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Effect of the trimming of the toe region of healthy horses forelimb hooves on morphology, distal angles and locomotion by cinematography

[*Efeito do casqueamento da região da pinça dos cascos torácicos de equinos sadios sobre a morfologia dos cascos, ângulos articulares distais e locomoção por cinematografia*]

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ABSTRACT

Seven forelimb hooves from healthy horses were submitted to regular trimming and fourteen days later, submitted to toe trimming. Toe angle and length, lateral and medial heels, frog and sole length and width, distal, proximal, and metacarpal phalangeal interphalangeal angles were measured, as well as locomotion evaluation through cinematographic analysis. The measurements were performed ten, 14, 15, 30 and 45 days after the regular trimming, and at 14 days two measurements, one before and one after the toe trimming, were carried out. For cinematography, the sequence of supports and time spent in each support were taken. The comparison of the means obtained from the individuals regarding the variables, between limbs, limbs for each individual, time – points, moments for each individual and between limbs for each moment, as well as the time spent in each in the supports, was performed using ANOVA. Results lower than those of statistical significance ($p<0.05$) were submitted to Tukey's test. The toe trimming promotes changes in toe length, angle, lateral heel angle, medial and lateral heel length, frog length, width, and sole length, and changes the pattern of the trot of horses.

Keywords: Equine, arthrogoniometry, morphometry, joint, gait.

RESUMO

Sete cascos de membros posteriores de cavalos saudáveis foram submetidos ao corte regular e, quatorze dias depois, submetidos ao corte dos pés. Foram medidos ângulo e comprimento dos dedos, saltos laterais e mediais, comprimento e largura do sapo e da sola, ângulos interfalangianos distais, proximais e metacarpianos da falange, bem como avaliação da locomoção através de análise cinematográfica. As medições foram realizadas dez, 14, 15, 30 e 45 dias após o corte regular, e aos 14 dias foram realizadas duas medições, uma antes e uma depois do corte do dedo do pé. Para a cinematografia, foi feita a seqüência de suportes e o tempo gasto em cada suporte. A comparação dos meios obtidos dos indivíduos em relação às variáveis, entre membros, membros para cada indivíduo, tempo - pontos, momentos para cada indivíduo e entre membros para cada momento, assim como o tempo gasto em cada um dos suportes, foi realizada utilizando ANOVA. Resultados inferiores aos de significância estatística ($p<0,05$) foram submetidos ao teste de Tukey. O corte do pé promove mudanças no comprimento do pé, ângulo, ângulo do calcanhar lateral, comprimento do calcanhar medial e lateral, comprimento do sapo, largura e comprimento da sola, e muda o padrão do trote dos cavalos.

Palavras-chave: equino, artrogoniometria, morfometria, articulação, marcha

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INTRODUCTION

The equine hoof or horny capsule is an attachment to the integumentary system that surrounds, protects, and supports structures in the distal region of the limbs (Faramazi *et al*., 2018).

Equine hoof measurements have a conception of normality and are widely described in the literature (Souza *et al*., 2016). Among these measures, the pinch angle stands out, which, when altered, will influence the angles of the metacarpophalangeal, the distal and proximal interphalangeal the joints which make up the podophalangeal axis (Dyson *et al*., 2011).

Horse locomotion consists of moving the animal's center of gravity to forward, backward or to the side, so that the limbs act sequentially in the support and elevation phase (Huang *et al*., 2013). The elevation phase is composed of the lifting and advancement of the limb, and the support phase consists of the support and propulsion of the limb. The complete one-step cycle consists of fully carrying out the lifting and supporting phases (Dreyer *et al*., 2020). The different ways in which horses move characterize the different types of gaits.

The horse's gaits are classified with basis on characteristics such as speed, symmetry, sequence, and number of supports of the hooves on the ground, sequence of limbs and number of strikes caused by the contact of the hoof with the ground (Clayton and Hobbs, 2019). The types of gaits considered natural and consequently the most found in the equine species are walk, trot, equipped walk, and gallop (Hussni *et al*., 1996). The walk is a low-speed gait, characterized by eight symmetrical different moments of support, while the trot is a medium-speed gait, with two different moments of support and a moment of suspension, which is also symmetrical (Huang *et al*., 2013).

