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Original

Ultrasonographic determination of anatomical measurements of tendinous structures and palmar metacarpals ligaments in Colombian Creole donkeys

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ABSTRACT

Objective. To provide reference values for anatomical measurements of tendinous structures and metacarpal ligaments in Colombian Creole donkeys using ultrasonography as a measurement tool. **Materials and methods**. Ultrasonographic examination of the tendons and ligaments of the palmar metacarpal region of limbs was performed in 15 clinically healthy donkeys. The variables to be measured were: cross-sectional area (cm2), lateral medial width (ALM) (cm) and dorsal palmar thickness (EDP) (cm). **Results.** It was found that there is no difference in the measurements between the two members or in relation to sex. In addition, it was found that the structure with the largest area in the proximal areas (1A and 1B) was the suspensory ligament (0.548 cm2), and in the distal ones (2A and 2B) the deep digital flexor tendon (0.468 cm2). **Conclusions.** Anatomical measurements of the tendinous structures and the palmar metacarpal ligaments in Colombian Creole donkeys are similar to those found in the international literature. Reference values for anatomical (morphometric) measurements of palmar metacarpal tendons and ligaments in Colombian Creole donkeys were presented.

Keywords: Equidae; ultrasonography; orthopedics; metacarpus; body weights and measurements; anatomy (*Source: MeSH*).

RESUMEN

Objetivo. Proveer valores de referencia de medidas anatómicas de estructuras tendinosas y ligamentos metacarpales en burros criollos colombianos utilizando la ultrasonografía como herramienta de medición. **Materiales y métodos.** Se realizó la exploración ultrasonográfica de los tendones y ligamentos de la región metacarpiana palmar de ambos miembros en 15 burros clínicamente sanos. Las variables a medir fueron: área transversal (cm^2), ancho latero medial (ALM) (cm) y espesor dorso palmar (EDP) (cm). **Resultados.** Se encontró que no existe diferencia en las medidas entre

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los dos miembros ni en función del sexo. Además se encontró que la estructura de mayor área en las zonas proximales (1A y 1B) fue el ligamento suspensorio (0.548 cm^2), y en las distales (2A y 2B) el tendón flexor digital profundo (0.468 cm^2). **Conclusiones.** Las medidas anatómicas de las estructuras tendinosas y de los ligamentos metacarpales palmares en burros criollos colombianos son similares a las encontradas en la literatura internacional. Se presentaron los valores de referencia para las medidas anatómicas (morfométricas) de tendones y ligamentos metacarpales palmares en burros criollos colombianos.

Palabras clave: Equidae; ultrasonografía; ortopedia; metacarpo; pesos corporales y medidas; anatomía (Fuente: *MeSH*).

INTRODUCTION

The domestic donkey is a species derived from the African wild ass which survived in semi-arid and mountainous environments with scarce food sources and intermittent access to water. Domesticated only for approximately 5.000 years, the donkey has been and still is used for draft and production, as well as working and living alongside humans around the world (1). Lameness caused by diseases or injuries of the locomotor system is the main cause of inactivity in working donkeys; Lameness typically results from pain associated with abnormalities in the musculoskeletal system including joints, bones, tendons, ligaments, and muscles (2).

There are reports of the use of ultrasonography as a diagnostic aid in donkey medicine, such as ultrasound of the reproductive system (3), ultrasound of the ocular system (4), and ultrasound of the musculoskeletal system (5). Ultrasonography is a medical technique that was introduced to horses with great success. This technique was used for the first time and reported by Rantanen in 1982 (6) and there are currently reports of its use in donkey tendons and ligaments (7,8).

In the Colombian Creole donkey, some studies have been carried out in relation to blood and nutritional parameters (9,10), but there are no references of anatomical values of metacarpal tendons and ligaments in this breed. The main objective of this research is to provide reference values for anatomical measurements of tendon structures and metacarpal ligaments in Colombian Creole donkeys using ultrasonography as a measurement tool.

MATERIALS AND METHODS

Ethical guidelines. This study was endorsed by the Ethics Committee of the Faculty of Veterinary Medicine and Zootechnics of the University of Córdoba (Colombia) with resolution No. 008.

Animals. 15 Colombian Creole donkeys, 5 males and 10 females, clinically healthy, without any evident gait alteration, were used in the study. Their age ranged between 3 and 16 years, which was determined by dental chronometry (11). The weight of the animals was in the range of 155-244 kg, and was calculated using the formula: (Weight (kg) =0.000252 * height 0.24 * thoracic perimeter 2.575) (12).

