VIDEOGRAPHIC KINEMATIC ANALYSIS OF LAME HINDLIMB EQUINE MOVEMENTS

ANÁLISE CINEMÁTICA VIDEOGRÁFICA DOS MOVIMENTOS DE EQUINOS SUBMETIDOS À CLAUDICAÇÃO DO MEMBRO POSTERIOR

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SUMMARY

Lameness is one of the most common and complex locomotor disorders which compromises the athletic horse. Qualitative gait analysis is an important tool for equine lameness evaluation, applied by most of veterinary clinicians. This method is used to assign the lameness grade, but like any subjective method, it demands the clinician experience. Videographic kinematic analysis is a quantitative method that offers great accuracy without the biases of a qualitative assessment. The aim of the present study was to quantify the effects of a lame and non-lame hindlimb on the horse movement using three dimensional kinematic analyses based on cinematography. Six sound Purebred Arabian horses were filmed on a treadmill, at walk and trot, before and after induction of lameness. Lameness was induced in the left hindlimb using a transient lameness model. On both gaits, the animals demonstrated two vertical head movements per stride and after the induction of lameness this movement showed greater amplitude. After inducing lameness, the animals increased the stance time for the non-lame limbs and a global reduction in the stride length was observed. Changes details in the horse movements, which are important in the diagnosis of lameness, were provided by videographic analyses.

KEY-WORDS: Biomechanics. Cinematographic. Gait analysis. Lameness.

RESUMO

Claudicação é uma das mais complexas e comuns afecções do sistema locomotor que comprometem o cavalo atleta. A análise qualitativa de andamento é uma importante ferramenta na avaliação da claudicação, aplicada pela maioria dos clínicos veterinários. Este método é utilizado para avaliar o grau de claudicação, mas como qualquer método subjetivo, requer experiência por parte do clínico. A análise cinemática videográfica é um método quantitativo que oferece uma boa exatidão sem a variabilidade ligada a avaliação qualitativa. O objetivo deste estudo é quantificar os efeitos da claudicação em membros anteriores de um equino em movimento utilizando análise tridimensional baseada em cinematografia. Seis animais saudáveis da raça Puro Sangue Árabe foram filmados em uma esteira rolante, ao passo e ao trote, antes e após a indução da claudicação. A claudicação foi induzida no membro posterior esquerdo utilizando-se um modelo não-permanente. Em ambos os andamentos, os animais demonstraram dois movimentos verticais de cabeça por passada e, após a indução da claudicação, estes movimentos aumentaram a amplitude. Após a indução da claudicação, os animais aumentaram o tempo de apoio do membro não-claudicante e foi observada uma redução global no comprimento da passada. A análise videográfica fornece detalhes das mudanças no movimento dos cavalos, as quais são importantes para o diagnóstico da claudicação.

PALAVRAS-CHAVE: Análise de andamento. Biomecânica. Cinematografia. Claudicação.

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INTRODUCTION

Horse's conformational studies and locomotion characteristics are used to indicate the functionality, athletic potential and market value of those animals. The opinion of an experienced judge determines the outcome of equestrian sports like dressage or reining. The judgment of a committee can determine the inclusion of an animal in specific breed registration. However, this kind of gait analysis based only on observation carries subjective scores which normally are hard to be reproduced. In the equine lameness evaluation, qualitative gait analyses have been used as an important tool by veterinarians. This method is applied to evaluate the horse lameness grade (STASHAK, 1994), but demands experience from the clinician.

Lameness is one of the most common and complex locomotor disorders that compromises the athletic horse (CHRISTOVÃO et al., 2007). The anatomic conformation, type and intensity of the physical activity, trimming and/or shoeing and the presence of lesions are causal factors routinely involved in the diagnosis of the lame animal (TURNER, 2003). Movements of the head, body and limbs must be taken into account for a satisfactory lameness assessment because only observation is likely to be an insufficient technique to come with a more precise evaluation.

Videographic kinematic analysis is a quantitative method that offers great accuracy without the biases of a qualitative assessment. Horse's biomechanical studies have been improved by the utilization of treadmills which guarantee uniformity of the motion and environmental control, assuring, therefore, a reliability and precision to the results (FABER et al., 2002). Kinematic analysis quantifies the features of the gait that are assessed qualitatively during a visual examination (CLAYTON e SCHAMHARDT, 2001). The output is in the form of temporal (timing), linear and angular measurements that describe the movements of the body segments and joint angles. The aim of the present study was to quantify the effects of a lame and non-lame hindlimb on the horse movement using three dimensional kinematic analyses based on cinematography.

