89</td>
</tr>
<tr>
<td>pCO\textsubscript{2} (mm Hg)</td>
<td>Pull</td>
<td>44.34\textsuperscript{Aa} ± 2.40</td>
</tr>
<tr>
<td></td>
<td>Helper</td>
<td>45.16\textsuperscript{Aa} ± 1.30</td>
</tr>
<tr>
<td>CBase</td>
<td>Pull</td>
<td>1.40\textsuperscript{Aa} ± 2.61</td>
</tr>
<tr>
<td></td>
<td>Helper</td>
<td>1.60\textsuperscript{Aa} ± 1.34</td>
</tr>
</tbody>
</table>

T0: before the start of training; T1: immediately after three runs; T2: 1h after T1. Different uppercase letters in the same line indicate different values from each other (P<0.05) by Tukey’s test. Different lowercase letters in the same column indicate different values from each other (P<0.05) by Student’s t-test.

Source: the authors (2024)

Similar responses to these three parameters were observed in horses in a vaquejada competition shortly after concluding eight sprints on the first day, eight sprints on the second day and three sprints on the third day (ARRUDA et al., 2015). They also corroborate with Gomes et al. (2020a) who reported reduction in the mean values of these parameters in quarter horses in barrel racing.

Reduction in pH and the HCO\textsubscript{3}̄ concentration after exercise indicated occurrence of metabolic acidosis, because when the blood pH decreases the organism uses especially HCO\textsubscript{3} to buffer the increase in H\textsuperscript{+}protons, endeavoring to reduce their excess in order to
help to control the metabolic acidosis (SILVA et al., 2009). Furthermore, the organism also requires more carbon dioxide (CO$_2$) elimination from the body through hyperventilation, leading to decreased pCO$_2$, collaborating in the control of the metabolic acidosis, that justifies the reduction in pCO$_2$ observed. According to Johnson (1995), pCO$_2$ decreases as compensatory response of the respiratory component to metabolic acidosis. Therefore, as the values decreased of the pH, HCO$_3^-$ and cBase, there was also decrease in the pCO$_2$.

Although the pH, HCO$_3^-$ and pCO$_2$ were recovered in T2 and were shown to be similar among the times and between the groups, there were some differences in the CBase, because this decreased in T1 in both groups in relation to T0 and T2 (P<0.05). (Table 3). This decrease occurred because, besides using the HCO$_3^-$ to buffer the increase in H$^+$prótons, the organism also requires bigger carbon dioxide elimination (CO$_2$) from the body, reducing the pCO$_2$, and base actions that reduce the pCO$_2$ and body cBase value, to control the metabolic acidosis, confirming that the CBase value can accompany the direction of HCO$_3^-$ in horses after exercise (LINHARES et al., 2017). Due to this, the cBase also decreased in the horses after concluding three sprints, CBase or base excess (EB) represents the base accumulation or nonvolatile acid in the blood, excluding the plasma HCO$_3^-$ and the hemoglobin concentration in the blood (LIDINGER and WALLER, 2008). A positive CBase value indicates metabolic alkalosis while a negative value indicates metabolic acidosis (FIDKOWSKI and HELSTROM, 2009).

The mean CBase values (not more than -7) in the pull and helper horses in the present study did not decrease as much as those reported in some studies. Comparatively, in quarter horses, that did three days of vaquejada tests, the means decreased to -14.09 on the first day of the competition, -14.25 on the second day and only on the third day decreased to -7.06, when the number of sprints was reduced to almost half compared to the previous days (ARRUDA et al., 2015). When the horses exercised on a treadmill, Thoroughbred also presented values much lower than obtained here, with a mean -14.23 (KOWAL et al., 2014). The values found in Arab Pure Breed Horses also diverged; metabolic alkalosis was diagnosed with mean cBase values reaching 9.1 in the animals that did 60 Km in an endurance test (Di FILIPPO et al., 2009). On the other hand, a study on Arab Pure Breed Horses after prolonged endurance exercise reported that the cBase remained at normal reference limits (1.91) although it had been significantly different at the pre-exercise time (DUMONT et al., 2012). The type and intensity of the exercise and
Conditioning of the horses may have influenced the differences in the cBase among the other studies described.

CONCLUSIONS

The exercise performed by the horses in the proposed training design did not alter the sodium and potassium cations, nor the chloride anion, but caused hypocalcemia and hyperlactatemia and metabolic acidosis in both groups, however, a greater lactic acidosis in the pulling group, characterizing that in this group the anaerobic metabolism was of greater intensity.

REFERENCES