The height of the animals was between 1.04–1.17 m at the withers and the BMI was calculated with the following formula: (Weight (kg) / [Height at the withers (m)]2) (13).

The animals were clinically evaluated before taking measurements, confirming that they did not present obvious gait alterations, as well as no disease that could affect the study.

Animals preparation. A trichotomy was performed between the distal aspect of the accessory carpal bone (os carpis accesorium) and the apex of the sesamoid bones with an Oster A5 electronic machine (USA, 2000). Similarly, the lateral and medial area proximal to the fetlock was shaved for evaluation of the branches of the suspensory ligament. The region was measured from the accessory carpal bone to the apex of the proximal sesamoids and divided into 4 equal parts (1A, 1B, 2A and 2B), adapting the procedure previously applied in the equine metacarpus (14). The total value of the cane measurement was divided into 4 and from the

distal aspect of the carpal accessory, the areas to be studied were marked with white watercolor on the lateropalmar aspect (14). Finally, before starting the ultrasound examination, the animals were sedated with xylazine at a concentration of 10% (Erma, Colombia), using 5 ml disposable syringes and 21 Gauje needles. All animals were supporting their weight evenly on all 4 limbs.

Ultrasound evaluation. The study area was washed with soap and then alcohol was applied to degrease the skin, and finally ultrasound gel to improve acoustic coupling (13). All ultrasound examinations were performed by the same operator, to avoid inter-operator variability, and the equipment configuration was the same in all cases (15). The equipment used was a SonoEscape Evet 2 medical ultrasound machine (2021, Guangdong, China) with a multifrequency linear ultrasound probe from 4 to 16 MHz and a contact pad. Transverse images of the palmar aspect were taken in regions 1A, 1B, and 2A, while the suspensory ligament branch in 2A and 2B was evaluated in the medial and lateral aspects (14). The following anatomical structures were studied: Superficial digital flexor muscle tendon (SDFT), Deep digital flexor muscle tendon (DDFT), Accessory ligament of TFDP (AL-DDFT) and Suspensory ligament of the fetlock (SL) (7).

Information gathering. Two images were taken in each region for subsequent measurement of the structures with the equipment's software. The two values of each variable in each structure were averaged and the variation coefficient was calculated, which if greater than 10%, the measurement was repeated (14). The variables to study in each structure were: the cross-sectional area (CSA), the dorsopalmar thickness (DP) and the lateral medial width (LM) (13). The CSA was obtained with the area calculation application delimiting all the edges of the structure, the LM by measuring the line between the most lateral and the most medial edge of the structure, and the DP was obtained by tracing the most dorsal point to the most palmar. of each structure.

Statistic analysis. The data was tabulated in Excel spreadsheets (Microssoft Excell 2021). The Wilcoxon signed rank test was used to determine the difference between the 2 members and according to sex for all variables. To determine if there was a difference between the structures in each zone, as well as the same structure between zones, the Kruskal-Wallis test was used, followed by the Tukey-Kramer mean comparison test. The R-project software (R Core Time, 2020) was used for all statistical analyses.

RESULTS

In the different regions, clear ultrasound images were obtained in accordance with the reference literature (Figure 1), as well as the measures initially proposed.

