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Original

Ultrasonographic evaluation of morphometric measurements of plantar metatarsal tendons and ligaments in Colombian Creole horses

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ABSTRACT

Objective. Determine the morphometric values of the plantar metatarsal tendons and ligaments in clinically healthy animals. **Materials and methods.** Thirty animals were used throughout the study, the plantar metatarsal tendons and ligaments were evaluated starting from the plantaromedial aspect of the proximal region to the insertion of the suspensory branches in the sesamoids bones. The variables to be studied in each structure were cross-sectional area (cm2), lateral medial width (ALM) (cm) and dorsal palmar thickness (EDP) (cm). **Results.** It was found that the structure with the largest area in the proximal regions was the suspensory ligament (0.858 cm^2) followed by the lateral digital flexor (0.759 cm^2), in regions 1B and 2A the largest structure remained the suspensory ligament and in the region 2B, the deep digital flexor tendon was the largest structure (0.804 cm^2). **Conclusions**. The behavior of the variables in the Colombian Creole horse is similar to that reported in the literature and finally the first reference values of morphometric measurements of the tendons and ligaments of the plantar metatarsal in this breed are presented.

Keywords: Metatarsal bones; equine; ultrasonography; orthopedics (*Source: MeSH*).

RESUMEN

Objetivo. Determinar los valores morfométricos de los tendones y ligamentos del metatarso plantar en animales clínicamente sanos. **Materiales y métodos.** 30 animales fueron utilizados a lo largo del estudio, se evaluaron los tendones y ligamentos del metatarso plantar empezando desde el aspecto plantaromedial de la región proximal hasta la inserción de las ramas del suspensorio en los sesamoideos. Las variables a estudiar en cada estructura fueron área transversal (cm^2), ancho latero medial (ALM) (cm) y espesor dorso palmar (EDP) (cm). **Resultados.** Se encontró que la estructura de mayor área en las regiones proximales fue el ligamento suspensorio (0.858 cm^2) seguido del

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Flexor digital lateral (0.759 cm^2), en las regiones 1B y 2A la estructura de mayor tamaño siguió siendo el ligamento suspensorio y en la región 2B el Tendón flexor digital profundo fue la estructura de mayor tamaño (0.804 cm^2). **Conclusiones.** El comportamiento de las variables en el caballo criollo colombiano es similar al reportado por la literatura y finalmente se presentan los primeros valores referentes de medidas morfométricas de los tendones y los ligamentos del metatarso plantar en esta raza.

Palabras clave: Huesos metatarsianos; equino; ultrasonografía; ortopedia (*Fuente: MeSH*).

INTRODUCTION

Ultrasound was first introduced into equine practice at the turn of the previous century in the 1970s, when it was used primarily for the evaluation of the reproductive organs and the cardiovascular system. Over time, its use has expanded to be part of the diagnosis of musculoskeletal injuries, among others (1).

Lameness originating in the suspensory ligament (SL) is a common finding in high performance horses (2). These injuries are a major problem in equine orthopedics (3). Ultrasound is the most widely used technique to evaluate the suspension apparatus (4).

In Colombian Creole horses there are reports of lameness at the level of the hind limbs (5), in addition, there are studies on the normal morphometric measurements of reference in tendons and ligaments of the forelimb (6), but there are no reports on these measures in hind limbs.

Based on the above, the objective of the present study was to evaluate the morphometric values of the plantar metatarsal tendons and ligaments in clinically healthy adult animals.

MATERIALS AND METHODS

Ethical guidelines. The study was endorsed by the ethics committee of the University of Córdoba through resolution 009.

Animals. 30 animals were evaluated throughout the study (16 females and 14 males), with ages ranging between 3 and 15 years, corroborated by dental chronometry (7). The weight of the animals ranged between 285 and 380 kilograms, and the height between 1.28 and 1.46 m at the withers.

The study animals were in good health conditions, all were in training processes and did not report current pathologies in hind limbs. After examination, the locomotor system was evaluated for the presence of inflammation or abnormalities in the region to be studied in order to rule out diseased animals (8).