MATERIALS AND METHODS

With approval of the FCAV/UNESP Ethics and Animal Welfare Committee (protocol no. 006981), six sound Arabian Purebred were used in the study. The group had 330 *kg* mean weight and was averaging 3 years old. The horses were clinically examined by a veterinarian and an experienced farrier balanced the hooves of each animal. A treadmill adaptation protocol was applied to the group in a period of 3 days before starting the test campaign.

Kinematic reflective markers were fixed on the skin in the zygomatic process region of the temporal bone, on the extremity of the sixth thoracic vertebra (T6) spiny process, on the extremity of the first lumbar vertebra (L1) spiny process, on each proximal phalange and hindlimbs.

Three-dimensional data were collected in the Horse Exercise Physiology Laboratory using two digital cameras recording at 60 Hz. A reference volume measuring 3.50 *m* by 1.00 *m* by 2.00 *m* with 6 markers on each side was calibrated using a wand technique. It was found a 0.8% coefficient of variation when measuring a known stick length within the reference volume. The data acquired was post processed by an image tracking software Dvideow (FIGUEROA et al., 2003) based on DLT (Direct Linear Transformation) method (ABDEL-AZIZ e KARARA, 1971).

Each successful trial consisted of nine complete strides. After collecting data from the non-lame condition, the horses were induced to lame by placing a 20 *mm* diameter metal sphere in the medial region of the left posterior hoof, in the vertex of the frog. Both lame and non-lame conditions were tested for walk and trot, at speeds of 1.7 and 3.0 *m/s*, respectively.

Kinematic data were handled using a fourth-order low-pass Butterworth filter and analyzed using a custom written code in Matlab (MathWorks Inc, Natick, MA, USA). The limbs and head vertical displacement were obtained in the lame and non-lame conditions by plotting the skin marker coordinates. The stance duration was obtained by the time the limb was in contact with the treadmill and the mean stance time was calculated using eight stance phases on each limb. Stride length was determined based on stride time and treadmill speed. Data were statistically analyzed using *Student's t* test.

RESULTS AND DISCUSSION

Head vertical displacement

Walk - All horses showed two head movements per stride on both lame and non-lame conditions (Figure 1). However, the average maximum value of head displacement obtained for non-lame horses was 1.65 ± 0.02 *m* and for lame horses was 1.61 ± 0.02 *m* and the average (mean ± standard deviation) minimum values were 1.53 ± 0.03 *m* and 1.49 ± 0.03 *m*, respectively. Thus, it was obtained a substantial difference for the values of average minimum displacement in the lame condition ($P \leq 0.05$). There was no relevant difference between the amplitude of head displacement for the lame and non-lame conditions. The amplitude values were 11.50 ± 0.03 *cm* and 12.50 ± 0.02 *cm*, respectively.

