

Determination of the morphometric characteristics of donkey (*Equus asinus*) populations reared in Turkey*

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Received: 23.11.2021 • Accepted/Published Online: 17.04.2022 • Final Version: 13.06.2022

Abstract: This research aims to determine the morphometric characteristics of the donkey (*Equus asinus*) populations reared in Turkey. For this purpose, live weights and body measurements were collected from 500 donkeys. The donkeys were grouped according to the factors of color, age, sex, and province and the live weights (LW) (kg), withers heights (WH), rump heights (RH), body lengths (BL), chest circumferences (CC), chest depths (CD), front shank circumferences (FSC), head lengths (HL) and ear lengths (EL) (cm) of the donkeys were measured. In the study, the males were found to have higher values of live weight, withers height, rump height, and chest depth than the females ($p < 0.05$). Significant differences in the live weights of the donkeys were seen by province, age, color, and sex ($p < 0.01$ and $p < 0.05$). Significant differences were found among the age groups as well ($p < 0.01$). Accordingly, the least squares means of the animals aged 1–3 years, 4–5 years, 6–8 years, and 9 years and over for live weight were measured as 112.10 ± 3.11 kg, 141.54 ± 2.76 kg, 153.98 ± 2.42 kg, and 152.95 ± 2.34 kg, respectively. The least squares mean of live weights were also determined as significant between the female and male animals (138.08 ± 1.96 kg) and (142.21 ± 2.25 kg), respectively ($p < 0.05$). The highest correlation coefficient was calculated between live weight and body length among the donkeys ($r = 0.83$). Furthermore, the classical method (CM) and the fixed object photo (FOP) method were compared for photographed animals in the study. No difference in WH, RH, CD or HL was seen between the two methods ($p > 0.05$). In conclusion, the morphometric characteristics of the donkeys were determined and it was shown that the populations were not distinguished clearly from each other and that this was fundamentally due to the transitions among the donkey populations for long years.

Key words: Donkey, body measurements, live weight, native breed, Turkey

1. Introduction

According to the data by the Turkish Statistical Institute (TURKSTAT), the number of donkeys in Turkey was 943,751 head in 1991 but decreased to 126,912 head in recently and the rate of decrease in the number of donkeys in Turkey was calculated as 87% [1]. The donkey stock on earth was about 37 million head 1961, while this number was reported as about 50.5 million head in recently by the FAO. The number of donkeys has rapidly decreased in such countries as Bulgaria, China, France, Italy, Greece, and Turkey [2]. There remained no need for donkeys in the rural section upon development, which caused both a decrease in the number of donkeys and the extinction of donkey breeds. The fact that the composition of donkey's

milk is close to that of human's milk, [3–5]. It was seen that whilst the donkey stock was increasing slowly on earth, the number of donkeys decreased and some donkey breeds were endangered in both Europe and our country. There were 140 donkey breeds in the category of native breeds in the world and that the most breeds were in Asia, Europe, and the Caucasus [6].

The ancestors of the domestic donkey (*Equus asinus asinus*) are reported to have inhabited the deserts in the Sudan, Ethiopia, and Somali. Characteristically, the Nubian ass has a dorsal stripe on the backbone, whereas the Somali ass lacks it. While the feet are white and the crosswise stripe on the shoulder draws attention in the Nubian ass, the Somali ass is light red, lacks a crosswise

* This research is a part of the project funded by the Scientific and Technological Research Council of Turkey (TÜBİTAK), grant number 215O555.

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stripe on the shoulder, and contains band stripes on the feet. The withers height is 110–122 cm in the Nubian ass but 130–140 cm in the Somali ass [7,8].

When the overall characteristics of domestic donkeys are evaluated, it is seen that their live weights range from 80 to 480 kg and their withers heights from 80 to 160 cm. Donkeys have a lifespan of 25–35 years on average and their growth is completed at 4–5 years of age [9]. Their gestation period is 12 months on average and they generally give birth to a single foal [10]. Birth weights vary between 20 and 25 kg in donkeys. The head and ears of a donkey are longer, and the mane and the tail hair are shorter, than those of a horse. Donkeys digest forage better than horses and do not need concentrate feed very much. Thus, it is easier and more economical to feed donkeys [11].