The understanding of the locomotion physiology is essential for the clinician since it is based on the alterations presented during the physical examination of the locomotor system that the veterinarian will establish the diagnosis of a lame horse (Dreyer *et al*., 2020).

Another tool used to assess equine progress is cinematography, which consists of filming the animal in movement and subsequent evaluation of the same parameters described in the physical examination (Schmid *et al*., 2009). Cinematography has advantages over direct inspection, since through films is possible to determine the characteristics of each gait more accurately, with emphasis on the moments and time of support of each member, time of a complete step cycle, phases support and advancement (Clayton and Hobbs, 2019).

Diseases that affect the internal structures of the horse's hoof, such as laminitis and navicular syndrome, need, among other treatments, trimming of the toe through the dorsal wall and sole of the affected hooves (Parks, 2010). This technique aims of decreasing the tension exerted by the deep digital flexor tendon on the third phalanx and the pressure of the same tendon on the navicular bone (Kelleher *et al*., 2021). Authors such as Eliashar *et al*. (2002) and Heel *et al*. (2006) have described the effect of such a trimming technique in relation to kinetics and kinematics in horses with horseshoes. However, there is no information in the literature about the effects of the described trimming technique on the locomotion of barefoot horses.

Therefore, this study aims to evaluate the effect of toe removal through the dorsal wall and sole of the hooves of forelimbs of healthy horses on morphology, distal joint angles, and locomotion with the aid of cinematography.

MATERIALS AND METHODS

This study was approved by the Ethics Committee on the Use of Animals (CEUA) of the School of Veterinary Medicine and Animal Science at São Paulo State University (Unesp), Campus of Botucatu, São Paulo State, Brazil, under protocol 122/2016.

Seven crossbred adult mestizos' horses, both sexes, and acquired by the University for this experiment, were selected. Inclusion criterion of the animals was health, and the exclusion criterion was lameness. The horses had an average of 7.5 years (±1.5), and a mean body weight of 293.3 kg (±21.72). The equines had not been hoofed for at least six months. Horses' health was confirmed by prior specific physical examination (locomotor apparatus), followed by regular trimming (**RT**) for hygienic maintenance of the hooves (Proske *et al*., 2017). During the entire study period, the animals were kept free-range in paddocks of 15 X 20m^2 of earth floor, fed with coast cross grass hay, ryegrass silage and water *ad libitum*.

Ten days after regular trimming, the measurements of the hoof variables of both forelimbs limbs were carried out, at an initial time - point (M0). The morphological evaluation was made based on protocol described by Nicoletti *et al*. (2000) (Figure 1) in which the measurements of the hoof consider the angular parameters (degrees) formed between the toe hoof and the ground (**αT**, with goniometer). Then, medial and lateral photographs (Sony Cyber-shot® 7,2 Megapixels, USA) of the digits were acquired in order to measure the lateral (**αLH**) and medial (**αMH**) heels angles using an angular dimension tool (software Corel Draw X7, Canada). With a flexible measuring tape, the measurement of linear patterns (centimeters) dorsal length of toe (**T**), height of medial (**hMH**) and lateral (**hLH**) heels, length (**Lf**) and width (**Wf**) frog, width (**Wh**) and length (**Lh**) hooves. The distal joint angles were evaluated by lateromedial radiographic (Figure 2) of both forelimbs, focusing on correct alignment of the metacarpophalangeal (α**MTCJ**), proximal (**αPIJ**) and distal (**αDIJ**) interphalangeal joints. The arthrogoniometry was performed according to the techniques previously described in the literature (Hussni *et al*., 2010, 2015; Page and Hagen, 2002) and the angles measured performed with the aid of Clear Canvas® software (Clear Canvas, Personal Edition, Canada).

