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Research Article

Structural and Functional Properties of the Distal Muscles of Front and Hind Legs of Malakan Horses *(Equus caballus)* [1]

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Abstract

The purpose of this study was to determine the structural and functional properties of the distal muscles of front and hind legs of Malakan Horses. Thus, totally 10 Malakan horses (5 females and 5 males) were used in the study. From front and hind legs of the horses, the findings of totally 28 muscles were received. Accordingly, it is determined that the longest muscle in the distal of the front leg was m. flexor carpi ulnaris, the heaviest one was m. extensor carpi radialis and the muscle with the highest value in terms of parameters of tendon length and total muscle tendon length was m. extensor digitorum communis. From the distal muscles of the hind leg; it is observed that the longest one was m. tibialis cranialis, the heaviest one was m. gastrocnemius and the muscle with the highest value in terms of parameters of tendon length and total muscle tendon length was m. flexor digitorum superficialis. It was observed that while the difference determined between some of the values in the front and hind leg muscles had a statistical significance in the comparison performed between the genders ($P<0.05$), the differences had no statistical significance in the comparison performed based on the direction (right-left).

Keywords: *Muscle, Malakan horse, Tendon, Front and hind leg*

Malakan Atlarında *(Equus caballus)* Ön ve Arka Bacağın Distal'indeki Kasların Yapısal ve Fonksiyonel Özellikleri

Özet

Bu çalışma, Malakan Atlarında ön ve arka bacağın distal'inde bulunan kasların yapısal ve fonksiyonel özelliklerini belirlemek amacıyla yapıldı. Bu amaçla 5 dişi, 5 erkek olmak üzere toplam 10 Malakan Atı kullanıldı. Atların ön ve arka bacağından toplam 28 kasın bulgusu alındı. Buna göre; ön bacağın distal'inde bulunan kaslardan en uzununun m. flexor carpi ulnaris, en ağırının m. extensor carpi radialis, tendo uzunluğu ve toplam kas tendo uzunluğu parametreleri bakımından ise en yüksek değere sahip olan kasın m. extensor digitorum communis olduğu belirlendi. Arka bacağın distal kaslarından en uzun olanın m. tibialis cranialis, en ağır olanın m. gastrocnemius, tendo uzunluğu ve toplam kas-tendo uzunluğu bakımından ise en yüksek değere sahip olan kasın m. flexor digitorum superficialis olduğu görüldü. Cinsiyetler arası yapılan karşılaştırmada ön ve arka bacakta kasların bazı değerleri arasında belirlenen farkın istatistiksel önem taşıdığı belirlenirken ($P<0.05$), yöne (sağ-sol) göre yapılan kıyaslamada farkların istatistiksel anlam taşımadığı tespit edildi.

Anahtar sözcükler: *Kas, Malakan atı, Tendo, Ön ve arka bacak*

INTRODUCTION

Malakan Horse is an endemic horse breed which is raised in the north-eastern regions of Eastern Anatolia, can resist to extreme winter conditions and is used in carriage, draught, and horse riding. Its wide body and thick bone structure are remarkable. Also, the commonly seen types are the ones with black, gray, bay, and red coats [1-3]. There has been a serious literature deficit regarding this horse race in terms of basic sciences, clinical sciences

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and raising, husbandry and feeding in veterinary medicine.

Morphologic structure of the muscle determines its function [4-6]. While the muscle structure may vary between different muscles of the individual [7,8], the same muscles in different individuals can be different in terms of structure [9,10]. Also it is known that exercise [11], genetic structure and gender [12] are effective on the characteristics of the muscle structure. Burkholder [13] also add the muscle fiber volume, physiological characteristics, number of the fibers and their sequence to the factors affecting the structure of the muscle. Regarding the structural and functional properties of the muscles in Equidae family, Brown et al.[7] and Payne et al.[8] conducted a study on horses and Fayed [14] and Demiraslan and Özcan [15] conducted a study on donkeys. Also, the studies conducted on the muscle-tendon structure of four-leg animals is rather important in order to reveal the differences between the functions of front and hind legs [7,8].

The purpose of the study was to determine structural and functional properties of the distal muscles of front and hind legs of Malakan horses which are a native horse breed.

MATERIAL and METHODS

Totally 10 Malakan horses (5 males and 5 females) aged between 5 and 7 years were used in the study. The Malakan horses used had gray (3 males, 1 female), isabella (1 female), bay (2 males, 1 female), and red (2 females) coats. Average live weights of male and female Malakan horses were 314.00±5.47 kg and 287.80±7.69 kg, average cidago height was 142.40±3.04 cm and 138.40±1.14 cm, and average ridge height was 146.20±2.94 cm and 142.40±0.89 cm.