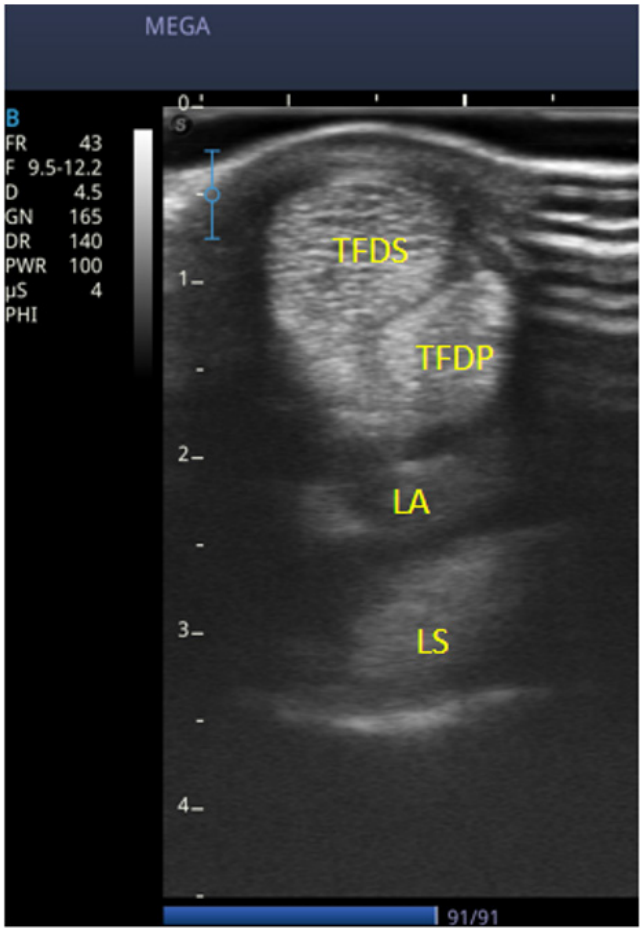

Figure 1. Ultrasound image of zone 1A (palmar aspect) of the metacarpus of a Colombian creole donkey (SDFT: superficial digital flexor muscle tendon; TFDP: deep digital flexor muscle tendon; LA: accessory ligament of the DDFT; LS: suspensory ligament of the fetlock).

Once the data was analyzed, the mean values of the anatomical measurements of the palmar metacarpal tendons and ligaments were obtained in the 15 Colombian Creole donkeys (Table 1).

Table 1. Mean values and standard deviation (±SD) of the ultrasound morphometric values of the tendons and ligaments of the palmar metacarpal region of 15 Colombian Creole donkeys, obtained in the 4 study areas (1A, 1B, 2A and 2B).

Structure	Zone	Left forelimb			Right forelimb		
		CSA (cm^2)	LM (cm)	DP (cm)	CSA (cm^2)	LM (cm)	DP (cm)
SDFT	1A	0.320 ± 0.060	0.771 ± 0.110	0.478 ± 0.068	0.315 ± 0.056	0.773 ± 0.107	0.453 ± 0.099
	1B	0.308 ± 0.049	0.947 ± 0.128	0.352 ± 0.098	0.308 ± 0.038	0.935 ± 0.141	0.360 ± 0.080
	2A	0.347 ± 0.054	1.308 ± 0.116	0.284 ± 0.031	0.348 ± 0.093	1.258 ± 0.169	0.291 ± 0.084
DDFT	1A	0.436 ± 0.070	0.842 ± 0.082	0.558 ± 0.068	0.449 ± 0.075	0.830 ± 0.114	0.570 ± 0.047
	1B	0.380± 0.058	0.684 ± 0.056	0.615 ± 0.074	0.390 ± 0.041	0.732 ± 0.071	0.625 ± 0.059
	2A	0.444 ± 0.056	0.822 ± 0.075	0.607 ± 0.039	0.468 ± 0.068	0.809 ± 0.093	0.623 ± 0.036
AL	1A	0.273 ± 0.046	0.815 ± 0.094	0.385 ± 0.041	0.272 ± 0.065	0.800 ± 0.104	0.383 ± 0.052
	1B	0.170 ± 0.037	0.627 ± 0.074	0.349 ± 0.072	0.176 ± 0.031	0.650 ± 0.681	0.330 ± 0.040
SL	1A	0.522 ± 0.070	0.943 ± 0.108	0.560 ± 0.056	0.548 ± 0.067	0.950 ± 0.099	0.582 ± 0.044
	1B	0.493 ± 0.053	0.850 ± 0.093	0.578 ± 0.058	0.499 ± 0.060	0.885 ± 0.081	0.570 ± 0.043
MB	2A	0.259 ± 0.041	0.425 ± 0.040	0.662 ± 0.075	0.255 ± 0.020	0.409 ± 0.034	0.653 ± 0.085
	2B	0.270 ± 0.030	0.434 ± 0.055	0.666 ± 0.068	0.260 ± 0.025	0.041 ± 0.046	0.656 ± 0.069
LB	2A	0.262 ± 0.022	0.429 ± 0.056	0.673 ± 0.072	0.262 ± 0.028	0.425 ± 0.042	0.700 ± 0.058
	2B	0.274 ± 0.030	0.454 ± 0.048	0.677 ± 0.077	0.274 ± 0.037	0.446 ± 0.037	0.704 ± 0.068

SDFT: Superficial digital flexor tendon, DDFT: Deep digital flexor tendon, AL: Accesory ligament, SL: suspensory ligament of fetlock, MB: Suspensory ligament medial branch, LB: suspensory ligament lateral branch
CSA: Cross sectional área , LM: latero medial width, DP: dorso palmar thickness

Next, the behavior of the variables studied in the 15 animals was analyzed by means of graphs, relating the different study areas. (The graph corresponding to the lateral branch of the suspensory ligament is ignored because there was no statistically significant difference p>0.05 with respect to the medial branch) (Figures 2, 3, 4, 5 and 6).