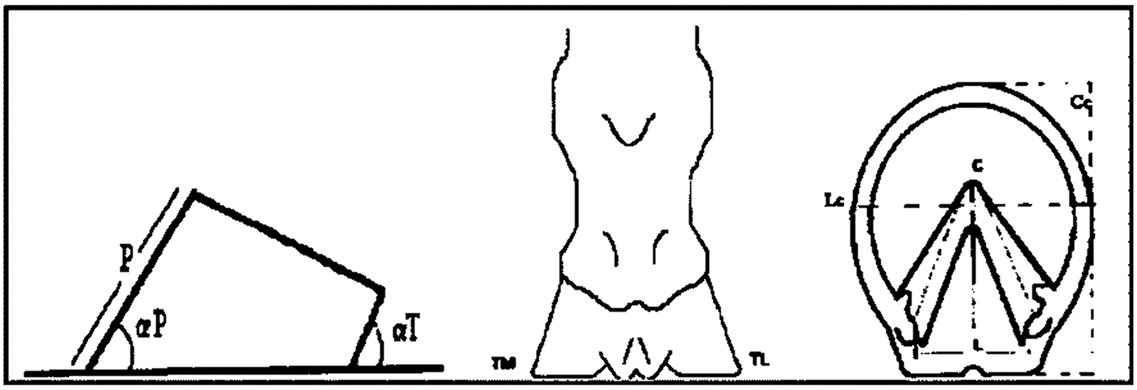

Figure 1. Protocol used by Nicoletti *et al*., 2000. P = T, αP = αT, αT = αMH and αLH, TM = hMH, TL = hLH. C = Lf, L = Wf, Lc = Wh, Cc = Lh.

Figure 2. Lateromedial radiographic projection for goniometric visualization of the distal joints.

The cinematographic analysis was carried out through filming (Sony, HDR PJ200, Japan) with 30 frames per second (FPS) and generating files with high definition (AVCHD). Each animal film was rated on walk and trot gaits under a straight line, on a five meters flat and rigid (concrete) track, led always by the same horseman. The shots were taken on the animal's left side, with the camera always positioned at eight meters and 1.5 meters above the ground.

The videos were analyzed frame by frame, and the support sequences of each animal were taken, at all time - points for both gaits, considering: the average speed (meters per second, mps) of the route, the number of frames and the total time in seconds (**TTS**) that each animal remained in moments of support or suspension (Hildebrand, 1965; Hussni *et al*., 1996).

The TTS remaining in each support or suspension moment was obtained by multiplication of the total number of frames remained in the respective phases by 0.03 seconds (equivalent in seconds for each frame). With the TTS, the statistical analysis was evaluated using analysis of variance, comparing the TTS of each animal for each support or suspension phasis, both in walk and trot, between individuals and time – points, and those among the different time - points. The values obtained from hooves and distal joint angles were subjected to analysis of variance, comparing the right and left limbs per individual at different moments, between moments for each individual and between members for each moment. For all statistical analyses a significance level of 5% ($p < 0.05$) was considered. Results under level of significance were submitted to the Tukey test (Pagano and Gauvreau, 2004).

The time - points were selected based on the physiology and growing of the equine hoof capsule. The data collected from the own horses prior any hoof treatment was considered as control group of themselves. Events were divided in initial (**M0**), 10 days after the first trimming; in 14 days after trimming (**M14**) with taking measurements and filming performed before (**M14A**, Fig.3) and after (**M14B**) the toe trimming (**Tt**) reduction (Fig.3); 15 (**M15**), 30 (**M30**) and 45 (**M45**) days after the initial trimming (M0, Figure 4).

Figure 3. Appearance of hooves of the forelimbs after the trimming toe (Tt) with hoof rasp on the dorsal wall and sole. A - side view. B - view from the sole.

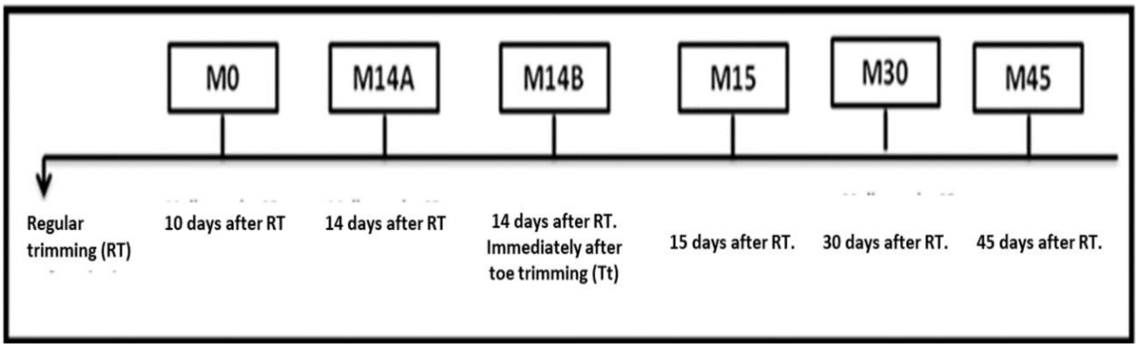

Figure 4. Representation in chronological order of the different time – points for measurements and production of videos of study animals.