In this study, approval of the ethics committee was taken upon the decision no. 31 dated 20.02.2014 of Atatürk University Animal Experiments Local Ethics Committee regarding the usage of Malakan horses. The animals were taken to deep anesthesia according to the cadaver preparation techniques. Xylazine HCl (8 ml/100 kg, intravenous) and cloralhydrate (20 mg/kg intraperitoneal) were applied for this process [16]. After the blood of the animals taken to deep anesthesia was drained through arteria carotis communis, the front legs were cut from the art. humeri level and the hind legs were cut from the art. coxae level and separated as right and left. Then, in order to reduce the effect of rigor mortis that could occur in the muscles, the legs were kept in extension position in the refrigerator of Kafkas University Faculty of Veterinary Medicine Department of Anatomy at 4°C for 24 h and within 48 h, the distal muscles of the front and hind legs were dissected and required results were taken. In order to determine the study limits, only the distal muscles of the front and hind legs were preferred.

The dissected muscles were subject to a set of measurements and calculations in order to determine the structural and functional properties. For these measurements, Payne et al.[8] and Fayed [14] were taken as a reference. While the structural parameters in the study were determined as muscle length (KU cm), tendon length (TU cm), total muscle-tendon length (TKTU cm), muscle weight (KA g), tendon weight (TA g), total muscle-tendon weight (TKTA g), muscle volume (KH cm^3), tendon volume (TH cm^3), total muscle-tendon volume (TKTH cm^3), pennation angle (PA°), and muscle bundle length (KDU cm), the functional parameters were determined as the physiological cross-sectional area of the muscle (PCSA cm^2), maximum isometric force (FmaxMPa), structural index (AI), tendon cross-sectional area (TCSA cm^2), tendon pressure on the maximum isometric force (TSfmaxMPa) and the percentage of the distention ratio on the tendon pressure (TS%).

Functional parameters were calculated by using the following parameters.

a. PCSA = KH/KDU	d. TCSA = TH/TU
b. Fmax = PCSA x 0.3 MPa	e. TSfmax = Fmax/TCSA
c. AI = KDU/KU	f. TS% = TSfmax/1.5 GPa

While the distal front leg muscles evaluated in the study was examined as m. extensor carpi radialis (ECR), m. extensor digitalis lateralis (EDlat), m. extensor carpi obliquus (OEM), m. flexor carpi radialis (FCR), m. flexor carpi ulnaris (FCU), m. extensor carpi ulnaris (ECU), m. flexor digitorum superficialis (FDS) and mm. interossei (MIO); m. extensor digitorum communis (EDC) was investigated in two parts as superficial head, Thierness (Th) and deep head, Philips (Ph) and mm. flexores digitorum profundii (FDP) was observed in three parts as caput humerale (FDPH), ulnare (FDPU), and radiale (FDPR). While the distal hind leg muscles were examined as m. extensor digitorum longus (EDL), m. extensor digitorum lateralis (EDlat), m. peroneus tertius (PT), m. tibialis cranialis (Tcr), m. soleus (S), m. flexor digitorum superficialis (FDS), m. popliteus (P), m. extensor digitorum brevis (EDB), m. interosseus medius (lig. suspensorium - MIO), m. flexores digitorum profundi (FDP) was examined in three parts as m. flexor digitorum medialis (FDM), m. flexor digitorum lateralis (FDL), m. tibialis caudalis (Tcd) and m. gastrocnemius (G) was examined in two parts as caput lateralis (GL) and caput medialis (GM).

Data obtained from the study were standardized because the horses were at different ages (5-7) and different live weights (CA) [17]. Geometric similarity method was used in the study for standardization [18-20]. According to this method, data were calculated by using the following formulas.

a. KA/CA   b. TA/CA   c. TU/CA   d. KDU/CA   e. PCSA/CA

For the analysis of the descriptive values of the measurements and the calculations obtained from the study according to gender and direction (right/left), 2-t test (P≤0.05), a parametric test, was performed in SPSS statistical package software (16.0 version). In this study, terms in Nomina Anatomica Veterinaria [21] were taken as a basis.

RESULTS

Table 1, 2, 3, and *4* illustrates mean and standard deviation data of structural and functional properties obtained in the study.

Accordingly, it was observed that the muscle with maximum KU value in the front leg distal of Malakan horse was FCU and the muscle with minimum KU value was FDPR. When considered in terms of TU and TKTU parameters, it was observed that EDC had the maximum value. When KDU parameter was observed, it was determined that maximum and minimum values belonged to Th and FDS. ECR had the maximum KA and TKTA values and FDPH had the maximum TA value in the distal muscles of the front leg. When functional muscle properties were considered, it was observed that FDS and Th had the maximum and minimum PCSA and Fmax values in the distal of the front leg. In terms of TCSA, it was considered that the maximum value belonged to MIO. The muscles having the maximum and minimum values in terms of PA were determined as FCU and Th, respectively.