Preparation of the animals. Sedation was performed prior to work with the horses and 10% xylazine (9) was used (Equitec xylazine 10%). An electric machine (Oster Golden A5, 2000, USA) was used to shave the skin from the heads of the fourth and second metatarsals in the plantar and plantaromedial aspect of the most proximal region (10), and it was continued in the plantar aspect of the cane to the region of the base of the sesamoid bones, in the most distal region the medial and lateral aspects were shaved to be able to evaluate the suspensory branch.

The cane was divided into 5 equal parts (6), marking each point with white watercolor and then the area was washed with soap and water and finally the skin was degreased with antiseptic alcohol.

Ultrasound exam. All ultrasound evaluations were performed with the same rigor and technique as the professional in charge of the images to prevent interoperator variations (11). The images obtained were transversal (dorsal anatomical plane) in the 5 zones (1A,1B,2A,2B,3A), using a portable medical ultrasound machine (SonoEscape Evet2 (2021, Guangdong, China), probe with 4-16 MHz linear frequency and a contact PAD. The first region was delimited from the head of the fourth and second metatarsals (1A), in this area a plantaromedial access was used to be able to evaluate the anatomically correct shape of the origin of the ligament and the structures evaluated, which were: Superficial digital flexor tendon (SDFT), Lateral digital flexor (LDF), Medial digital flexor (MDF) and Suspensory ligament (SL) (11). In the

second region (1B) the SDFT, deep digital flexor tendon (DDFT) and the SL were evaluated. In the third region (2A), SDFT, DDFT and SL were also evaluated. In the fourth zone (2B), the DDFT together with the SDFT was evaluated on the plantar image and the branches of the SL were evaluated individually in the lateral and medial aspects. In the last region (3A), the SL branches on its two sides were evaluated separately (6).

The focus and brightness commands were adjusted and used homogeneously in each image, varying only in the image where the SL branches were evaluated separately (the focus was adjusted to the structure in this image).

Variables. Three variables were measured: Cross-sectional area (CSA) in cm2, which was calculated by delimiting the edges of the structure, the Dorso-Plantar Thickness that was evaluated in centimeters measuring from the most dorsal to the most plantar point of each structure (taking into account that in image 1A the location is modified by the plantaromedial access) and finally the Latero-Medial Width (LM) calculated in centimeters and obtained by measuring from the most lateral point to the most medial point in each of the structures (taking into account that in zone 1A it is modified by the plantaromedial access)(6,10).

Each variable was measured twice and an average of the two values was obtained as final data. If the coefficient of variation was greater than 10%, the measurements were repeated (6).

Statistic analysis. The program (Microsoft Excel) was used where all the data was stored and tabulated, descriptive statistics (mean and standard deviation) were performed on all the variables. Assumptions of normality and homogeneity of variance were validated. Inferential statistics were made using the Kruskall-wallis test for the comparison of measurements (CSA, DP, LM) between structures and zones due to the non-normality of the variables of interest, later Tukey Krammer was used, with the R-project software. (R Core Time, 2020) for all statistical analyses.

RESULTS

It was possible to identify and evaluate the structures proposed in the methodology (Figure 1), taking into account the coefficient of variation, mean and standard deviation (±SD) were obtained in the morphometric measurements by ultrasound in five zones of tendons and metatarsal ligaments in their plantar aspect of the study animals (Table 1).

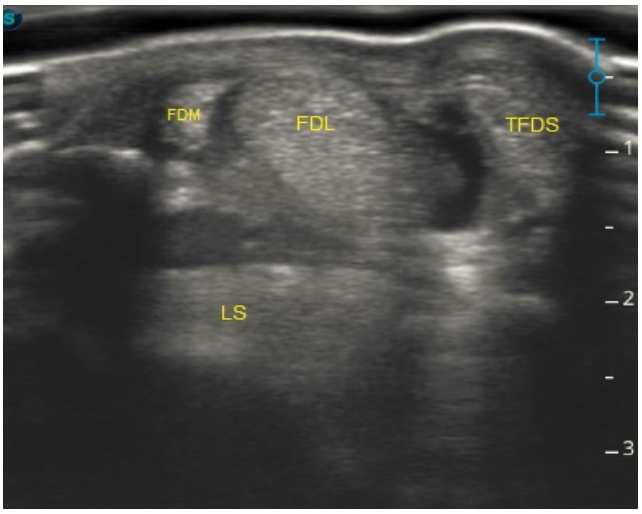

Figure 1. Zone 1A image through ultrasound, plantar metatarsal aspect of a Colombian Creole horse.