RESULTS AND DISCUSSION

The cinematography was a useful, simple and cheap way to analyses horses' locomotion. The most limiting factor of the study was the low precision of the movies taken for the cinematography and consequently low number of FPS, which result in a more inaccurate notation of the support or suspension moments during the walk and trot. Many other methods have been described to evaluate equine gait. Methods like equine objective or quantitative lameness assessment (Kelleher *et al*., 2021), the use of accelerometers (Thompson *et al*., 2017), wireless technology (Müller-Quirin *et al*., 2020), high-speed cameras cinematography or electro goniometry (Bragança *et al*., 2020) can present accurate features and a high precision of the observation. However, they can be expensive and require a specific technology not available to the authors routine.

Statistical analysis of variable T revealed difference (P < 0.001) only between time - points. M0 and M14A did not differ between them, however, they differed from the others (Table 1). The significant decrease observed from M14A is due to the Tt and remains until M45. When considering the mean before Tt at M0, the values are close to the mean of 8.3cm, values found by Ovnicek *et al*. (2003), who performed measurements on wild equine hooves that had never been subjected to any intervention on the hoof and kept on a sand floor. In a study whose objective was to evaluate the morphology of the athlete equine hooves, Nicoletti *et al*. (2000) found approximate values (8.25 and 8.97) of this study. The variable T was also studied by authors such as Schade *et al*., (2012), who described the value of 8.63±0.88, and by Souza *et al*. (2016), who found the value of 8.59±0.69, and in both studies the values described are close to those found in this study and presented in Table 1.

The αT showed significant differences (P = 0.012) between time – points M0 and M45 (Table 1). Values differed from those found by Ovnicek *et al*. (2003), which ranged between 57° and 68° degrees. This is most likely because the wear pattern of the horny case differs between sand and earth floors, used in this work. On the sand floor, the horny case tends to acquire prominences in the transition region between the clamp and the lateral and medial quarters, whose function is to provide greater friction between the hoof and the ground (Ovnicek *et al*., 2003). Nicoletti *et al*. (2000), described values between 50.66º and 53.50º for the same variable, while Schade *et al*. (2012) found a mean value of 49.1º. On the other hand, Souza *et al*., (2016), found values between 49.46º and 55.56º. Despite the variation, the three works present numbers close to those described in this work for αT.

The statistical analysis of the αLH revealed a significant difference between forelimbs (P=0.017) in M14A (P=0.012), M14B (P=0.001), M15 (P<0.001) and M30 (P=0.006), and between time – points M0 and M15 for the right limb (P>0.001) (Table 1). The difference between the limbs is because, despite of RT, in certain individuals wasn't possible to completely eliminate the asymmetries caused by the long period of stay without proper hoof maintenance. The same variable was presented by Nicoletti *et al*. (2000), with values of 36.88º for the right forelimb and 35.94º for the left, both values not being similar to those presented in this work. Souza *et al*. (2016), found values between 40.26º and 51º for the same variable, which are close to the values described in this study.

The hLH and hMH variables showed significant differences between the time – points (P<0.001), and for both, only M0 differed from the other time – points (Table 1). In a work carried out by Schade *et al*. (2012), in horses used for traction, considerably different means were observed. The values found were between 3.01 and 3.51cm, and between 3.02 and 3.5cm for hLH and hMH, respectively. This difference is due to the more abrasive aspect of the concrete terrain on which the individuals were kept. In a study whose objective was to compare changes in the forelimbs hooves of horses submitted to two different surgical techniques, Hussni *et al*. (2015) obtained general values between 3.8 and 4.6cm for the heels, values that were also found slightly below the averages obtained in the present work. Souza *et al*. (2016), described higher values than those described here, between 4.51 and 5.57cm for hMH and between 4.55 and 5.59 for hLH. Based on the means of the limbs at different time – points, is possible to claim that there was no asymmetry between the hMH and hLH of the corneal case, since the imbalance is considered when the difference is above half a centimeter (O'Grady and Poupard, 2003).