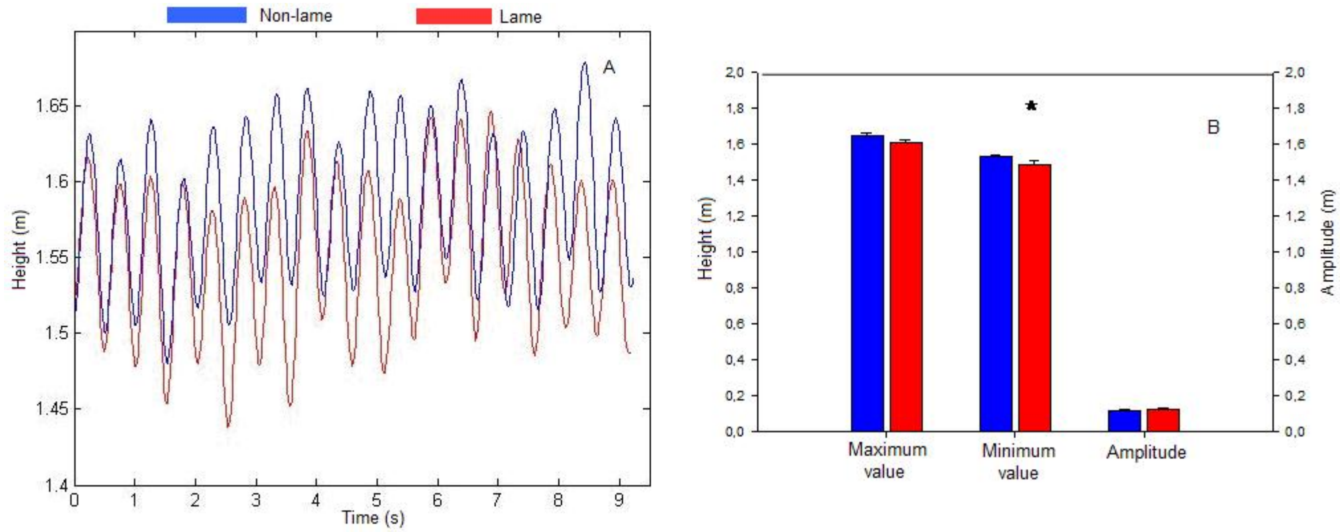

Figure 1- (A) Head positioning for lame and non-lame horses at walk. Speed = 1.7 *m/s*. The line corresponds to one stride. (B) Mean values for maximum and minimum head height for lame and non-lame horses. Head movement amplitude for lame and non-lame horses at walk. *Significant difference in relation to non-lame group. ($P \leq 0.05$).

Trot – Similarly to the walk condition, during trot the animals showed two head movements per stride on both lame and non-lame conditions (Figure 2). The average maximum value of head displacement obtained for non-lame horses was 1.67 ± 0.03 *m* and for lame horses was 1.65 ± 0.03 *m*. The average minimum values were 1.57 ± 0.02 *m* and 1.57 ± 0.03 *m*, respectively. There was no significant difference between the maximum and minimum values of average head displacement for lame and non-lame conditions. Although, there was a significant difference ($P \leq 0.05$) in the mean amplitude for lame horses (8.10 ± 0.02 *cm*) when compared to the non-lame mean amplitude (8.80 ± 0.005 *cm*).

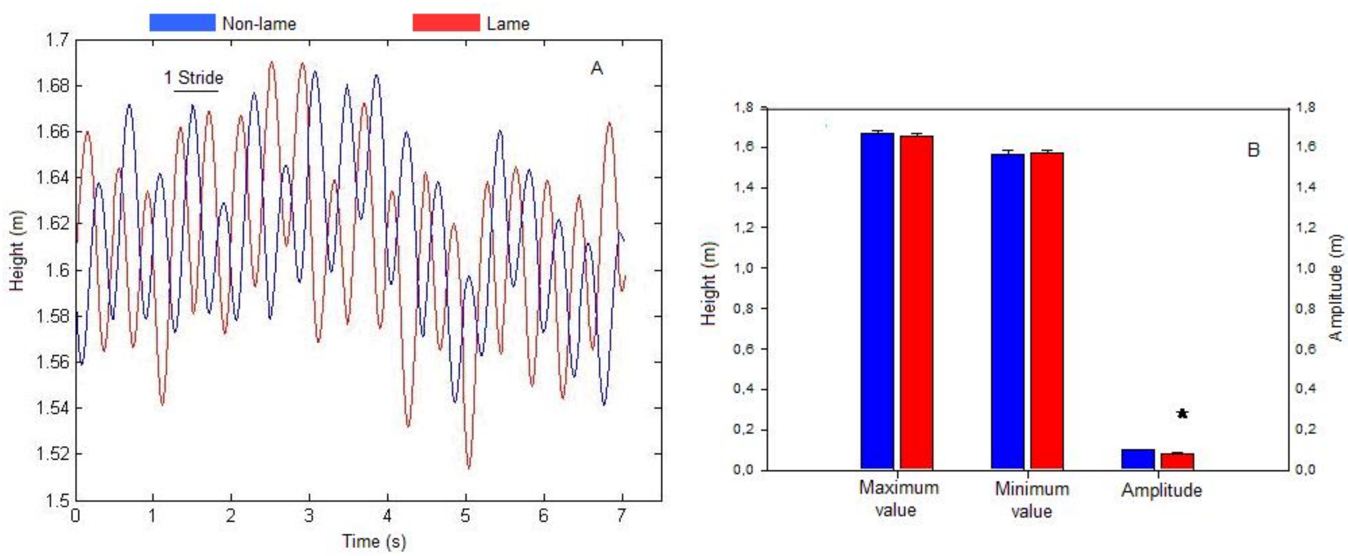

Figure 2. (A) Head positioning for lame and non-lame horses at trot. Speed = 3.0 *m/s*. The line corresponds to one stride. (B) Mean values for maximum and minimum head height for lame and non-lame horses. Head movement amplitude for lame and non-lame horses at trot. *Significant difference in relation to non-lame group. ($P \leq 0.05$).