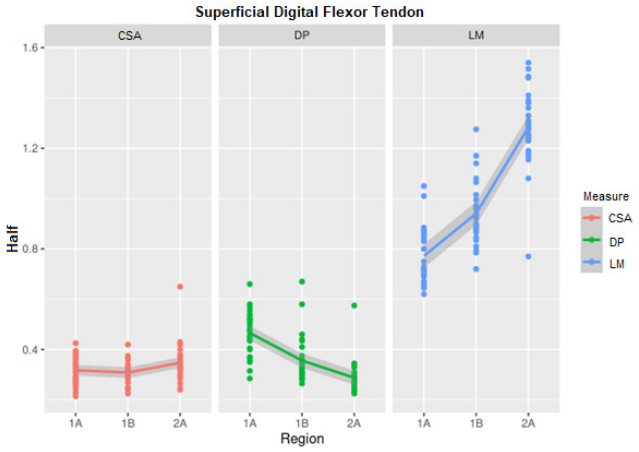

Figure 2. Mean values of the ultrasound measurements of the tendon of the superficial digital flexor muscle of the metacarpal region (1A-2A) of 15 Colombian Creole donkeys. CSA: cross-sectional area, DP: dorsopalmar thickness and LM: lateromedial width.

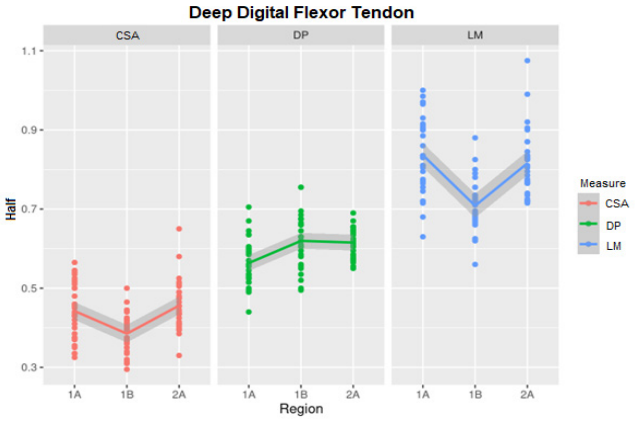

Figure 3. Mean values of the ultrasound measurements of the deep digital flexor muscle tendon of the metacarpal region (1A-2A) of 15 Colombian Creole donkeys. CSA: cross-sectional area, D: dorsopalmar thickness and LM: lateromedial width.

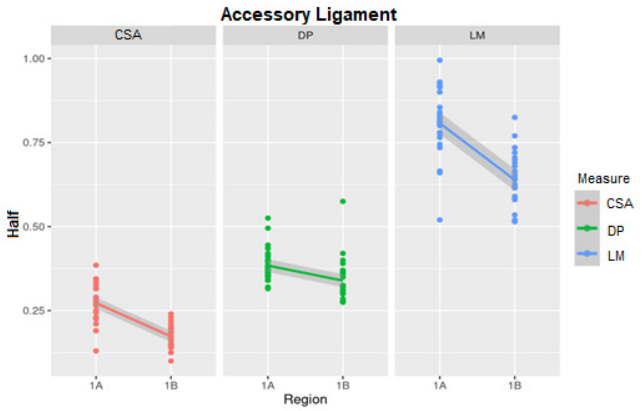

Figure 4. Mean values of the ultrasound measurements of the accessory ligament of the TFDP of the metacarpal region (1A-1B) of 15 Colombian Creole donkeys. CSA: cross-sectional area, DP: dorsopalmar thickness and LM: lateromedial width.