Transverse area of the tendons. In zone 1A, it was found that the SL and the LDF were the largest structures, while the MDF was the structure with the smallest area in this zone. The comparison between structures by zone showed notable differences, as can be seen in the table 2. The SL continued to be the structure with the largest size in zone 1B and zone 2A, followed by the deep digital flexor tendon (product of the fusion of the LDF + MDF) and finally the SDFT. In region 2B, the DDFT had a larger area than the SDFT as expected, and from this area the SL was evaluated in the form of branches, where no difference ($p>0.05$) was found between the lateral and medial branches (Table 2) unlike region 3A in which a difference ($p<0.05$) was found between the branches of the SL (SB > MB).

L-M and D-P. The behavior of the DP and LM was similar to the CSA, finding variations between structures in the same area (Table 2) and between areas in the same structure as shown in Table 3. Figures 2,3.4.5.6 show the distribution of the variables in each zone for each structure separately.

Table 1. Mean and standard deviation (± SD) of morphometric measurements by ultrasonography in 5 zones in tendons and ligaments of the metatarsal in its plantar aspect.

Structure	Zone	Left limb			Right member		
		CSA (cm^2)	L-M (cm)	D-P (cm)	CSA (cm^2)	L-M (cm)	D-P (cm)
SDFT	1A	0.340 ± 0.041	0.902 ± 0.128	0.438 ± 0.039	0.326 ± 0.067	0.887 ± 0.128	0.442 ± 0.057
	1B	0.374 ± 0.061	1.063 ± 0.143	0.406 ± 0.056	0.350 ± 0.066	1.031 ± 0.116	0.395 ± 0.050
	2A	0.402 ± 0.065	1.248 ± 0.142	0.350 ± 0.034	0.387 ± 0.067	1.183 ± 0.106	0.336 ± 0.047
	2B	0.447 ± 0.069	1.543 ± 0.097	0.313 ± 0.053	0.444 ± 0.069	1.526 ± 0.154	0.314 ± 0.065
LDF	1A	0.759 ± 0.078	1.203 ± 0.094	0.750 ± 0.084	0.766 ± 0.089	0.772 ± 0.075	1.208 ± 0.082
MDF	1A	0.100 ± 0.020	0.386 ± 0.065	0.282 ± 0.048	0.098 ± 0.015	0.257 ± 0.036	0.402 ± 0.049
DDFT	1B	0.693 ± 0.129	1.005 ± 0.134	0.828 ± 0.074	0.665 ± 0.124	0.804 ± 0.075	0.956 ± 0.135
	2A	0.650 ± 0.108	0.956 ± 0.118	0.796 ± 0.087	0.647 ± 0.080	0.908 ± 0.126	0.813 ± 0.088
	2B	0.804 ± 0.088	1.129 ± 0.096	0.816 ± 0.067	0.766 ± 0.093	1.126 ± 0.084	0.804 ± 0.069
SL	1A	0.858 ± 0.116	1.212 ± 0.147	0.733 ± 0.087	0.909 ± 0.160	1.125 ± 0.216	0.767 ± 0.089
	1B	0.815 ± 0.152	1.105 ± 0.172	0.781 ± 0.094	0.794 ± 0.107	1.062 ± 0.117	0.782 ± 0.062
	2A	0.751 ± 0.106	1.067 ± 0.122	0.729 ± 0.095	0.721 ± 0.088	1.082 ± 0.128	0.705 ± 0.070
MB	2B	0.330 ± 0.060	0.484 ± 0.066	0.737 ± 0.112	0.341 ± 0.063	0.488 ± 0.063	0.779 ± 0.077
	3A	0.348 ± 0.048	0.468 ± 0.065	0.798 ± 0.074	0.354 ± 0.065	0.497 ± 0.069	0.789 ± 0.089
LB	2B	0.362 ± 0.057	0.500 ± 0.053	0.808 ± 0.089	0.364 ± 0.057	0.487 ± 0.066	0.797 ± 0.089
	3A	0.369 ± 0.055	0.509 ± 0.049	0.809 ± 0.077	0.382 ± 0.060	0.521 ± 0.072	0.806 ± 0.106

S.D.F.T: superficial digital flexor tendon, D.D.F.T: deep digital flexor tendon, S.L: suspensory ligament, M.B: medial branch of the suspensory ligament, L.B: lateral branch of the suspensory ligament.
CSA: cross-sectional area, L-M: latero-medial width, D-P: dorso-palmar width

Table 2. Comparison (difference in means) of the morphometric measurements by ultrasonography between the tendon and ligament structures of the metatarsal in its plantar aspect in 30 Colombian Criollo Horses.