Limbs vertical displacement

Walk – Figure 3 shows the minimum and maximum average values in the limb displacement amplitude. There was a reduction in the values for the lame group, but it was obtained statistical difference only for the forelimbs. The average value of vertical displacement in the left thoracic limb was 7.900 ± 0.003 *cm* (non-lame) and 3.600 ± 0.005 *cm* (lame). For left pelvic limb, the average value of vertical displacement was 8.400 ± 0.005 *cm* (non-lame) and 7.70 ± 0.02 *cm* (lame). The right forelimb had displacements of 10.000 ± 0.004 *cm* (non-lame) and 7.30 ± 0.02 *cm* (lame) and the right hindlimb had 9.500 ± 0.003 *cm* (non-lame) and 6.500 ± 0.009 *cm* (lame).

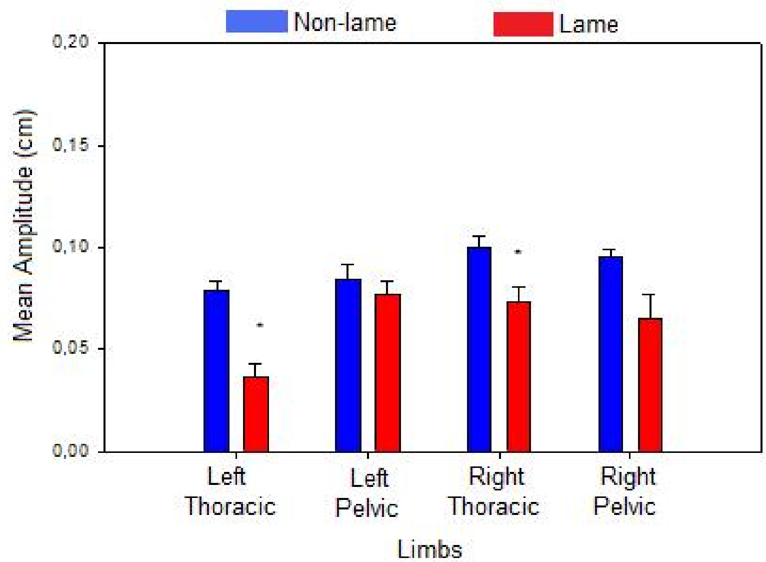

Figure 3. Vertical limbs amplitude at walk for lame and non-lame conditions. Speed = 1.7 *m/s*. *Significant difference in relation to non-lame group. ($P \leq 0.05$).

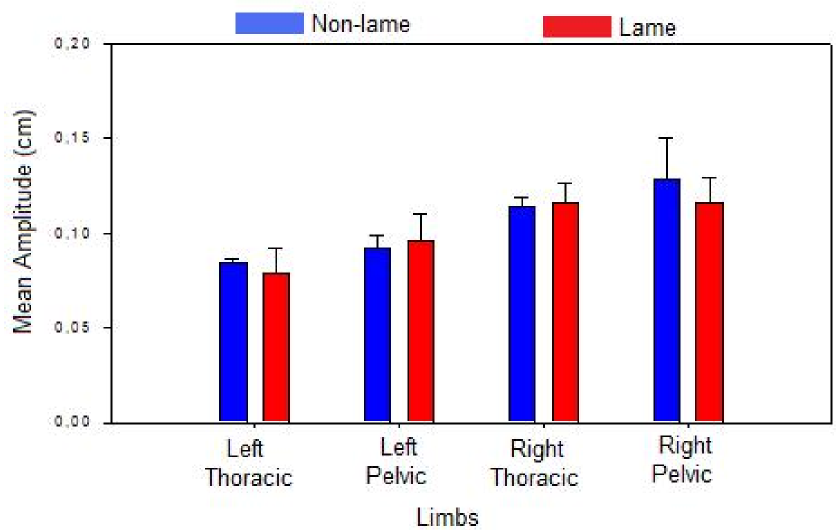

Figure 4. Vertical limbs amplitude at trot for lame and non-lame conditions. Speed = 3.0 *m/s*. *Significant difference in relation to non-lame group. ($P \leq 0.05$).

Trot – There was no significant changes in the movement displacements and amplitudes for the lame and non-lame conditions (Figure 4). The average value of the vertical displacement in the left thoracic limb was 8.400 ± 0.004 *cm* (non-lame) and 7.90 ± 0.02 *cm* (lame). For the left pelvic limb, the average value of the vertical displacement was 9.20 ± 0.03 *cm* (non-lame) and 9.70 ± 0.01 *cm* (lame). The right forelimb had displacements of 11.40 ± 0.03 *cm* (non-lame) and 11.70 ± 0.02 *cm* (lame) and the right hindlimb had 12.800 ± 0.002 *cm* and 11.70 ± 0.02 *cm*, respectively.