Among the measured variables of the frog (Lf and Wf), only Lf showed significant differences (P = 0.021), observed between time – points M0 and M14A, M14B and M30 (Table 1). The values described were very close to those observed by Nicoletti *et al*. (2000), Schade *et al*. (2012) and Souza *et al*. (2016), whose values were between 7.81 and 7.87, 8, 59 and 8.66 and between 7.6 and 9.02 centimeters, respectively.

Wh and Lh showed significant differences (P<0.001), both between all time – points. In relation to Wh, after M0 there was a significant decrease that remains until M15, but in M30 it did not exist (Table 1). The values found are similar to those described by Nicoletti *et al*. (2000) (11.08 and 11.12 cm), Schade *et al*. (2012) (12.09 and 12.1 cm) and Hussni *et al*. (2015) (11.9 and 12.4 cm).

The Lh, after the clamping of the forceps (M14B) there was a significant decrease in the measure that remains until M45 (Table 1). If the means before the interventions on the hoofs are considered, the values obtained in this work (Table 1) are slightly above the values described by Nicoletti *et al*. (2000), Schade *et al*. (2012) and Souza *et al*. (2016) whose values were 13.01, 12.85±1.20 and 12.91±0.68, respectively.

The trimming performed did not promote differences in the distal joint angles. This is because the procedure in question did not influence the αT to the point of changing the αMCFJ, αPIJ and αDIJ.

The cinematography of the walk of all individuals at all time – points showed the characteristic sequence of the gait described in the literature (Hussni *et al*., 1996), which consists of eight support moments (Fig. 5), as well as a symmetrical gait and of low speed, whose average speed was 1.576, 1.507, 1.510, 1.529, 1.507 and 1.529, meters per second in M0, M14A, M14B, M15, M30 and M45, respectively.

The cinematographic analysis of the trot showed at M0, the characteristic sequence of the movement described in the literature (Hussni *et al*., 1996) for all animals, which consists of bipedal diagonal supports alternating with moments of suspension (Fig.3). The average speed during the trot was 3.021, 3.096, 3.080, 3.019, 3.083 and 3.276 at M0, M14A, M14B, M15, M30 and M45, respectively. However, from M0 onwards three changes not characteristic of the gait.

Table 1. Means of measurements obtained from the hoof on both forelimbs of seven animals whose differences were statistically significant ($p<0.05$), at different time - points of the experiment. Different lowercase letters in different rows represent statistical differences ($p<0.05$) between different time - points, and different uppercase letters in the same row and in different columns represent statistical difference between the right and left members at different time - points

Hoof measurements	Time-points	Members	
		Right	Left
Toe length (T)	M0	8.157^{a}	8.257^{a}
	M14A	7.671^{a}	7.700^{a}
	M14B	6.314^{b}	6.286^{b}
	M15	6.314^{b}	6.286^{b}
	M30	6.700^{b}	6.771^{b}
	M45	6.686^{b}	6.514^{b}
Toe angle (AT)	M0	49.857°^{b}	41.971°^{b}
	M14A	47.714°^{ab}	49.571°^{ab}
	M14B	48.571°^{ab}	48.429°^{ab}
	M15	48.571°^{ab}	48.429°^{ab}
	M30	53.143°^{ab}	52.143°^{ab}
	M45	54°^{a}	54.143°^{a}
Lateral heel angle (αLH)	M0	40.857°^{bA}	40.857°^{A}
	M14A	44.857°^{abA}	42.286°^{B}
	M14B	46.143°^{abA}	42.714°^{B}
	M15	46.857°^{aA}	42.857°^{B}
	M30	45.571°^{abA}	42.714°^{B}
	M45	45.571°^{abA}	45.571°^{A}
Medial heel angle (αMH)	M0	40.714°	41.714°
	M14A	42.857°	42.714°
	M14B	43.286°	44.429°
	M15	43.429°	44.714°
	M30	42.714°	45.143°
	M45	42.143°	42.429°
Medial heel height (hMH)	M0	5.043^{a}	5.086^{a}
	M14A	4.271^{b}	4.114^{b}
	M14B	4.271^{b}	4.114^{b}
	M15	4.271^{b}	4.114^{b}
	M30	4.286^{b}	4.129^{b}
	M45	4.143^{b}	3.857^{b}
Lateral heel height (hLH)	M0	5.129^{a}	5.114^{a}
	M14A	4.329^{b}	4.129^{b}
	M14B	4.329^{b}	4.129^{b}
	M15	4.329^{b}	4.129^{b}
	M30	4.386^{b}	4.143^{b}
	M45	4.114^{b}	3.957^{b}
Frog length (Lf)	M0	8.129^{a}	8.143^{a}
	M14A	7.629^{b}	7.557^{b}
	M14B	7.629^{b}	7.557^{b}
	M15	7.629^{b}	7.557^{b}
	M30	7.757^{ab}	7.629^{ab}
	M45	7.643^{ab}	7.671^{ab}
Hooves width (Wh)	M0	11.400^{a}	11.529^{a}
	M14A	11.100^{b}	11.129^{b}
	M14B	11.100^{b}	11.129^{b}
	M15	11.100^{b}	11.129^{b}
	M30	11.157^{a}	11.329^{a}
	M45	11.371^{ab}	11.443^{ab}
Hooves length (Lh)	M0	14.171^{a}	14.214^{a}
	M14A	13.757^{a}	13.786^{a}
	M14B	12.629^{b}	12.543^{b}
	M15	12.629^{b}	12.543^{b}
	M30	12.771^{b}	12.829^{b}
	M45	12.900^{b}	12.957^{b}

