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Effect of lunging exercise program with Pessoa training aid on cardiac physical conditioning predictors in adult horses

[*Efeito de um programa de exercício utilizando Rédea Pessoa sobre preditores de condicionamento físico em cavalos adultos*]

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ABSTRACT

The aim of this study was to evaluate the effect the Pessoa training aid (PTA) exercise program exerts in some physical conditioning predictors. Eight detrained adult horses were evaluated in 12 sessions of work with PTA (3 sessions per week). All horses used a heart rate monitor and GPS (V800, Polar Electro) and data was used to calculate energy expenditure (EE), net cost of transport (COT), metabolic energy requirement (Pmet), oxygen pulse, oxygen utilization, heart rate and heart rate variability (HRV). The horses were weighted, and the thoracolumbar shape were measured at the level of the 18th (T18), 13th (T13) and 8th (T8) thoracic vertebrae with a flexible ruler before and after the experimental period. Data obtained weekly were submitted to ANOVA and Tukey test ($p \leq 0.05$). Data obtained just before and after the experimental period were submitted to paired t test. There was a decrease in left-right asymmetry. In the third week there was an increase in HR, EE, oxygen pulse and oxygen utilization followed by a decrease in the fourth week. The biomechanics related parameters, COT and Pmet decreased week by week. The HRV showed a sympathetic stimulus in the third week followed by a shift to parasympathetic in the fourth week. We conclude that 12 sessions of lunge exercise with PTA contributed to physical condition improvement.

Keywords: horse, muscle, exercise, energy, balance

RESUMO

O objetivo deste estudo foi avaliar o efeito que um programa de exercício com Rédea Pessoa exerce sobre algumas variáveis de condicionamento físico. Oito cavalos adultos destreinados foram avaliados em 12 sessões de exercício de chão com Rédea Pessoa. Todos os cavalos trabalharam com frequencímetro cardíaco e GPS para a obtenção das frequências cardíacas (HR) e variabilidade de frequência cardíaca (HRV) e cálculos de gasto energético (EE), custo de transporte metabólico (COT), requerimento de energia metabólica (Pmet), pulso de oxigênio e utilização de oxigênio. Também foram avaliadas medidas na altura das vértebras torácicas T18, T13 e T8 com régua flexível antes e depois do experimento quando os animais foram pesados. Os dados obtidos semanalmente foram analisados por ANOVA e Tukey teste ($p \leq 0.05$). Os dados obtidos somente antes e após o período experimental foram analisados pelo teste t pareado. Houve diminuição da assimetria entre os lados direito e esquerdo. Na terceira semana houve aumento da FC, EE, pulso de oxigênio e utilização de oxigênio seguido de diminuição na quarta semana. Os parâmetros relacionados à biomecânica, COT e Pmet diminuíram semana a semana. A VFC apresentou estímulo simpático na terceira semana seguido de desvio para parassimpático na quarta semana. Concluiu-se que 12 sessões de exercício com a Rédea Pessoa contribuíram para melhora do condicionamento físico.

Palavras-chave: cavalo, músculo, energia, exercício, equilíbrio

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INTRODUCTION

Training programs consist of macrocycles, usually constructed around a specific goal for the season. Some variables such as duration, intensity and frequency of each training session can be manipulated to achieve adaptive responses that vary with individual horses, depending on their previous training and inherent athletic ability. Exercise creates a need for efficient use of all the physiological systems of the horse's body and complex and integrated responses occur to allow muscular contraction while maintaining organism homeostasis. Training causes prolongation of the time to fatigue due to physiological adaptations to training stimuli that include increases in aerobic power and anaerobic capacity. On the other hand, inappropriate management or training methods can lead to an injury and overtraining syndrome.

Monitoring horse heart rate (HR) during exercise has been used as a means of prescribing work effort, monitoring the changes in aerobic capacity during training and as part of the clinical examination of horse performance for many decades. It also allows the estimating of other metabolic parameters in field conditions, such oxygen consumption, energy expenditure, net cost of transport and metabolic power that are calculated via mathematical formulas.

Heart rate variability (HRV) analysis in horses has been used for stress, pain, and behavior investigations (Reid *et al.*, 2017; Nyerges-Bohák *et al.*, 2018; Gehlen *et al.*, 2020). In recent years, the use of HRV has been proposed as another assessment tool of performance in athletic horses and as a refinement of available methods (Nyerges-Bohák *et al.*, 2021; Contreras-Aguilar *et al.*, 2021), although the studies are still few, and the results are contradictory.