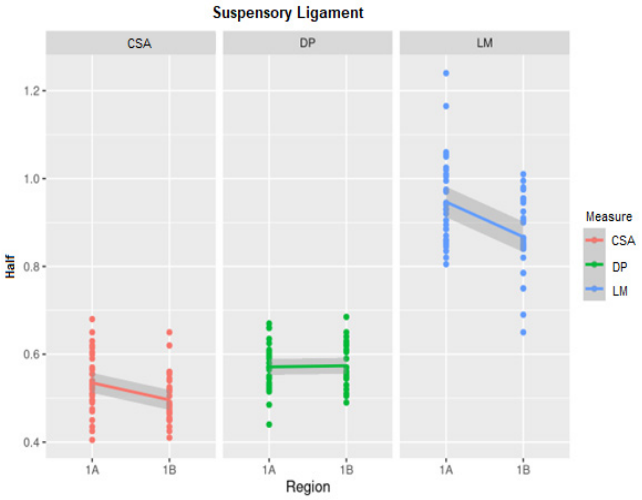

Figure 5. Mean values of the ultrasound measurements of the suspensory ligament of the fetlock of the metacarpal region (1A-1B) of 15 Colombian Creole donkeys. CSA: cross-sectional area, DP: dorsopalmar thickness and LM: lateromedial width.

Comparisons between groups, structures and zones. When comparing the study variables between the left and right limb, no statistically significant evidence was found ($p>0.05$), in the same way when comparing males and females it was determined that there are no significant differences ($p>0.05$) based on sex. When comparing by age group and BMI, no statistically significant difference was found either ($p>0.05$). However, when each area under study was evaluated, statistically significant differences were found between structures (Table 2). And finally, when studying the behavior of the variables of the same structure between the different zones, it was also found that there are statistically significant differences (Table 3).

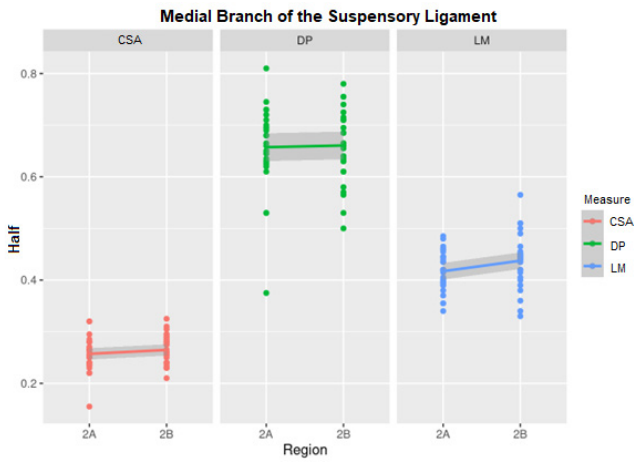

Figure 6. Mean values of the ultrasound measurements of the medial branch of the suspensory ligament (2A-2B) of 15 Colombian Creole donkeys. CSA: cross-sectional area, DP: dorsopalmar thickness and LM: lateromedial width.

by the DDFT, and the smallest structure was the AL followed by the SDFT. In the distal regions (2A and 2B) it was observed that there was no statistically significant difference ($p>0.05$) between the SL branches, as mentioned above. In addition, the structure with the largest size in these areas was the DDFT followed by the SDFT (2A) and finally the branches of the SL.

In relation to the LM, it was found that the structure with a superior lateromedial width in the first proximal zone (1A) was the SL, followed by the DDFT, AL and finally the SDFT. In the second zone (1B), the SDFT was the structure with the greatest width, followed by the SL and DDFT, with the DDFT being the smallest structure in this zone. In the distal regions (2A and 2B), the SDFT was the widest structure, followed by the DDFT and finally the SL branches.

In the proximal zone (1A) the structure with the greatest dorsopalmar thickness was the SL, followed by the DDFT, SDFT and finally the AL; In region 1B, the DDFT was the thickest structure, followed by the SL and the SDFT and finally the AL again. In the most distal regions (2A and 2B) the structures where the greatest thickness was observed were the SL branches, followed by the DDFT and finally the SDFT.

As no statistically significant differences ($p<0.05$) were found in relation to sex, age and BMI, confidence intervals (95% reliability) were issued taking into account the structures, the area and the limb (Table 4).

Table 2. Comparison (mean difference) of the ultrasonographic morphometric measurements between different structures, digital flexor tendons and ligaments of the palmar metacarpal region, in 15 Colombian Creole donkeys.