When the structural parameters of the distal muscles of front leg according to the gender were examined, it was found that FCR (12.50-10.13) and ECU (9.25-6.63) in terms of TU, FCU (117.27-85.97), ECU (147.94-113.22) and FDS (109.74-73.92) in terms of KA (g), ECR (15.14-11.36), FCR (2.62-1.55) and FDS (45.99-36.49) in terms of TA (g), FCR (83.69-76.72) in terms of TKTA (g), FCU (110.63-81.11), ECU (139.57-106.81) and FDS (103.53-69.74) in terms of KH (cm³), ECR (13.52-10.15), FCR (2.34-1.38) and FDS (41.06-32.58) in terms of TH (cm³), FCR (78.82-72.29) in

Table 1. *Structural parameters of distal muscle of front leg*
Tablo 1. *Ön bacağın distal kaslarına ait yapısal parametreler*

Muscles		KU (cm)	TU (cm)	TKTU (cm)	KDU (cm)	AI	KA (g)	TA (g)	TKTA (g)	PA (°)	KH (cm³)	TH (cm³)	TKTH (cm³)
ECR	Mean	29.64	15.46	45.10	6.70	0.15	354.18	13.25	367.43	35.80	334.13	11.83	345.96
	SD	1.57	0.82	1.06	1.80	0.04	42.95	2.43	44.47	5.50	34.86	2.17	36.21
OEM	Mean	15.93	10.63	26.55	0.94	0.04	11.93	1.34	13.27	31.30	11.26	1.20	12.45
	SD	2.34	4.08	5.32	0.22	0.01	1.10	0.43	1.21	7.00	1.04	0.39	1.13
FCR	Mean	26.28	11.31	34.21	7.82	0.23	78.12	2.09	80.20	22.00	73.69	1.86	75.55
	SD	1.04	1.67	8.70	1.44	0.13	4.58	0.66	5.09	4.00	4.32	0.59	4.77
FCU	Mean	34.18		34.18	1.69	0.05	101.62		101.62	47.90	95.87		95.87
	SD	1.10		1.10	2.29	0.06	18.40		18.40	2.00	17.36		17.36
ECU	Mean	33.02	8.00	41.02	1.30	0.03	128.18	6.23	134.41	45.40	120.92	5.57	126.49
	SD	1.11	1.55	1.10	1.15	0.03	22.31	5.56	24.98	5.00	21.05	4.96	23.41
EDC	Mean	25.53	45.21	70.74	5.67	0.08	122.04	20.15	142.18	25.80	115.13	17.99	133.11
	SD	1.77	2.40	2.17	1.02	0.02	17.55	6.35	22.35	3.00	16.55	5.67	20.83
EDLat	Mean	23.24	33.50	56.74	2.56	0.04	23.89	6.60	30.49	21.20	22.54	5.89	28.43
	SD	1.83	2.99	2.33	0.36	0.01	2.34	1.27	2.63	2.00	2.20	1.13	2.46
Ph	Mean	23.24	33.50	56.74	2.56	0.04	23.89	6.60	30.49	21.20	22.54	5.89	28.43
	SD	1.83	2.99	2.33	0.36	0.01	2.34	1.27	2.63	2.50	2.20	1.13	2.46
Th	Mean	19.20		19.20	8.25	0.41	10.77		11.31	20.40	10.16		10.64
	SD	5.15		5.15	3.64	0.20	7.89		9.11	1.11	7.45		8.53
FDS	Mean	30.33	32.59	62.91	0.54	0.01	91.83	41.24	133.07	30.10	86.63	36.82	123.45
	SD	1.11	8.87	9.11	0.32	0.00	10.06	5.38	15.01	2.00	8.92	4.80	13.34
FDPH	Mean	31.90	37.20	69.10	5.76	0.08	272.63	50.87	323.50	39.70	257.20	45.42	302.62
	SD	1.16	2.46	2.25	2.06	0.03	50.51	3.52	52.57	3.00	47.65	3.14	49.48
FDPR	Mean	15.68	2.94	18.61	0.94	0.05	16.51	1.40	17.91	27.98	15.57	1.25	16.82
	SD	2.68	1.05	3.19	0.29	0.02	5.12	0.86	5.63	4.74	4.83	0.77	5.28
FDPU	Mean	20.08	16.21	36.29	2.54	0.07	41.55	1.90	43.45	29.20	39.20	1.70	40.89
	SD	2.11	4.09	3.43	0.63	0.02	7.98	0.73	7.84	2.00	7.52	0.65	7.40
MIO	Mean		27.15	27.15				41.01	41.01			36.62	36.62
	SD		0.95	0.95				4.52	4.52			4.04	4.04