Horse lunging is a training method that involves having the horse move in a large circle and is commonly used by horse trainers and veterinarians for many purposes to establish communication to strengthen muscles, especially the hindquarters. Adding a training aid (supplementary equipment) while lunging is a way to improve balance and core muscle engagement. A Pessoa training aid (PTA) is commonly used for equine training and rehabilitation (Tabor and Williams, 2018). It consists of a series of ropes and pulleys placed around the horse's hindquarters that affect the horse's head and neck position. The first section is attached to the bit and the second to a roller (William 2020). Although PTA is widely used by horse trainers and riders as part of training programs, scientific studies focus on its use for rehabilitation (Walker *et al.*, 2013; Clayton, 2016).

We hypothesize that groundwork with a system that engages posture could also be beneficial to metabolic and physical conditioning.

The aim of this study was to evaluate the effect that PTA exercise program exerts in the cardiovascular system and metabolic variables to verify if this type of groundwork would have a physical conditioning benefit.

MATERIALS AND METHODS

This study was approved by the Use of Animals Ethics Committee of Universidade Federal de Santa Maria under protocol number CEUA 5955010722.

Eight adult (mean age 7±3.92 years old) Crioulo and cross Crioulo horses were included in this study (3 mares and 5 geldings), with a mean initial body weight of 435 (±5.42) kg. They were housed in paddocks at the university campus. They were previously used for ranch work, however, all of them were living in the university fields without working for 1 year before the experiment. Therefore, they were untrained at the start of the study. All the horses were unshod, and their hooves were trimmed one week before the lunge work.

The inclusion criteria for horses considered: locomotor soundness (no clinical signs of lameness or musculoskeletal injury), no dental problems, no pregnancy, and metabolic soundness (hemogram, renal and hepatic function). All exams were performed by an experienced veterinary and consisted of static inspection and palpation of four limbs, neck, and top line and propulsor muscles, and dynamic inspection of trotting in hand in straight line and in circles (to left side and to right side).

The horses were weighed weekly with a measuring tape and calculations were done according to the formula (Caroll and Huntington, 1988):

$$\text{Weight (kg} = \frac{[(\text{girth mesurement in cm})^2 \text{ x } (\text{lengh mesurement in cm})]}{11.900}$$

The assessment of body condition score was performed before and after the experimental phase, by triple blind evaluation, palpating the fat deposit areas.

The horses were subjected to 12 lunge exercise sessions on the 16 m diameter sand ground arena with the Pessoa reins system, conducted by an experienced rider (handler). The PTA comprises of a loop that attaches to a lunging surcingle, runs behind the hindquarters, and attaches to the bit (O-ring snaffle was used). The objective of using this system in the present study was to ensure that the pressure on the hindquarters and the bit were equal on the left and right sides and engage the horse in a circle.

There were 3 lunge sessions per week on Mondays, Wednesdays, and Fridays, totaling 4 weeks (12 sessions). The exercise protocol is illustrated in Fig. 1:

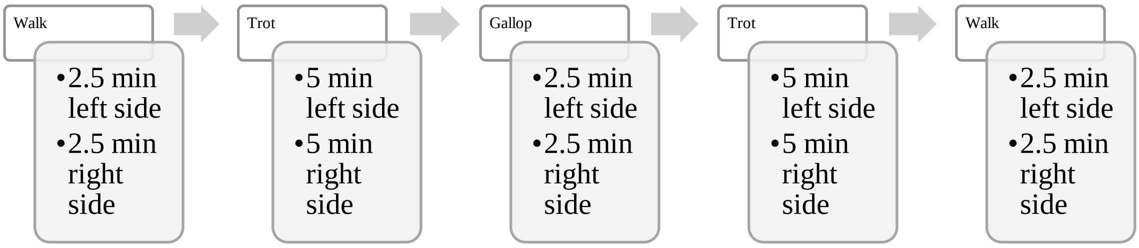

Figure 1. Illustration of each lunge session with PTA.