Zone	Structure	Compared structure	CSA (cm^2)	LM (cm)	DP (cm)
1A	SDFT	DDFT	< 0.001 ***	0.071	< 0.001 ***
		AL	0.034*	0.528	0.026*
		SL	< 0.001 ***	< 0.001 ***	0.002**
	DDFT	AL	< 0.001 ***	0.688	< 0.001 ***
		SL	< 0.001 ***	< 0.001 ***	< 0.001 ***
	AL	SL	< 0.001 ***	< 0.001 ***	< 0.001 ***
1B	SDFT	DDFT	< 0.001 ***	< 0.001 ***	< 0.001 ***
		AL	< 0.001 ***	< 0.001 ***	0.804
		SL	< 0.001 ***	0.016*	< 0.001 ***
	DDFT	AL	< 0.001 ***	0.026*	< 0.001 ***
		SL	< 0.001 ***	< 0.001 ***	< 0.001 ***
	AL	SL	< 0.001 ***	< 0.001 ***	< 0.001 ***
2A	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 ***	0.029*
		LBSL	< 0.001 ***	< 0.001 ***	0.498
	MBSL	LBSL	0.983	0.972	0.621
2B	MBSL	LBSL	0.254	0.311	0.108

SDFT: Superficial digital flexor tendon, DDFT: Deep digital flexor tendon, AL: Accesory ligament, SL: suspensory ligament of fetlock, MB: Suspensory ligament medial branch, LB: suspensory ligament lateral branch
CSA: Cross sectional area, LM: latero medial width, DP: dorso palmar thickness
*= p< 0.05, **= p<0.01, ***= p<0.001.

Table 3. Comparison (mean difference) of the ultrasonographic morphometric measurements between different areas of the digital flexor tendons and ligaments of the palmar metacarpal region in 15 Colombian Creole donkeys.

Structure	Zone	Compared zone	CSA	LM	DP
SDFT	1A	1B	0.823	< 0.001 ***	< 0.001 ***
		2A	0.132	< 0.001 ***	< 0.001 ***
	1B	2A	0.034*	< 0.001 ***	0.003**
DDFT	1A	1B	0.001 **	< 0.001 ***	0.251
		2A	0.662	0.608	0.772
	1B	2A	< 0.001***	< 0.001 ***	0.06
AL	1A	1B	< 0.01***	< 0.001 ***	< 0.001 ***
SL	1A	1B	0.016*	0.006**	0.935
MBSL	2A	2B	0.427	0.074	0.935
LBSL	2A	2B	0.130	0.056	0.824

SDFT: Superficial digital flexor tendon, DDFT: Deep digital flexor tendon, AL: Accesory ligament, SL: suspensory ligament of fetlock, MB: Suspensory ligament medial branch, LB: suspensory ligament lateral branch.
CSA: Cross sectional area, LM: latero medial width, DP: dorso palmar thickness
*= p< 0.05, **= p<0.01, ***= p<0.001

Table 4. Confidence intervals of 95% of the morphometric measurements obtained by ultrasound in four zones of the tendons and digital flexor ligaments of the palmar metacarpal region in 15 Colombian Creole donkeys.

Structure	Zone	Left forelimb			Right forelimb		
		CSA (cm^2)	LM (cm)	DP (cm)	CSA ($cm^{2)}$	LM (cm)	DP (cm)
SDFT	1A	0.287 – 0.353	0.710 – 0.832	0.441 – 0.515	0.248 – 0.346	0.714 – 0.833	0.399 - 0.508
	1B	0.281 – 0.335	0.876 – 1.020	0.298 – 0.407	0.287 – 0.329	0.853 – 1.010	0.315 – 0.404
	2A	0.317 – 0.377	1.240 – 1.370	0.267 – 0.301	0.296 – 0.400	1.160 – 1.350	0.245 – 0.338
DDFT	1A	0.397 – 0.475	0.797 – 0.888	0.520 – 0.596	0.407 – 0.491	0.767 – 0.894	0.543 – 0.596
	1B	0.348 - 0.412	0.653 – 0.715	0.574 – 0.656	0.368 – 0.413	0.693 – 0.772	0.592 – 0.657
	2A	0.413 – 0.475	0.781 – 0.864	0.586 – 0.629	0.431– 0.506	0.757 – 0.861	0.603 – 0.644
AL	1A	0.247 – 0.299	0.763 – 0.867	0.362 – 0.407	0.236– 0.308	0.743 – 0.858	0.354 – 0.412
	1B	0.150 – 0.191	0.586 – 0.668	0.309 – 0.389	0.159 – 0.193	0.606 – 0.695	0.307 – 0.352
SL	1A	0.483 - 0.560	0.883 – 1.000	0.529 – 0.591	0.511 – 0.585	0.895 – 1.010	0.558 – 0.607
	1B	0.464 – 0.522	0.798 – 0.901	0.546 – 0.609	0.465 – 0.532	0.840 – 0.929	0.546 – 0.594
MBSL	2A	0.237 – 0.281	0.403 – 0.447	0.620 – 0.703	0.244 – 0.266	0.390 – 0.428	0.606 – 0.700
	2B	0.252 – 0.287	0.404 – 0.464	0.628 – 0.703	0.246 – 0273	0.416 – 0.466	0.617 – 0.694
LBSL	2A	0.250 – 0.274	0.398 – 0.460	0.633 – 0.712	0.247 – 0.277	0.402 – 0.448	0.668 – 0.732
	2B	0.257 – 0.291	0.427 – 0.480	0.634 – 0.720	0.253 – 0.294	0.425 – 0.466	0.666 – 0.741