Table 2. *Functional parameters of distal muscle of front leg*
Tablo 2. *Ön bacağın distal kaslarına ait fonksiyonel parametreler*

Muscles		PCSA (cm²)	TCSA (cm²)	Fmax (MPa)	TSFmax (MPa)	%TZ	KA/CA	KDU/CA$^{1/3}$	TA/CA	TKTA/CA	PCSA/Ca$^{2/3}$	TU/CA$^{1/3}$
ECR	Mean	54.46	0.76	16.34	21.03	14.02	1.18	1.00	0.04	1.23	1.21	2.32
	SD	11.72	0.13	4.52	2.30	4.20	0.48	0.27	0.01	0.48	0.69	0.11
OEM	Mean	12.51	0.12	3.75	33.22	22.15	0.04	0.14	0.01	0.04	0.28	1.59
	SD	2.72	0.03	0.81	11.09	7.39	0.00	0.03	0.00	0.00	0.07	0.60
FCR	Mean	9.74	0.16	2.92	18.39	12.26	0.26	1.17	0.01	0.27	0.22	1.69
	SD	2.01	0.03	0.60	4.22	2.82	0.01	0.22	0.00	0.01	0.04	0.23
FCU	Mean	103.16		30.95			0.34	0.26		0.34	2.31	1.69
	SD	44.00		13.20			0.04	0.35		0.04	1.01	0.23
ECU	Mean	124.91	0.63	37.47	81.59	54.39	0.43	0.19	0.02	0.45	2.82	1.20
	SD	15.16	0.45	13.55	16.76	17.84	0.05	0.17	0.02	0.06	1.05	0.21
EDC	Mean	20.76	0.40	6.23	16.28	10.85	0.41	0.85	0.07	0.48	0.46	6.78
	SD	3.95	0.14	1.19	3.36	2.24	0.05	0.16	0.02	0.06	0.08	0.37
EDLat	Mean	8.96	0.18	2.69	15.67	10.45	0.08	0.38	0.02	0.10	0.20	5.02
	SD	1.43	0.03	0.43	3.58	2.39	0.01	0.05	0.00	0.01	0.04	0.46
Ph	Mean	8.96	0.18	2.69	15.67	10.45	0.08	0.38	0.02	0.10	0.20	5.02
	SD	1.43	0.03	0.43	3.58	2.39	0.01	0.05	0.01	0.01	0.04	0.46
Th	Mean	3.73		1.12			0.04	1.24		0.04	0.08	1.59
	SD	7.34		2.20			0.02	0.55		0.03	0.16	0.60
FDS	Mean	184.27	1.27	55.28	47.78	31.85	0.31	0.08	0.14	0.44	4.15	4.89
	SD	21.57	0.64	8.47	8.81	2.54	0.05	0.05	0.01	0.06	1.39	1.31
FDPH	Mean	49.99	1.17	15.00	11.27	7.51	0.92	0.86	0.17	1.10	1.13	5.59
	SD	19.15	0.09	5.74	3.84	2.56	0.15	0.30	0.01	0.15	0.43	0.35
FDPR	Mean	17.20	0.43	5.16	14.90	9.94	0.06	0.14	0.00	0.06	0.39	0.45
	SD	5.48	0.21	1.64	10.48	6.99	0.02	0.04	0.00	0.02	0.13	0.14
FDPU	Mean	15.76	0.11	4.73	47.82	31.88	0.14	0.38	0.01	0.15	0.35	2.44
	SD	2.87	0.04	0.86	5.66	5.44	0.02	0.09	0.00	0.02	0.06	0.65
MIO	Mean		1.35						0.14	0.14		4.07
	SD		0.18						0.02	0.02		0.17

terms of TKTH (cm³) were higher in males compared to females and the difference was statistically significant ($P<0.05$). It was determined that FDS (29.53-31.13) in terms of KU (cm) and Th (0.29-0.60) in terms of Yİ were higher in females compared to males and the difference was statistically significant ($P<0.05$).

When the functional parameters of the distal muscles of front leg according to the gender were examined, it was found that ECR (0.86-0.67) and FCR (0.19-0.14) in terms of TCSA (cm²), FCU (0.37-0.31), ECU (0.47-0.40), and FDS (0.35-0.26) in terms of KA/CA, ECU (0.50-0.41) in terms of TKTA/CA, FCR (1.84-1.55) and ECU (1.36-1.01) in terms of TU/CA$^{1/3}$ were higher in males compared to females and the difference was statistically significant ($P<0.05$). It was determined that ECU (37.65-126.50) in terms of TSFmax (MPa) and FDS (4.81-4.96) in terms of TU/CA$^{1/3}$ had a higher value in females compared to males and the difference was statistically significant ($P<0.05$).