The thoracolumbar shape and symmetry were measured at the level of the 18th (T18), 13th (T13), and 8th (T8) thoracic vertebrae, identified by palpation of the ribs. A 100 cm flexible curve ruler was shaped around the dorsum, perpendicular to the dorsal midline, to follow the body contours and the resultant shape was drawn on graph paper (Greeve and Dyson, 2013). All measurements were performed with the horses standing squarely on a level surface before and after the experimental phase. Ratios of the width of the horse's back 7.5 (A) and 18 cm (B) ventral to the dorsal midline, determined from the lines drawn on graph paper were calculated for each of the four measurement sites (left and right sides). Back curvature was calculated with a ruler placed perpendicularly across the dorsal midline at T13 and T18 to the *longissimus dorsi* at 7 cm (T13) and 15 cm (T18) out from the midline (Fig. 2). The measurements were taken before the experimental period and after the 12 exercise sessions.

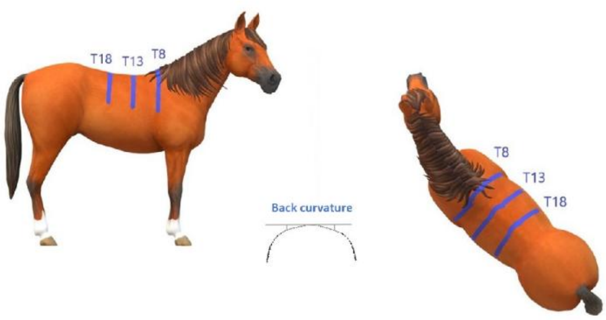

Figure 2. Illustration of how the flexible ruler was positioned to obtain measurements at T8, T13, and T18 and how the back curvature was drawn.

All horses used an integrated heart rate (HR) and GPS monitoring system (V800, Polar Electro, Lake Success, NY, USA) which recorded HR, speed, and distance every 1s throughout the entire duration of exercise. Later, data were transferred and analyzed using Polar Flow Software (Polar Electro, Lake Success, NY, USA).

The intervals between R wave peaks (RR) were recorded during the entire exercise with the heart rate monitor with a precision of 1 ms. HRV analysis was performed using Kubios HRV Standard software (Version 3.0.2, Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland). To clean the data from transmission errors and other noise, we removed sessions with <30 measurements and removed NN-interval values (intervals between normal R-peaks) that deviated more than two standard deviations from the respective session mean. Use of Polar heart rate monitor to assess heart rate variability in horses was previously validated (Mott *et al.*, 2021).

The time domain analysis is based on the analyses of the inter-beat interval, which is the time between consecutive heartbeats (NN = Normal to Normal intervals). The parameters of the time domain analyses were mean RR interval, standard deviation (SD) of RR intervals, root mean square (RMSSD) of successive differences of RR intervals, NN50 (number of successive RR interval pairs that differ more than 50 ms), pNN50 (percentage of successive RR interval pairs that differ more than 50 ms), HRV triangular index, the integral of the RR interval histogram divided by the height of the histogram and stress index. Frequency-domain analysis was performed using the Fast Fourier Transform method with sampling frequency set at 8 Hz. The HRV parameters in the frequency domain were the high-frequency (HF) ranges, low-frequency (LF) ranges, and the low-/high-frequency ratio (LF/HF). The HF power shows mainly the vagal activity, whereas the LF power presents both vagal and sympathetic activity. The LF/HF ratio represented the sympathetic-vagal balance. Non-linear properties of HRV were studied through Poincaré plot (SD1 describing the short-term variability, SD2 describing the long-term variability and SD2/SD1 ratio), approximate entropy (ApEn) that provides a measure of the irregularity of the signal. Detrended fluctuation analysis (DFA) was performed to determine long-range correlations in non-stationary physiological time series, yielding both short-term fluctuation (α1) and long-term fluctuation (α2) slopes.

Determination of energy expenditure (EE), net cost of transport (COT) and metabolic power (Pmet) were calculated using formulas used in previous studies (Coelho *et al.*, 2021; Lage *et al.*, 2017), considering mean HR (beats/min), total body weight (kg), and distance run (m) for COT and time (min) for Pmet.

$EE\ (J\ kg^{-1}\ min^{-1}) = 0.0566 \times HR^{1.9955}$ (Coenen, 2010).
$COT\ (beats\ kg^{-1}\ m^{-1} \times 10^3) =$
$(HR - 35) kg^{-1}\ m^{-1} \times 10^3$ (Williams *et al*, 2009).
$Pmet\ (beats\ min^{-1} kg^{-1}) = (HR - 35) min^{-1} kg^{-1}$
(Schroter *et al*, 1996).
$O2\ Pulse$ ($mLO2min^{-1}$) $= HR\ x\ 0.05$ (Coenen, 2010).
$O2\ utilization\ (mLO2/kg/min) = 0.0019\ x\ (HR)^{2.0653}$
(Coenen, 2005).