Stance time

Table 1 shows the average stance time obtained for 8 strides during walk and trot, lame and non-lame conditions. Data showed that the trot stance time had a significant reduction compared to the walk stance time. Besides, after inducing lameness, it was observed a longer stance time for non-lame limbs on both trot and walk conditions compared to the lame hindlimb, which had a reduction of the stance time.

Table 1. Forelimbs and hindlimbs average stance time (mean ± standard deviation) for lame and non-lame conditions (n = 8 strides).

	Stance time (s)			
	At walk		At trot	
Limb	Non-lame	Lame	Non-lame	Lame
Left forelimb	0.61 ± 0.03	0.63 ± 0.02	0.32 ± 0.02	0.35[a] ± 0.03
Left hindlimb	0.62 ± 0.04	0.62 ± 0.03	0.29 ± 0.02	0.30 ± 0.04
Right forelimb	0.61 ± 0.04	0.64 ± 0.02	0.31 ± 0.02	0.35[a] ± 0.02
Right hindlimb	0.61 ± 0.04	0.63 ± 0.04	0.29 ± 0.02	0.32[a] ± 0.03

[a] Signifficant difference for lame animals ($P < 0.05$).

Table 2. Average stride length (mean ± standard deviation) for lame and non-lame conditions (n = 8 strides).

Stride length (m)			
At walk		At trot	
Non-lame	Lame	Non-lame	Lame
1.85 ± 0.40	1.73 ± 0.90[a]	2.58 ± 0.50	2.26 ± 0.40[a]

[a] Signifficant difference for lame animals ($P < 0.01$).

Stride length

The amplitude of the lame and non-lame left pelvic limb horizontal displacement is showed on Table 2. It was observed a significant reduction in the stride length for the lame horses during walk and trot conditions.

Videographic kinematic analysis was used in the present study to evaluate the effects of lameness in the body motion of horses. Cinematography has proved to be an important tool in the diagnosis of locomotor diseases and helps clinicians to estimate the effect of the chosen treatment (LEACH e DAGG, 1983). This method allows the movement analysis of small parts of the body in a short period of time, impossible to be visualized by an observer with naked eye (GRUEN, 1997). In this study, the method applied to induce lameness in the horses was a reversible, non invasive and without posterior sequela model (MERKENS e SCHAMHARDT, 1988, DEUEL et al., 1995).

It is very common during the clinical examination of a lame animal to take into consideration the moment at which the head is in the highest position to identify the lame limb, regardless whether the lameness is in the fore or hindlimb (BUCHNER et al., 1996, KELMER et al., 2005). Concordantly, this videographic analysis also demonstrated that the highest position was coincident with the moment of the lame limb ground contact.

Nevertheless, the examiner shall be attentive for the alterations in the movements of the limbs, especially in the flexion articulation angles and in the symmetry of gluteus (STASHAK, 1994). When the animals were submitted to walk, it was observed a statistic difference in the minimum head displacement. Only at trot, the animals decreased the amplitude of head movement after inducing lameness in the hindlimb.

Although lameness clinical evaluation is usually performed with the animal trotting, this study demonstrated that the mechanical changes of the movement are present in both trot and walk. Moreover, experiments of other authors have showed a discrete increment in the lame hindlimb movement amplitude, as a mechanism to reduce pain caused by the support time (VORSTENBOSCH et al., 1997). This was not observed in this study, in which it was found no differences in the amplitude of the limb movement at trot, however it was noticed a reduction of this amplitude in the lame forelimbs at walk.

In a lame animal, the support time may be modified by the painful process, inducing a reduction of this character in the lame limbs and, therefore, an increment of this support time in the non-lame limbs (ROONEY, 1969). In the present study, after inducing lameness, the animals were increased the support time for the non-lame limbs and it was observed a global reduction in the stride length.

CONCLUSION

Three dimensional kinematic analyses were conducted by combining applicable locomotion variables. The data obtained allowed the quantitative and qualitative evaluation of head and limbs movement in horses with induced lameness. The major changes were manifested during trot, despite the same modifications could also be detected during walk.

The precision obtained in the cinematographic analysis, guaranteed by a rigorously calibrated system, allowed the researcher to obtain a highly reliable data, although further investigations are needed to determine the lesion location responsible for the lameness. In such cases, it should be necessary to use an animal with lameness history, so the gaits could be analyzed to verify if different lesion locations induce different dynamic patterns.

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