When the results regarding the distal muscles of the hind leg were considered, the muscles with maximum and minimum KU values were determined as Tcr and EDB. In terms of TU and TKTU, the muscles with high and low values were specified as FDS and EBD. It was observed that in the distal of the hind leg, maximum value in terms of the KDU parameter belonged to S and minimum value belonged to FDS. G had the maximum value in terms of KA and TKTA, and FDS had the maximum value in terms of TA. When the functional properties of the muscles were considered, it was observed that maximum and minimum values of PCSA and Fmax parameters belonged to FDL and S, maximum TCSA parameter belonged to G, maximum value in terms of PA belonged to FDS and minimum value belonged to FDM.

When the structural parameters of the distal muscles of hind leg according to the gender were observed, it was found that Tcr (30.88-28.85), GM (24.45-21.50), FDL

Table 3. *Structural parameters of distal muscle of hind leg*
Tablo 3. *Arka bacağın distal kaslarına ait yapısal parametreler*

Muscles		KU (cm)	TU (cm)	TKTU (cm)	KDU (cm)	AI	KA (g)	TA (g)	TKTA (g)	PA (°)	KH (cm^3)	TH (cm^3)	TKTH (cm^3)
EDL	Mean	25.31	45.65	70.96	5.82	0.08	197.61	26.44	224.05	29.60	186.42	23.61	210.03
	SD	1.51	3.12	3.91	0.82	0.01	27.01	3.79	20.22	3.00	13.22	2.31	15.00
EDlat	Mean	26.80	19.59	46.39	4.72	0.10	124.11	8.90	133.01	30.90	117.09	7.94	125.03
	SD	4.33	1.95	4.31	1.03	0.03	24.21	9.73	33.92	4.50	11.71	8.68	20.38
Tcr	Mean	29.86	8.84	38.70	6.07	0.18	147.71	4.65	152.35	35.40	139.35	4.15	143.50
	SD	1.34	0.72	1.21	0.62	0.02	18.47	0.54	18.56	3.00	17.42	0.49	17.50
PT	Mean		40.31	40.31				45.29	45.29			40.44	40.44
	SD		1.16	1.16				3.22	3.22			2.87	2.87
GL	Mean	25.13	16.80	37.73	3.02	0.08	451.98	29.41	474.05	36.30	426.41	26.26	446.10
	SD	0.99	1.76	7.67	0.54	0.01	22.10	1.25	28.12	4.00	20.84	1.12	26.10
GM	Mean	22.98		32.60	4.07	0.13	380.26		398.01	29.20	358.72		374.58
	SD	2.02		7.49	0.34	0.03	37.94		35.87	2.00	35.81		33.80
S	Mean	25.68	9.19	33.86	14.97	0.45	5.19	0.60	5.71	25.00	4.89	0.52	5.36
	SD	2.80	1.00	4.61	2.12	0.08	0.86	0.21	1.01	2.00	0.81	0.20	0.95
EDB	Mean	8.45	2.38	8.70	6.41	0.60	3.07	0.10	3.08	27.00	2.90	0.09	2.91
	SD	1.77	0.44	2.13	1.27	0.17	1.16	0.01	1.17	3.00	1.10	-	1.11
FDS	Mean	24.44	60.69	85.13	0.30	0.00	58.72	81.73	140.44	52.30	55.39	72.98	128.36
	SD	2.54	2.45	2.85	0.07	0.00	14.84	8.03	20.17	5.00	13.99	7.18	18.71
FDM	Mean	19.95	25.55	45.50	7.08	0.16	92.62	3.71	96.33	20.30	87.38	3.31	90.69
	SD	1.16	1.41	1.07	2.13	0.05	6.00	0.41	6.34	2.00	5.66	0.37	5.97
FDL	Mean	26.25	46.50	72.75	1.04	0.01	354.10	68.20	422.31	41.40	334.06	60.90	394.96
	SD	1.04	1.63	2.24	0.19	0.00	73.72	4.28	72.64	4.00	69.55	3.83	68.58
Tcd	Mean	21.28	8.89	30.16	4.64	0.15	91.67	1.10	92.77	29.00	86.47	0.99	87.46
	SD	1.38	1.17	1.45	0.32	0.01	25.34	0.41	25.62	2.00	23.90	0.37	24.16
P	Mean	19.50		19.50	3.50	0.18	173.30		173.30	43.70	163.50		163.50
	SD	1.51		1.51	0.75	0.03	7.01		7.01	6.00	6.61		6.61
MIO	Mean		30.75	30.75				40.78	40.79			36.42	36.42
	SD		1.56	1.56				7.83	7.84			7.00	7.00