Analyses of weight, body score condition, and muscle symmetry were performed before and after the experiment. The variables obtained through the heart rate monitor (heart rate, HRV, EE, COT, Pmet, O_2 pulse and O_2 utilization) were analyzed per week.

The variables were assessed for normality of distribution using the Kolmogorov-Smirnov test and each variable was normally distributed. The influence of exercise in HR, HRV, EE, COT and Pmet parameters (analyzed weekly) was evaluated through analysis of variance for repeated measures (ANOVA), followed by comparison between mean by Tukey test. Variables measured before and after experimental period (weight, BCS, asymmetry) were analyzed through paired T test. Results were analyzed using a computerized statistical program (Minitab® 19 Statistical Software, Lean Six Sigma, Philadelphia, PA, USA) and were presented as mean ± SD. Significance was set at $p \leq 0.05$ in all cases.

RESULTS

All horses were asymmetrical on the right and left sides at both heights A and B before being exercised ($p<0.001$) and after the 12 lunge sessions with Pessoa training aid this asymmetry disappeared ($p=0.876$) at both heights A and B. The same occurred with the back curvature in T13 and T18 (Table 1).

Table 1. Media (±SD) of T8, T13, T18 shape measurements (left and right side) with flexible rule and back curvature at T13 and T18, in height A (7.5 cm) and height B (15 cm), before and after 12 sessions of lunge work with PTA

		T8	T13	T18
A (7.5 cm)				
Before	Left	9.37 (±0.12)	13.83 (±1.02)^{B}	15.05 (±1.23)^{A}
	Right	9.68 (±0.09)	14.92 (±1.26)^{A}	14.03 (±1.31)^{B}
	p	0.878	0.002	0.002
After	Left	8.95 (±0.10)	13.27 (±1.11)	14.36 (±1.12)
	Right	8.93 (±0.11)	13.23 (±1.21)	14.31 (±1.24)
	p	0.989	0.982	0.788
B (18 cm)				
Before	Left	17.00 (±1.23)	23.18 (±1.48)^{B}	23.85 (±1.88)^{A}
	Right	17.96 (±1.32)	25.04 (±1.62)^{A}	22.63 (±1.76)^{B}
	p	0.788	0.001	0.002
After	Left	16.48 (±1.12)	20.85 (±1.70)	21.58 (±1.82)
	Right	16.28 (±1.24)	20.73 (±1.48)	21.29 (±1.66)
	p	0.963	0.889	0.862
Back Curvature (cm)				
Before	Left	__	1.03 (±0.02)^{B}	2.03 (±0.22)^{B}
	Right	__	1.94 (±0.14)^{A}	2.83 (±0.18)^{A}
	p		0.001	0.001
After	Left	__	1.15 (±0.12)	2.37 (±0.28)
	Right	__	1.13 (±0.14)	2.41 (±0.22)
	p		0.846	0.673

Different letters mean differences ($p<0.05$) among lines.

The horses lost body weight and there was a decrease in girth circumference and body score condition as shown in Table 2 and looking at values in Table 1, we can see that although there was an improvement in the asymmetry between the right and left sides, there was also a decrease in the values of the shape measurements performed before and after the 4 weeks of training due to weight loss.

Table 2. Body weight, girth circumference and body condition score before and after 4-week exercise protocol with Pessoa training aid

	Body Weight (kg)	Girth Circumference (cm)	Body Condition Score
Before	435 (±5.42)^{A}	167 (±0.57)^{A}	5.83 (±0.51)^{A}
After	398 (±6.41)^{B}	164 (±0.58)^{B}	5.00 (±0.32)^{B}
p	0.003	0.002	0.004

Different letters mean differences ($p<0.05$) among lines.

Monitoring heart rate during exercise makes it possible to quantify the workload intensity contributing for the assessment of physical fitness and allows estimating other important metabolic parameters such energy expenditure, cost of transport, metabolic power, oxygen pulse and oxygen utilization (Tab. 3).

There was an increase in HR, maximal HR, energy expenditure, oxygen pulse and oxygen utilization in the third week ($p>0.001$). On the other hand, the cost of transport and the metabolic power (both influenced by biomechanics factors) were decreasing week by week.