Zones	Structures	Compared Structures	CSA (cm^2)	L-M (cm)	D-P (cm)
1A	SDFT	LDF	< 0.001 ***	< 0.001***	< 0.001 ***
		MDF	< 0.001***	< 0.001***	< 0.001 ***
		SL	< 0.001***	< 0.001 ***	< 0.001 ***
	LDF	MDF	< 0.001***	< 0.001***	< 0.001 ***
		SL	< 0.001***	0.594	0.806
	MDF	SL	< 0.001***	< 0.001 ***	< 0.001 ***
1B	SDFT	DDFT	< 0.001 ***	0.023*	< 0.001 ***
		SL	< 0.001 ***	0.312	< 0.001 ***
	DDFT	SL	< 0.001 ***	< 0.001 ***	< 0.001 ***
2A	SDFT	DDFT	< 0.001 ***	< 0.001 ***	< 0.001 ***
		SL	< 0.001 ***	< 0.001 ***	< 0.001 ***
	DDFT	SL	< 0.001 ***	< 0.001 ***	< 0.001 ***
2B	SDFT	DDFT	< 0.001 ***	< 0.001 ***	< 0.001 ***
		MBSL	< 0.001 ***	< 0.001 ***	< 0.001 ***
		LBSL	< 0.001 ***	< 0.001 ***	< 0.001 ***
	DDFT	MBSL	< 0.001 ***	< 0.001 ***	< 0.001 ***
		LBSL	< 0.001 ***	< 0.001 ***	< 0.001 ***
	MBSL	LBSL	0.154	0.973	0.242
3A	MBSL	LBSL	0.016*	0.006**	0.2312

S.D.F.T: superficial digital flexor tendon, D.D.F.T: deep digital flexor tendon, S.L: Suspensory ligament, M.B.S.L: Medial branch of the suspensory ligament, L.B.S.L: Lateral branch of the suspensory ligament CSA: cross-sectional area, L-M: latero-medial width, D-P: back-palm width
*= p< 0.05, **= p<0.01, ***= p<0.001.

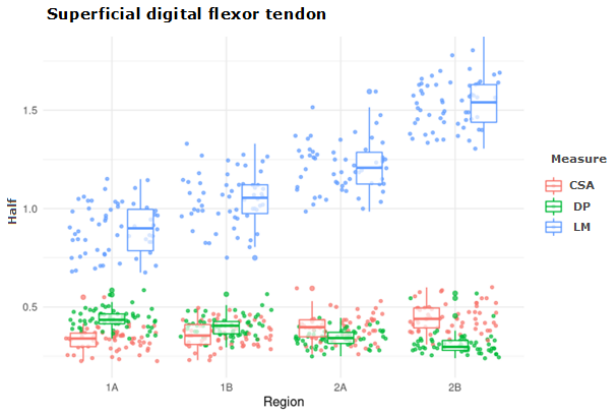

Figure 2. Mean values for ultrasonography of the SDFT in the plantar aspect of the metatarsal in zones (1A to 2B) of 30 CCC. CSA: cross-sectional area (cm2), D-P: dorsal-plantar thickness (cm) and L-M: latero-medial width (cm).