(27.00-25.50), and Tcd (22.30-20.25) in terms of KU (cm), EDL (48.05-43.25) and PT (41.13-39.50) in terms of TU (cm), FDM (46.30-44.70) in terms of TKTU (cm), Tcr (0.19-0.16) in terms of Yİ, GM (405.90-354.62) in terms of KA (g), GL (30.07-28.10) and FDM (4.05-3.37) in terms of TA (g), GL(496.58-451.52) in terms of TKTA (g), GM (382.93-334.52) in terms of KH (cm^3), GL (26.85-25.08) and FDM (3.62-3.00) in terms of TH (cm^3), GL (466.95-425.25) in terms of TKTH (cm^3) were higher in males compared to females and the difference was statistically significant ($P<0.05$). It was observed that EDB (5.22-7.60) in terms of KDU (cm) and EDL (0.08-0.09) and EDB (0.44-0.76) in terms of Yİ were higher in females compared to males and the difference was statistically significant ($P<0.05$).

When the functional parameters of the distal muscles of hind leg according to the gender were observed, it was found that GM (98.26-78.88) and EDB (0.65-0.52) in terms of PCSA (cm^2), GM (29.48-23.67) and EDB (0.19-0.16) in terms of Fmax (Mpa), Edlat (39.60 20.66) in terms of TSFmax (MPa), Edlat (26.40 13.77) in terms of %TZ, GM (2.13-18.4) in terms of PCSA/$Ca^{2/3}$ were higher in males compared to females and the difference was statistically significant ($P<0.05$). EDL (0.78-0.97) in terms of KDU/$Ca^{1/3}$, S (1.31-1.45) in terms of TU/$CA^{1/3}$ were higher in females compared to males and the difference was statistically significant ($P<0.05$).

In the analysis performed according to the direction (right-left), no statistically significant difference was determined.

DISCUSSION

In the study, structural and functional properties of the distal muscles of front and hind legs of Malakan Horses and the possible differences of these properties between the right-left legs and females-males were determined. Since the obtained results have distinguishing characteristics

Table 4. *Functional parameters of distal muscle of hind leg*
Tablo 4. *Arka bacağın distal kaslarına ait fonksiyonel parametreler*

Muscles		PCSA (cm^2)	TCSA (cm^2)	Fmax (MPa)	TSFmax (MPa)	%TZ	KA/CA	KDU/CA$^{1/3}$	TA/CA	TKTA/CA	PCSA/Ca$^{2/3}$	TU/CA$^{1/3}$
EDL	Mean	33.55	0.51	10.06	23.56	15.71	0.66	0.87	0.09	0.75	0.75	6.84
	SD	3.52	0.26	2.06	4.97	3.98	0.22	0.14	0.04	0.26	0.29	0.36
EDlat	Mean	26.36	0.38	7.91	30.13	20.08	0.42	0.71	0.03	0.45	0.60	2.94
	SD	1.74	0.38	3.52	3.72	4.15	0.17	0.16	0.04	0.21	0.28	0.30
Tcr	Mean	23.26	0.47	6.98	14.91	9.94	0.50	0.91	0.02	0.51	0.52	1.33
	SD	4.39	0.06	1.32	2.73	1.82	0.08	0.09	0.00	0.08	0.11	0.12
PT	Mean		1.00						0.15	0.15		6.04
	SD		0.07						0.01	0.01		0.11
GL	Mean	145.42	1.58	43.63	25.35	16.90	1.52	0.45	0.10	1.59	3.28	2.64
	SD	26.99	0.15	8.10	3.81	2.54	0.07	0.08	0.01	0.05	0.69	1.67
GM	Mean	88.57		26.57			1.28	0.61		1.34	1.98	2.64
	SD	11.51		3.45			0.09	0.06		0.11	0.19	1.67
S	Mean	0.33	0.10	0.10	1.81	1.22	0.02	2.24	0.00	0.02	0.01	1.38
	SD	0.07	0.13	0.02	0.55	0.35	0.00	0.28	0.00	0.00	0.00	0.16
EDB	Mean	0.59	0.04	0.18	4.33	2.89	0.01	0.77	0.00	0.01	0.01	1.38
	SD	0.07	0.01	0.02	1.20	0.50	0.00	0.39	0.00	0.00	0.00	0.16
FDS	Mean	203.22	1.20	60.97	49.56	33.04	0.20	0.05	0.27	0.47	4.54	9.09
	SD	87.23	0.13	26.17	18.75	12.50	0.05	0.01	0.03	0.06	1.91	0.29
FDM	Mean	13.38	0.13	4.01	32.35	21.57	0.31	1.06	0.01	0.33	0.30	3.83
	SD	3.93	0.02	1.18	14.11	9.41	0.02	0.31	0.00	0.02	0.10	0.20
FDL	Mean	326.53	1.31	97.96	74.63	49.76	1.20	0.16	0.23	1.42	7.32	6.97
	SD	87.41	0.06	26.22	18.20	12.13	0.25	0.03	0.01	0.25	1.82	0.24
Tcd	Mean	18.62	0.11	5.59	53.40	35.60	0.31	0.69	0.00	0.31	0.42	1.33
	SD	5.18	0.04	1.56	14.82	9.88	0.08	0.04	0.00	0.08	0.11	0.18
P	Mean	48.33		14.50			0.58	0.52		0.58	1.09	1.33
	SD	8.75		2.62			0.03	0.10		0.03	0.22	0.18
MIO	Mean		1.19						0.14	0.14		4.61
	SD		0.25						0.03	0.03		0.25