There was a fluctuation of the variables that are influenced by the parasympathetic nervous system in HRV analysis as indicated in Tab.4. In the third week there was a decrease in mean RR followed by an increase in the fourth week of mean RR intervals, SDNN, RMSSD, NN50, pNN50, RR triangular index, SD1 and SD2.

Table 3. Weekly assessment of heart rate (HR), maximum heart rate (HRmax), total energy expenditure (EE), cost of transport (COT), metabolic power (Pmet), oxygen pulse (O_2 pulse) and oxygen utilization

	Week 1	Week 2	Week 3	Week 4	p
HR (beats/min)	98.81 (±18.12)^{B}	99.10 (±18.51)^{B}	108.00 (±17.96)^{A}	98.36 (±15.24)^{B}	>0.001
HRmax (beats/min)	150.44 (±28.12)^{B}	156.94 (±29.56)^{AB}	171.06 (±27.66)^{A}	161.44 (±28.15)^{AB}	>0.001
EE (J/min^{-1})	49.59 (±19.77)^{B}	50.65 (±19.48)^{AB}	52.87 (±18.56)^{A}	43.52 (±16.23)^{C}	>0.001
COT (HR/kgBW/m.10^{3})	417.36 (±11.32)^{A}	371.20 (±12.84)^{B}	310.67 (±9.46)^{C}	233.68 (±9.27)^{D}	>0.001
Pmet (HR/min/kg^{-1})	5614.8 (±29.39)^{A}	5405.7 (±37.31)^{B}	4694.4 (±24.43)^{C}	3748.7 (±35.40)^{D}	>0.001
O_2 pulse (mLO_2/min^{-1})	4.79 (±0.89)^{B}	5.00 (±0.93)^{A}	5.41 (±0.76)^{A}	4.98 (±0.73)^{B}	>0.001
O_2 utilization (mLO_2/kgBW/min)	118.46 (±11.77)^{C}	135.20 (±16.22)^{A}	138.77 (±18.43)^{A}	126.83 (±17.38)^{B}	>0.001

Different letters mean differences (p<0.05) among columns.

Table 4. Weekly analysis of mean (±standard deviation) of the time-domain, frequency-domain, and nonlinear results of HRV variables

Time-Domain Results					
Variable	Week 1	Week 2	Week 3	Week 4	p
Mean RR (ms)	736.2 (±15.42)^{A}	728.8 (±14.70)^{B}	701.80 (±13.45)^{C}	788.8 (±19.12)^{D}	0.001
SDNN (ms)	318.3 (±19.71)^{B}	302.0 (±18.60)^{B}	281.30 (±17.28)^{B}	380.6 (±15.24)^{A}	>0.001
RMSSD (ms)	429.2 (±28.77)^{B}	412.6 (±33.37)^{B}	416.80 (±17.12)^{B}	528.5 (±38.56)^{A}	>0.001
NN50 (beats)	174.7 (±8.95)^{B}	172.7 (±7.01)^{B}	168.40 (±9.21)^{B}	227.7 (±10.29)^{A}	>0.001
pNN50 (%)	43.6 (±4.24)^{B}	39.8 (±3.30)^{B}	39.70 (±3.28)^{B}	56.8 (±4.32)^{A}	>0.001
RR Triangular index	24.7 (±2.13)^{B}	23.5 (±2.17)^{B}	21.30 (±2.11)^{B}	31.5 (±3.17)^{A}	0.002
Stress index	2.8 (±0.20)	3.6 (±0.26)	3.1 (±0.25)	3.8 (±0.27)	0.596
Frequency-Domain Results					
	Week 1	Week 2	Week 3	Week 4	p
VLF (%)	4.8 (±0.48)^{B}	4.5 (±0.35)^{B}	4.2 (±0.61)^{B}	6.7 (±0.84)^{A}	0.001
LF (%)	42.7 (±1.96)	39.7 (±1.46)	42.6 (±1.17)	37.2 (±0.83)	0.415
HF (%)	52.3 (±1.09)	55.5 (±1.62)	53.3 (±1.58)	55.8 (±1.42)	0.846
LF/HF Ratio	0.9 (±0.40)	0.7 (±0.32)	0.8 (±0.24)	0.6 (±0.39)	0.848
Nonlinear Results					
	Week 1	Week 2	Week 3	Week 4	p
Poincare Plot					
SD1	318.1 (±20.36)^{B}	292.1 (±23.84)^{B}	265.50 (±16.49)^{B}	367.2 (±27.30)^{A}	>0.001
SD2	310.7 (±19.44)^{B}	303.1 (±22.65)^{B}	269.30 (±20.83)^{B}	380.5 (±28.50)^{A}	0.002
SD2/SD1	0.9 (±0.09)	1.03 (±0.09)	1.03 (±0.08)	1,11 (±0.04)	0.679

Different letters mean differences (p<0.05) among columns.