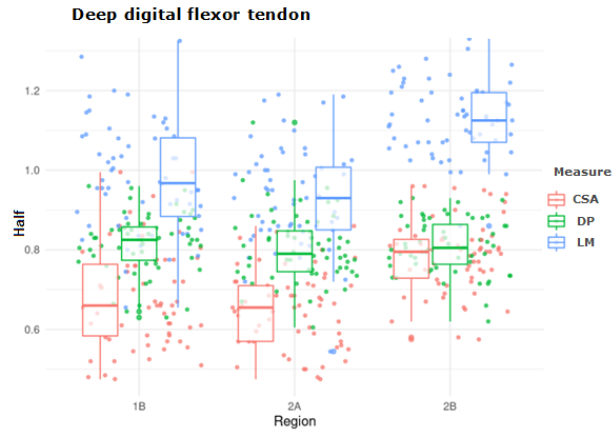

Figure 3. Mean values by ultrasonography of the DDFT in the plantar aspect of the metatarsal in the zones (1B-2A and 2B) of 30 CCC. CSA: cross-sectional area (cm2), D-P: dorsal-plantar thickness (cm) and L-M: latero-medial width (cm).

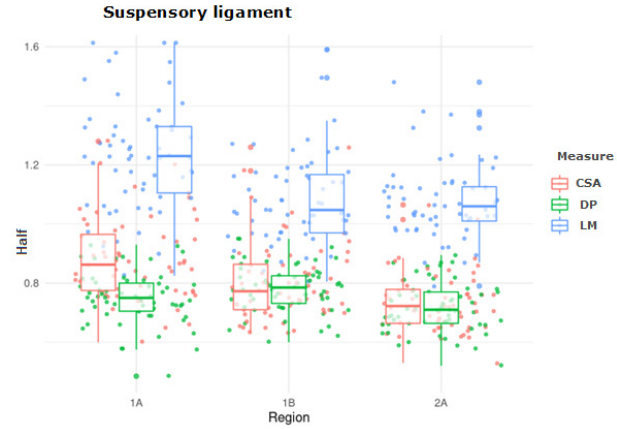

Figure 4. Ultrasonography means values of the SL in the plantar aspect of the metatarsal in zones (1A, 1B and 2A) of 30 CCC. CSA: cross-sectional area (cm2), D-P: dorsal-plantar thickness (cm) and L-M: latero-medial width (cm).

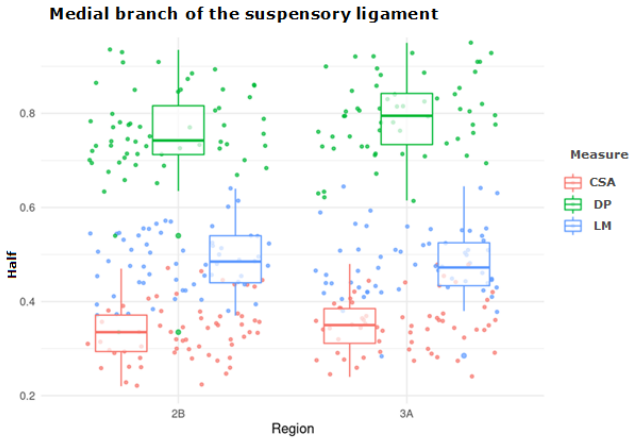

Figure 5. Mean values by ultrasonography of the medial branch of the suspensory ligament of the metatarsal region (2B and 3A) of 30 CCC. CSA: cross-sectional area (cm2), DP: dorsal-plantar thickness (cm) and L-M: latero-medial width (cm).

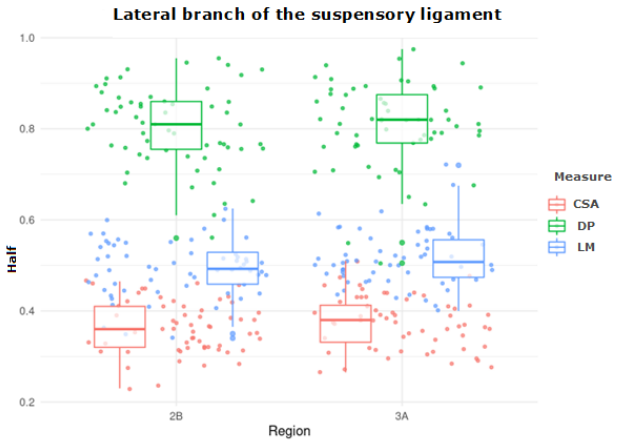

Figura 6. Mean valúes by ultrasonography of the lateral branch of the SL in the plantar aspect of the metatarsal (2B and 3A) of 30 CCC. CSA: cross-sectional area, D-P: dorsal-plantar thickness and L-M: latero-medial width.