SDFT: Superficial digital flexor tendon, DDFT: Deep digital flexor tendon, AL: Accesory ligament, SL: suspensory ligament of fetlock, MB: Suspensory ligament medial branch, LB: suspensory ligament lateral branch
CSA: Cross sectional area, LM: latero medial width, DP: dorso palmar thickness

Analysis of the variables in the different zones. When analyzing the CSA of each structure, it was found that in the most proximal regions (1A and 1B) the largest structure was the SL followed

DISCUSSION

All the ultrasound structures observed at the different levels evaluated agreed with what was previously reported in other breeds of donkeys worldwide (7).

Due to the scarce information related to this topic, it is not easy to compare the measurements of this study with other breeds of donkeys. On the other hand, more information is found in horses, because although it is a different species, it has a very close anatomical relationship. Such is the case of a similar study in Colombian Creole horses (14) where a great similarity in the distribution of structures throughout the zones could be observed.

The variations between structures in each area are as expected, due to the strict relationship that each anatomical structure has with its biomechanical function, in this way it can be concluded that donkeys perform biomechanical tasks very similar to horses. The existence of variations in the same structure throughout the different zones was also to be expected due to the anatomical characterization very well described in donkeys and horses (16), where we can find that the musculoskeletal system between these two species is very similar, but with great exceptions at the hull level.

Nazem et al (7,17) report the presence of a new accessory ligament of the SDFT called the second accessory ligament of the superficial digital flexor tendon in Anatolian donkeys, which differs from what was found in the current study, since it was not evidenced in ultrasound images the presence of this ligament in the Colombian Creole donkeys evaluated. On the other hand, the distribution of other structures along the metacarpus was the same in Anatolian donkeys and in Colombian Creole donkeys.

When comparing the values of the morphometric measurements of Colombian Creole donkeys with Colombian Creole horses (CCC), a certain relationship was found in these measurements. In the proximal regions, it was found that the structure with the largest area was the suspensory ligament, both in Colombian Creole horses and in the study donkeys, but in the distal regions in the donkeys, the structure with the

largest area was the deep digital flexor tendon, which differs from the CCC because in the distal areas of the CCC the structure with the greatest area was the suspensory ligament (14). This variation may be related to the differences in the delimitations of the areas to be studied, since, due to differences in the sizes of the cane between horses and donkeys, these could not be the same.

In the literature there are studies on the anatomical measurements of palmar metacarpal tendons and ligaments in donkeys using the Magnetic Resonance Imaging (MRI) technique (18), where the presence of a new accessory ligament of the SDFT is also reported, in this case on miniature donkeys. This also differs from what was found in our study, where no accessory ligament of the SDFT distal to the carpal tunnel was observed.

As additional information, the authors are concerned about the difficulty encountered in obtaining the animals for the study, which gives an idea of the notable decrease in the population of these animals in the northern region of Colombia.

Due to the scarce availability of information that exists on donkeys at a scientific level, it is advisable to take this type of study as a starting point to know the morphometry of these animals in each region, having clear values and knowledge about this type of animal in for the conservation of the species.

In conclusion, the anatomical measurements of tendinous structures and palmar metacarpal ligaments in Colombian Creole donkeys behave in a similar way to what is found in international literature reports, in addition, there are no differences between both limbs or according to sex. The values presented in this study are of great value since they help professionals in the field to improve the quality of veterinary care in these animals and provide a starting point for future research in the area of this type of animal.

Conflict of interests

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

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