Abbreviations: R-R = interval between R wave peaks (two consecutive heart beats); SDNN = standard deviation of all normal R-R intervals of the data set; RMSSD = the square root of the mean of the sum of the squares differences between adjacent normal R-R intervals; NN50 = consecutive R-R intervals that differed more than 50 ms; pNN50 = percentage of consecutive R-R intervals that differed more than 50 ms; ms = milliseconds; HF = high-frequency ranges in the frequency domain analysis; LF = low-frequency ranges in the frequency domain analysis; LF/HF = low-/high-frequency ratio; SD1 and SD2 are respectively the short and long term Poincare plot indexes.

DISCUSSION

Physical conditioning occurs in response to a stressful stimulus with a supercompensation mechanism in which the tissue adaptations overcome the period that precedes the stressful stimulus (Yanese *et al.*, 2021). Analyzing the data related to HR (Tab. 3), the moment when the stimulus of physical exercise with PTA was stronger occurred in the third week, a period in which an increase in HR is observed, as well as in the HRmax, EE, O_2 pulse and O_2 utilization, demonstrating an increase in physical effort to perform the same work. Training promotes physiological changes in the cardiorespiratory system and the adaptation is observed as a reduction in HR, an increase in heart volume and a higher systolic volume and a greater efficiency in cardiac contractility which contributes to less cardiac effort when performing a physical effort of the same intensity. In the fourth week, these adaptations can be observed through a decrease in HR, HRmax, EE, O_2 pulse and O_2 utilization.

While increases in HR are mainly caused by physical effort, decreases in HRV (Tab. 4) are associated with fatigue or low fitness level in humans (Plews *et al.*, 2013). Heart rate variability (HRV) is the physiological phenomenon of variation in the time interval between heartbeats, expressed as several parameters. HRV is useful to evaluate cardiac autonomic modulation through the sympathetic and parasympathetic branches that act on the heart, directly and differentially influencing the oscillations in this variable. Mean RR markedly decreased in the third week. In horses, the reductions in HRV are not necessarily associated with fatigue but may reflect positive adaptation to the training (Nyerges-Bohák *et al.*, 2021). This reduced HRV even with effective training can be explained with a physiological phenomenon, that has not yet been studied in horses; it is the so-called parasympathetic saturation (Iwasaki *et al.*, 2003). As the individual is physically conditioned, vagal tone predominates and increases HRV. Some parameters like RR interval, RMSSD, SDNN and SD1 are considered more appropriate to evaluate changes in vagal tonus in athletic horses (Szabó *et al.*, 2021). All parameters of time domain and non-linear analysis improved in the fourth week. The only component of spectral analysis that changed was %VLF, but it is poorly studied and seems to be related to thermoregulatory cycles or activity in renin-angiotensin system (Iwasaki *et al*, 2003).

In the beginning the horses were overweight with high BCC and at the end of experimental period they lost weight, there was a decrease in girth circumference and BCC reached 5.0 (0-9 scale). Regarding the response to the exercise program, these results are positive and desired (Table 2).

The first flex rule measurements showed significative asymmetry between left and right side at T8, T13, T18 and in back curvature at T13 and T18, although the horses were not lame. Despite these horses having spent one year without being ridden, they were previously ranch horses working with a treeless saddle called *Arreio Basto*, very common in this country region. This asymmetry may be because of the effect that treeless saddle or unfit saddle (or both) has on horse’s back, but it has not been investigated. Regardless of the reason, after 12 sessions of PTA lunge work asymmetry decreased in all measured points (Table 1). The use of training aids within equine training programs is well established across professional, amateur riders and horse owners and few studies have scientifically evaluated the impact of training aids on equine biomechanics, behavior, or muscle development (Walker *et al.*, 2013; Oliveira *et al.*, 2014; Calzone *et al.*, 2022). They conclude that PTA is capable of improving top line and core muscles strengthen that improves balance. Although flexible ruler measurement is not a sophisticated method of assessing musculature, it is easy and affordable for those non-veterinary horse professionals to do. In the current study it was a valid method both to detect the initial asymmetry, an unexpected data, and to evaluate the recovery of this asymmetry after work with PTA.