Taking into account the factors that had a statistically significant influence $p<0.05$ (structure and area), the Confidence Intervals were constructed, as can be seen in Table 4.

Table 3. Comparison (difference in means) of the morphometric measurements by ultrasonography between areas of tendons and ligaments of the metatarsal in its plantar aspect of 30 Colombian Creole Horses.

Structure	Zone	Compared Structures	CSA	L-M	D-P
SDFT	1A	1B	0.0631	< 0.001***	< 0.001 ***
		2A	< 0.001***	< 0.001 ***	< 0.001 ***
		2B	< 0.001***	< 0.001***	< 0.001***
	1B	2A	0.0290*	< 0.001 ***	< 0.001***
		2B	< 0.001***	< 0.001***	< 0.001***
	2A	2B	< 0.001***	< 0.001***	0.0084**
DDFT	1B	2A	0.255	0.0653	0.262
		2B	< 0.001***	< 0.001***	< 0.001***
	2A	2B	< 0.001***	< 0.001***	< 0.001***
SL	1A	1B	0.001**	< 0.001***	0.105
		2A	< 0.001***	< 0.001***	0.085
	1B	2A	0.008**	0.941	< 0.001***
MBSL	2B	3A	0.155	0.638	0.027*
LBSL	2B	3A	0.273	0.117	0.588

S.D.F.T: superficial digital flexor tendon, D.D.F.T: deep digital flexor tendon, S.L: suspensory ligament, M.B.S.L: medial branch of the suspensory ligament, L.B.S.L: lateral branch of the suspensory ligament
CSA: cross-sectional area, L-M: latero-medial width, D-P: dorso-palmar width.
*= p< 0.05, **= p<0.01, ***= p<0.001.

Table 4. Confidence intervals of 95% of the morphometric measurements by ultrasonography in 5 zones of tendons and ligaments of the metatarsal in its plantar aspect in the Colombian Criollo Horse.

Structure	Zone	Left			Right		
		CSA (cm^2)	L-M (cm)	D-P (cm)	CSA (cm^2)	L-M (cm)	D-P (cm)
SDFT	1A	0.301 – 0.355	0.854 – 0.950	0.424 – 0.453	0.301 – 0.351	0.839 – 0.935	0.420 - 0.463
	1B	0.351 – 0.397	1.010 – 1.120	0.384 – 0.427	0.326 – 0.375	0.988 – 1.070	0.376 – 0.414
	2A	0.377 – 0.426	1.190 – 1.300	0.337 – 0.362	0.362 – 0.412	1.140 – 1.220	0.319 – 0.354
	2B	0.421 – 0.472	1.510- 1.580	0.293-0.332	0.418 – 0.469	1.470 – 1.580	0.290 – 0.338
LDF	1A	0.730-0.788	1.170 – 1.240	0.719 – 0.782	0.732 – 0.799	1.180 – 1.240	0.744 – 0.800
MDF	1A	0.092- 0.108	0.362 – 0.411	0.264 – 0.301	0.092 – 0.104	0.383 – 0.420	0.243 – 0.270
DDFT	1B	0.645 – 0.741	0.955– 1.050	0.800 – 0.586	0.618 – 0.711	0.905 – 1.010	0.775 – 0.832
	2A	0.609 - 0.690	0.912 – 1.000	0.763 – 0.828	0.617 – 0.677	0.860 – 0.955	0.781 – 0.846
	2B	0.771 – 0.837	1.090 – 1.170	0.791 – 0.842	0.731– 0.801	1.090 – 1.160	0.778 – 0.830
SL	1A	0.814 – 0.901	1.160 – 1.270	0.701 – 0.766	0.850 – 0.969	1.170 – 1.340	0.733 – 0.800
	1B	0.758 – 0.872	1.040 – 1.170	0.746 – 0.816	0.754 – 0.834	1.020 – 1.110	0.758 – 0.805
	2A	0.711 – 0.790	1.020 – 1.110	0.694 – 0.764	0.688 – 0.754	1.030 – 1.130	0.679 – 0.731
MB	2B	0.308 – 0.352	0.459 – 0.509	0.695 – 0.778	0.318 – 0.365	0.465 – 0.512	0.750 – 0.808
	3A	0.330 – 0.366	0.444 – 0.493	0.770 – 0.826	0.329 – 0.378	0.471 – 0.523	0.756 – 0.822
LB	2B	0.341 – 0.383	0.480 – 0.520	0.774 – 0.841	0.343 – 0.385	0.462 – 0.511	0.763 – 0.830
	3A	0.348 – 0.389	0.491 – 0.528	0.780 – 0.838	0.360 – 0.405	0.494 – 0.548	0.766 – 0.845