compared to other animals (especially other horse breeds and donkeys), this study plays a key role in terms of making comparison and determining the locomotor activity.

Alexander et al.[22] argued that the decrease in the bundle length of the distal muscles in the legs of big animals can be tolerated by the tendons in this region which have a long and elastic structure. Shortening in the muscle bundles specified that the bundles can fit into a narrower area and number of fiber per unit area may increase. Thus, this situation caused an increase in PCSA and the force generated (see equipment and method). As a result, the short muscle fibers which can be packaged in a narrow area will be able to provide higher power generation by the increase of PCSA and able to increase the elastic energy quantity level which can be stored and released on the tendon via sufficient muscle-tendon movement [8]. Thus, the fact that muscles have small volume, short fibers and large PCSA shows that they have a high power generation capacity. Consequently, the force required for the muscle to be dynamic or static is produced by the muscles with a small volume and long tendons [7,8,23,24]. In the study, it was observed that the muscles in the distal of front and hind legs of Malakan horses generally had small volume, short fibers and high PCSA. The most significant muscles were determined as EDC, FDPH, FDS in the front leg and FDS and FDL in the hind leg.

Determination of the scaling and standardization of the findings obtained through the evaluation of muscle structure provides opportunity in the comparison of the animal types of results [22]. Alexander et al.[22] standardized various values (KA, TA, KDU, PCSA, TU) with the live body weight in their studies. Another standardization value in revealing the structural properties of the muscles is the structural index (KDU/KU). Structural index provides opportunity for the relatively comparison of the muscle

Table 5. *Some characteristics of hind leg distal muscle of horse, H: Horse (Payne et al.[8]), MH: Malakan Horse (Study), D: Donkey (Demiraslan, [26])*
Tablo 5. *At, Malakan Atı, ve merkep arka bacağı distal kaslarının bazı özellikleri, H: At (Payne et al.[8]), MH: Malakan Atı (Çalışma), D: Merkep (Demiraslan, [26])*

Muscles	KU (cm)			TU (cm)			KDU (cm)			KA (g)			TA (g)			PA (°)			PCSA (cm²)			TCSA (cm²)		
	H	MH	D	H	MH	D	H	MH	D	H	MH	D	H	MH	D	H	MH	D	H	MH	D	H	MH	D
EDL	27.1	25.31	18.06	47.2	45.65	35.51	8.1	5.82	3.65	462	197.61	60.08	59.6	26.44	12.65	29	29.6	25	54	33.55	15.5	1.13	0.51	0.32
EDlat	28.4	26.8	16.55	30.8	19.59	17.95	7	4.72	2.86	192	124.11	20.37	21	8.9	1.93	28	30.9	18	26	26.36	6.87	0.61	0.38	0.1
Tcr	32.6	29.86	21.48	9.2	8.84	7.59	4	6.07	3.36	309	147.71	37.82	26.9	4.65	2.74	41	35.4	33.35	73	23.26	10.52	2.61	0.47	0.33
PT				36.2	40.31	28.96							64.3	45.29	13.56							1.59	1	0.42
GL	26.2	25.13	17.62	24.4	16.8	14.87	5.6	3.02	2.25	808	451.98	92.95	90.7	29.41	12.2	34	36.3	37.8	137	145.42	40.25	3.32	1.58	0.73
GM	25.4	22.98	15.72				4.8	4.07	2.23	817	380.26	85.07				36	29.2	45.05	161	88.57	37.23			
S	15.5	25.68	17.47				12.1	14.97	6.05	6	5.19	1.81												
FDS	21.4	24.44	17.55	74.8	60.69	43.89	0.3	0.3	0.29	214	58.72	29.01	188.9	81.73	29.68	52	52.3	47.35	417	203.22	94.39	2.25	1.2	0.6
FDM	27	26.25	16.43	40.9	25.55	21.27	7	7.08	3.5	161	92.62	33.46	56.7	3.71	3.46	27	20.3	42.95	22	13.38	9.02	1.24	0.13	0.13
FDL	29.7	19.95	21.75	57.4	46.5	34.32	1	1.04	0.76	660	354.1	83.79	127	68.2	23.59	44	41.4	46.1	644	326.53	116.97	1.98	1.31	0.61
Tcd	24.2	21.28	15.95	13.1	8.89	10.42	5.7	4.64	2.43	224	91.67	19.27	6.1	1.1	0.91	31	29	13.7	37	18.62	7.61	0.42	0.11	0.08
P	23.5	19.5	16.19				3.8	3.5	1.84	280	173.3	54.91				42	43.7	38.3	70	48.33	28.69			
MIO				32.8	30.75	22.87							44.8	40.78	10.97							1.22	1.19	0.42