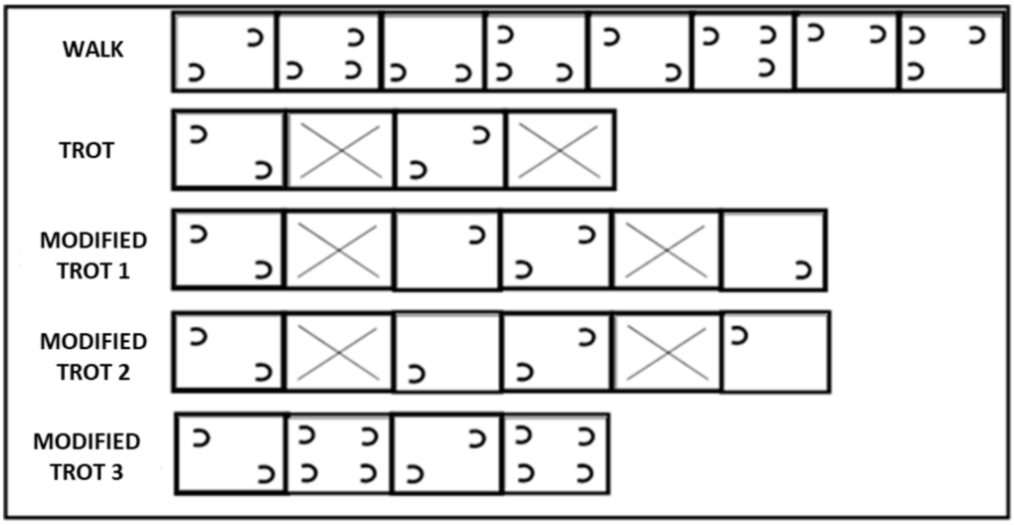

Figure 5. Demonstrative diagram of the support sequence of the walk and trot movements with their modifications presented by the animals at different time - points. Walk – presented by all animals at all time - points; Trot – presented by all animals at the initial.

The first modification of trot (Fig.5) is presented by animal 3 in M14B, animal 5 in M15 and M30, animal 6 in M14A and 45 and animal 7 in M14B and 30. The change consists of the appearance of a left anterior monopedal support (LAMs) moment immediately before of the left diagonal bipedal support (LDBs) and right anterior monopedal support (RAMs) immediately before the right diagonal bipedal support (RDBs). Associated with the trot modification, there is a decrease in the TTS remaining in both diagonal bipedal supports (Table 2).