Greeve *et al.* (2017) study had described that circles induce symmetrical asymmetry between the left and right reins in the thoracolumbar movement and in the hindlimb gait, in sound horses. This change in movement symmetry when turning may induced alterations in thoracolumbosacral kinematics and may have activated muscle groups that had not been developed correctly before the experiment.

Another study (Walker *et al.*, 2013) concluded that PTA reduce speed, stride length, head angle and lumbosacral angle at maximum hindlimb retraction and observed that dorsoventral displacement of the middle of the back improving posture, stimulating core muscle activation and improving overall way of moving, without increasing the loading of forelimb and hindlimb structures.

There was also an improvement in the energy efficiency of locomotion. COT is the cost to move a unit of weight for a certain distance and it is usually used to estimate biomechanical efficiency during locomotion (Piccione *et al.*, 2013). Pmet is a measure of the overall amount of energy required, per unit of time, to reconstitute the ATP utilized for work performance (Hoppe *et al.*, 2017). In the present study, the workload was not modified and both COT and Pmet were decreasing week by week corroborating this improvement in locomotion quality.

On the other hand, the total energy expenditure includes both the internal energy needed to move the limbs about the equine center of mass and the external work required to overcome gravity and air friction to move the center of mass (Schroter *et al.*, 1996). Energy expenditure is closely related to HR and oxygen consumption (Neri *et al.*, 2018) and these variables increased in the second and third weeks, probably because this was the period in which the exercise stimulus had the greatest metabolic impact. In the fourth week, there was a decrease in HR, EE, consumption, and use of O_2, indicating the recovery of the stimulus and the achievement of physical conditioning.

CONCLUSION

12 sessions of lunge work with PTA were beneficial to physical conditioning achievement since all fitness predictors examined in this study (HR, HRV parasympathetic parameters, oxygen consumption, oxygen utilization, EE, COT and Pmet) had improved in relation to the first day. But, as the horses didn't work without PTA, a limitation of this study is that is not possible to state that this improvement was only due to the use of the aid.

REFERENCES

CALZONE, S.; WILKINS, C.; DECKERS, I.; NANKERVS, K. The effects of EquiAmi training aid on the kinematics of the horse at the walk and trot in-hand. *J. Equine Vet. Sc.i*, v.111, p.103868, 2022.

CAROLL, C.L.; HUNTINGTON, P.J. Body condition scoring and weigh estimation of horses. *Equine Vet. J.*, v.20, p.41-45, 1988.

CLAYTON, H.M. Core training and rehabilitation in horses. *Vet. Clin. North Am. Equine Pract.*, v.32, p.49-71, 2016.

COELHO, C.S.; SODRE, T.D.R.; SOUSA, L.N. *et al.* How much energy Vaquejada horse spend in a field simulation test? *Animals*, v.11, p.3421, 2021.

COENEN, M. About the predictability of oxygen consumption and energy expenditure in the exercising horse. In: EQUINE SCIENCE SOCIETY, 19., 2005, Tucson. *Proceedings*… Tucson: [s.n.], 2005. p.123.

COENEN, M. Remarks on the benefits of heart rate recordings. In: KENTUCKY EQUINE RESEARCH, 17., 2010, Lexington. *Proceedings*… Lexington: [s.n.], 2010. p.42-54.

CONTRERAS-AGUILAR, M.D.; CERÓN, J.J.; MUÑOZ, A.; AYALA, Y. Changes in saliva biomarkers during a standardized increasing intensity field exercise test in endurance horses. *Animal*, v.15, p.100236, 2021.

GEHLEN, H.; FAUST, M.D.; GRZESKOWIAK, R.M.; TRACHSEL, D.S. Association between disease severity, heart rate variability (HRV) and serum cortisol concentrations in horses with acute abdominal pain. *Animal*, v.10, p.1563, 2020.

GREEVE, L.; DYSON, S.J. An investigation of the relationship between hindlimb lameness and saddle slip. *Equine Vet. J.*, v.45, p.570-577, 2013.

GREEVE, L.; PFAU, T.; DYSON, S.J. Thoracolumbar movement in sound horses trotting in straight lines in hand and on the lunge and the relationship with hind limb symmetry or asymmetry. *Vet. J.*, v.220, p.95-104, 2017.