S.D.F.T: superficial digital flexor tendon, D.D.F.T: deep digital flexor tendon, S.L: suspensory ligament, M.B: medial branch of the suspensory ligament, L.B: lateral branch of the suspensory ligament
A-T: cross-sectional area, L-M: latero-medial width, DP: dorso-palmar width

DISCUSSION

This is the first report made in Colombia of measurements in the tendons and ligaments of the plantar metatarsus of Colombian Creole horses.

Injuries of the proximal origin of the suspensory ligament are more common in hind limbs than is believed (12), the authors in said study evaluated the functionality during jogging of the suspensory ligament according to the absorption of forces, where significant differences were found between the healthy groups and the group with pathology of the proximal region of the SL, which proves the importance of this study since it provides reference values for monitoring the health of the suspensory ligament and thus avoid reaching clinical presentations of pathologies in this structure that obviously decreases the performance of the animals.

Reyes et al (6), reported reference values in the group of homologous tendons and ligaments in the thoracic limb in Colombian Creole horses (6). When analyzing the relationship that exists between the different structures evaluated by zone, it was found that the SL is the structure with the largest size in most of the zones together with the deep digital flexor tendon. It should be noted that in the hind limbs the digital flexor deep in zone 1A is still divided into medial digital flexor and lateral digital flexor.

Reyes et al (6), in their article, concluded that the branches of the suspensory ligament presented very similar values in the measurements, which agrees with the present study where the branches of the suspensory ligament did not present evident differences in terms of their size, It should be noted that the reference study is in forelimbs and there are no references to a study in hind limbs for the Colombian Creole horse (6).

In the specific case of region 3A, there was a statistically significant difference p=0.016, between the lateral and medial branches, with the lateral branch having the largest area only in this area. Despite this difference, it does not constitute a significant effect when analyzing the data, therefore, it is a finding that may be related to taking the measurements, taking into account that the location of the sonographer is always on the side of the limb and this makes it difficult in some cases to take the measurement of the medial branch since Colombian Creole horses are difficult to handle animals. Given the above, It is necessary to clarify that the size of the branches in the different segments does not undergo clinically significant variations since the variation found in a specific region is attributed more to the technique in taking the images due to the type of access and the temperament of the patients. study animals.

According to Rabba et al (13), in Quarter Horses, a study was conducted in clinically healthy animals (without lameness), where the branches of the suspensory ligament were evaluated, finding ultrasound abnormalities in B-mode and power Doppler in 20.8% of the animals. study animals, in addition to other reports of this condition mentioned by the authors (13). What is consistent in the present study, only clinically healthy animals were evaluated, however, no evident ultrasound lesions were found in B mode, except for 2 animals in which apparent lesions could be identified in the branches of the suspensory ligament, so not this structure was included. It should be noted that, despite the evidence of some injury to the branches, As there is no acute inflammation process, there will be no increase in the area of the tendon or increase in blood flow, therefore, there will be no pain or lameness in animals with this condition, although it would be important in these cases to use the power doopler tool to determine if it is an active process. For the authors, the use of Doppler as a tool to study the locomotor system in Colombian Creole horses could play a very important role in the future.

In conclusion, the study of the morphometric parameters is important for each breed, in Colombian Creole horses the measurements in the plantar metatarsal tendons and ligaments have a normal distribution and similar to that reported by the literature. Therefore, when evaluating these structures, it is important to have the reference values according to the area and structure evaluated, making this study a reference model in the daily clinic of the high-performance equine in Colombia for the comparison of the measurements and the diagnosis of possible injuries.

The authors recommend future research in this breed, where there is a high casuistry of locomotor pathologies, especially in hind limbs, and so on; the use of new tools such as doppler or magnetic resonance, which would be of great help for the development of equine veterinary medicine in Colombia.

Conflict of interests

The authors declare that there is no conflict of interest in this study.

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