bundle length among the muscles. Fayed [14] specified that AI value in the distal muscles of front leg of the donkey varied between 0.024 and 0.759 and Demiraslan and Özcan [15] stated that AI value in the distal muscles of the hind leg of the donkey varied between 0.02 and 0.34. According to the results obtained in the study, it was observed that the structural index values of the muscles varied between 0.01 and 0.23 for the front leg and between 0.01 and 0.60 for the hind leg.

Tendons provide the muscles and bones engage each other and also increase the mobility of the leg bones in the distal of the leg [25]. However, it is notified that tendons act as an elastic energy storage [7]. The muscles evaluated in the study with maximum TSfmax and TZ% values were determined as ECU for the front leg and as FDL for the hind leg. In the study of Fayed [14], he evaluated the front leg distal muscles of the donkeys and the muscle with maximum TSfmax value belonged to the caput accessorium of EDC (Thiernesse muscle-Th). Fayed [14] specified that maximum TS% value belonged to FDPU which is one of the digital flexor muscles in the front leg.

In a study of Payne et al.[8], they remarked that the volumes of the distal leg muscles and mean KDU values between each other were similar. In the study, this similarity was also determined in the distal leg muscles of Malakan horses. Payne et al.[8] specified in the same study that m. gastrocnemius was volumetrically the largest distal muscle in hind leg of the horse and it ended with a durable and a common tendon. The results obtained in the study revealed that in parallel to the literature, the most volumetric muscle among the distal muscles of the hind leg was m. gastrocnemius and it reached to insertion point with a durable and common tendon.

While Fayed [14] specified that TA/CA value of m. interosseus medius was 0.65, the same value was specified as 0.14 in this study. According to these values, it can be asserted that m. interosseus medius rendered more volume in the front leg of donkey compared to the front leg of Malakan horse.

Energy storage capability or number of the tendon depends on the size of the tendon and the pressure applied on that tendon. In this case, the energy storage capacity of the tendon can be estimated by the elongation amount of the tendon and weight of the tendon and the length in dysfunctional (at rest) position [20]. When TU and TA were considered in the study, it was determined that the muscles having the longest tendon were EDC, FDS, and FDPH in the front leg and EDL, FDS, and FDL in the hind leg.

In the study of Fayed [14] regarding the front leg distal muscles of the donkeys, he determined the muscles with maximum value in terms of KDU, KU, TU, KA, TA parameters were FCR, FCU, FDPH, ECR, and FDPH respectively. In the study, this sequence was specified as Th, FDPH, EDC, ECR, and FDPH. In this case, it is remarkable that sequence of high muscle length is different in donkeys and Malakan horses.

In the study conducted by Brown et al.[7], they evaluated the structural and functional properties of front leg distal muscles of the horses and specified that high values for KU, TU, KH, PCSA, and KDU parameters belonged to FDPH, FCU, ECR, FDS, and FCU muscles. In our study, these muscles were determined as FDPH, EDC, ECR, FDS, and TH.

Table 5 illustrates comparatively the results obtained from the hind leg distal muscles for the horses from the study of Payne et al.[8], for the donkeys from the study of Demiraslan [15] and for Malakan Horses from this study. When the muscles are generally observed according to the table, it is seen that high muscle structural and functional parameters are similar in horses and donkeys.

In the comparison performed between the genders; while it was specified that the difference observed between some values of the muscles in the front and hind legs had a statistical significance ($P<0.05$), the differences in the comparison performed according to the direction (right-left) had no statistically significance. Abe et al.[12] reported that gender is effective upon properties of the muscle structure. While the data obtained from our study support literature in terms of the differences between the genders, it also reveals that gender should not be neglected during the preparation of the anatomical or biomechanical muscle models in equidae.

In parallel to the results of the studies previously performed in the species of equidae family, it was determined for the Malakan horse that the regional muscles evaluated in the study had generally long tendons, pennate, and short muscle bundles. This situation is accepted as an indicator for the leg distal that acts as an elastic energy storage. Especially the extent of the effect of the differences between the species on structural and functional properties of the muscles are better understood at the end of the study. Thus, the thesis specifying that the differences between the species can be effective in developing a leg muscle model is supported by this study.

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