HOPPE, M.W.; BAUMGART, C.; SLOMKA, M. *et al.* Variability of metabolic power data in elite soccer players during pre-season matches. *J. Hum. Kinet.*, v.58, p.233-245, 2017.

IWASAKI, K.; ZHANG, R.; ZUCKERMAN, J.H.; LEVINE, B.D. Dose-response relationship of the cardiovascular adaptation to endurance training in healthy adults: how much training for what benefit? *J. Appl. Pysiol.*, v.95, p.1575-1583, 2003.

LAGE, J.; FONSECA, M.G.; BARROS, G.G.M. *et al.* Workload of oficial contests, net cost of transport, and metabolic power of Mangalarga Marchador horses of marcha batida or picada gaits. *J. Anim. Sci.*, v.95, p.2488-2495, 2017.

MOTT, R.; DOWELL, F.; EVANS, N. Use of polar V800 and actiheart 5 heart rate monitors for the assessment of heart rate variability in horses. *Appl. Anim. Behav. Sci.* v.241, p.10541-10547, 2021.

NERY, J.; RACIOPPI, F.; VALLE, E. *et al*. Proof of concept on energy expenditure assessment using heart rate monitors and inertial platforms in showjumping and riding school horses. *J. Equine Vet. Sci.*, v.61, p.1-6, 2018.

NYERGES-BOHÁK, Z.; HARNOS, A.; JOO, K. *et al*. Anticipatory response before competition in Standardbred racehorses. *PLoS One*, v.13, p.e0201691, 2018.

NYERGES-BOHÁK, Z.; NAGY, K.; RÓZSA, L. *et al*. Heart rate variability before and after 14 weeks of training in Thoroughbred horses and Standardbred trotters with different training experience. *PLoS One*, v.16, p.e0259933, 2021.

OLIVEIRA, K.; SOUTELLO, R.V.G.; FONSECA, R. *et al*. Biometria por ultrassonografia da musculatura epaxial e pélvica em equinos treinados com rédea pessoa. *Cienc. Rural*, v.44, p.2045-2051, 2014.

PICCIONE, G.; MESSINA, V.; BAZZANO, M. *et al*. Heart rate, net cost of transport, and metabolic power in horse subjected to different physical exercises. *J. Equine Vet. Sci.*, v.33, p.586-589, 2013.

PLEWS, D.J.; LAURSEN, P.B.; STANLEY, J. *et al*. Training adaptation and heart rate variability in elite endurance athletes: opening the door to effective monitoring. *Sports Med.*, v.43, p.773-781, 2013.

REID, K.; ROGERS, C.W.; GRONQVIST, G. *et al*. Anxiety and pain in horses measured by heart rate variability and behavior. *J. Vet. Behav.*, v.22, p.1-6, 2017.

SCHROTER, R.C.; BAYLIS, E.; MARLIN, D.J. Gait estimated net cost of transport and heat production at different speeds in three-day event horses. *Equine Vet. J.*, v.22, p.16-23, 1996.

SZABÓ, C.; VIZESI, Z.; VINCZE, A. Herat rate and heart rate variability of amateur show jumping horses competing on different levels. *Animal*, v.11, p.693-702, 2021.

TABOR, G.; WILLIAMS, J. Equine rehabilitation: a review of trunk and hind limb muscle activity and exercise selection. *J. Equine Vet. Sci.*, v.60, p.97-103, 2018.

WALKER, V.A.; DYSON, S.J.; MURRAY, R.C. Effect of a pessoa training aid on temporal, linear and angular variables of the working trot. *Vet. J.*, v.198, p.404-411, 2013.

WILLIAMS, J., Equine training aids: can they really improve performance? *UK-Vet-Equine*, v.4, n.6, p.196-200, 2020.

WILLIAMS, R.J.; NANKERVIS, K.J.; COLBORNE, G.R. *et al*. Heart rate, net transport cost and stride characteristic of horses exercising at walk and trot on positive and negative gradients. *Comp. Exerc. Physiol.*, v.6, p.113-119, 2009.

YANESE, L.; SANTANA, J.O.; FUKUSHIMA, A.R. *et al*. Síndrome do overtraining: a periodização do treinamento de força como estratégia. *Rev. Multidisc. Saúde*, v.3, p.22-36, 2021.