Table 2. Permanence time in seconds at different support moments of animals 3 in M0 and M14B, 5 in M0, M15 and M30, 6 in M0, M14A and M45 and 7 in M0, M14B and M30. RDBs = right diagonal bipedal; SUS = suspension; LAMs = left anterior monopedal; LDBs = left diagonal bipedal; RAMs = right anterior monopedal

Animals	Time – points	Time in seconds stayed in the respective support moments					
		RDBs	SUS	LAMs	LDBs	SUS	RAMs
3	M0	0.3	0.03	0	0.3	0.03	0
3	M14B	0.27	0.03	0.03	0.27	0.03	0.03
5	M0	0.3	0.03	0	0.3	0.03	0
5	M15	0.24	0.03	0.03	0.24	0.03	0.03
5	M30	0.24	0.03	0.03	0.24	0.03	0.03
6	M0	0.27	0.03	0	0.27	0.03	0
6	M14A	0.24	0.03	0.06	0.24	0.03	0.06
6	M45	0.27	0.03	0.03	0.27	0.03	0.03
7	M0	0.27	0.03	0	0.27	0.03	0
7	M14B	0.24	0.03	0.03	0.24	0.03	0.03
7	M30	0.24	0.03	0.03	0.24	0.03	0.03

The second modification of the trot (Fig.5) is presented by animal 1 in M15 and by animal 5 in M14B and consists of the right posterior monopedal support (RPMs) before the left diagonal bipedal (LDBs) and left posterior monopedal (LPMs) before the right diagonal bipedal (RDBs). Differently from what happens with the animals that presented the modified trot 1, the animals that presented the modified trot 2 show the emergence of a monopedal moment without other supports reducing their respective permanence times. Both animal 1 in M15 and animal 5 in M14B had a decrease in the TTS remaining in both diagonal bipedal supports (Table 3).

Table 3. Permanence time in seconds at different moments of support of animals 1 in M0 and M15, 5 in M0, M14B. RDB = right diagonal bipedal; SUS = suspension; RPM = right posterior monopedal; LDB = left diagonal bipedal; LPM = left posterior monopedal

Animals	Time – points	Time in seconds stayed in the respective support moments					
		RDBs	SUS	RPMs	LDBs	SUS	LPMs
1	M0	0.27	0.03	0	0.27	0.03	0
1	M15	0.24	0.03	0.03	0.24	0.03	0.03
5	M0	0.3	0.03	0	0.3	0.03	0
5	M14B	0.24	0.03	0.03	0.24	0.03	0.03

The third and last modification of trot (Fig.5) is presented only by animal 7 in M45 and consists of the appearance of quadrupedal support between the right (RDBs) and left (LDBs) diagonal bipedal supports, and the disappearance of the suspension (SUS) moment that characterizes the pace showing a trend of the individual in dissociating the trot in March. Differently from what happened with the animals that developed the modified trots 1 and 2, animal 7 in M45 did not show a decrease in the permanence time in the moments of bipedal support (Table 4).

Table 4. Permanence time in seconds at different moments of support of animal 7 at M0 and M45. RDB = right diagonal bipedal; SUS = suspension; QUA = quadrupedal; LDB = left diagonal bipedal

Animals	Time – points	Time in seconds stayed in the respective support moments					
		RDBs	SUS	QUAs	LDBs	SUS	QUAs
7	M0	0.24	0.03	0	0.24	0.03	0
7	M45	0.24	0	0.03	0.24	0	0.03

The statistical analysis of the TTS maintained in the walk support moments revealed that, between the different time – points, there was a decrease in the time spent in left lateral bipedal support between time – points M0 and M15, a difference that remains in M30 and in M45 no longer exists. At trot, however, there was a decrease, between M0 and M14B, in the time spent in both moments of suspension, a difference that persists only until M15.

There was no difference in the average speed of the route covered by the individuals in any of the gaits.

The modified trots 1, 2 and 3, highlights the importance of considering the horse activities at the time of Tt. Breeds like Mangalarga Marchador and Campolina are typical from Brazil, and are chosen and selected based on their gait, which is called Marcha (Bussiman *et al*., 2020). These breeds are mostly used in competitions in which the execution of the gait is the focus. Using the Tt must be carefully discussed with the owners and trainers before, especially if the technique is performed days before horse events.

CONCLUSION

Trimming with toe reduction in forelimbs of healthy horses promotes significant changes in parameters such as T, αT, αLH, hLH and hLH, Lf, Wh and Lh. However, the dorsal angles of the αMTCJ, αPIJ and αDIJ are not affected. Regarding locomotion, the reduction of the hoof in the toe-heel direction promoted a reduction in the time spent in left lateral bipedal support while walking, as well as the emergence of three variations of trot not described so far in the literature, and increased time for stay in suspension while trotting.

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