Some morphometric studies have been carried out on the Turkish donkey populations. In addition, donkey was expressed among the public that there were some Anatolian donkey breeds (the Central Anatolian Donkey, the Merzifon Donkey, the Karakaçan Donkey, the Mardin White Donkey, the Urfa Rahvan Donkey, and the Kars Yorga Donkey) [10–13]. Nevertheless, the donkey breeds in question failed to preserve their purity over time depending on the rearing system.

The study was specifically done based on the donkeys raised in Turkey and the samples of it were collected from different location of the region. Also, the number of the animals used in the study has a significant scale which puts the study in a specific and important position in its own area.

In this study, firstly it was intended to make the morphometric determination of the Turkish native donkeys according to their body measurements and to compare them by color, age, sex, and province factor. Secondly, the classical method (CM) and the fixed object photo (FOP) method were compared with photographed group in the study.

2. Material and methods

2.1. Animal materials

Firstly, the donkey taxonomically belongs to species *Equus asinus*, genus *Equus*, family *Equidae*, order *Perissodactyla*, subclass *Theria*, class *Mammalia*, subphylum *Vertebrata*, and phylum *Chordata* in kingdom *Animalia* [14,15].

The animal material of the study consisted of the donkeys owned by the breeders and the donkeys on the few donkey farms in the provinces with a large number of donkeys. The Provincial and District Directorates for Agriculture in the provinces to be sampled were talked to beforehand and both the villages to be visited and the breeders to be sampled were determined. In the study, live weights and various body measurements were collected from 500 different donkeys from 16 different provinces

(Merzifon, Amasya, Antalya, Aydın, Isparta, İstanbul, Kahramanmaraş, Kars, Kastamonu, Kırklareli, Konya, Kütahya, Mardin, Muğla, Şanlıurfa, Tekirdağ, and Tokat) considering province, sex, color, and age groups.

2.2. Morphological characteristics

The donkeys were distributed by color as follows: 183 grey donkeys (37%), 194 brown donkeys (39%), 73 black donkeys (14%), and 50 white donkeys (10%). The donkeys were grouped as 1–3 years, 4–5 years, 6–8 years, and 9–13 years of age according to age groups and as grey, brown, black, and white according to their body colors. Accordingly, the 500 head of donkeys used were distributed as 89 donkeys aged 1–3 years (18%), 110 donkeys aged 4–5 years (22%), 148 donkeys aged 6–8 years (29%), and 148 donkeys aged 9–13 years (31%) according to their % frequency distribution by age. The donkeys were distributed as 286 female donkeys (57%) and 214 male donkeys (43%) by sex.

2.3. Morphometric characteristics

In this research, live weights and various body measurements were collected from the native donkey populations in different provinces of Turkey in order to determine their morphological characteristics. The equipment required for morphological measurements (an electronic scale, a measuring stick, a tape measure, etc.) was brought to the villages by us and the body measurements were collected. To measure the live weights of the donkeys, a folding and portable electronic scale was brought to all provinces to be sampled. As in many previous studies, such actual determination of the live weights of the donkeys turned out more appropriate than various live weight estimation methods.

A total of 9 different body measurements including live weight were collected from the donkeys. **Live weight (LW)**: It is the total body weight and was measured by means of a folding and portable electronic scale. **Withers height (WH)**: It is the vertical distance from the highest point of the withers to the ground. It was determined by means of a measuring stick. **Rump height (RH)**: It is the vertical distance from the highest point in the rump (*Tuber sacrale*) area to the ground. It was measured by means of a measuring stick. **Body length (BL)**: It is the horizontal distance between *Caput humeri* and *Tuber ischii*. It was determined by means of a tape measure. **Chest circumference (CC)**: It is the surface distance which encircles the withers and the *sternum*. It was measured by means of a tape measure. **Chest depth (CD)**: It is the vertical distance between the withers and the *sternum*. It was determined by means of a measuring stick. **Front shank circumference (FSC)**: It is the outer edge surface distance which encircles the front shank (*cannon bone/Third metacarpal*) bone. It was measured by means of a tape measure. **Head length (HL)**: It is the surface distance

from the area between the two ears (*Crista occipitalis*) to the upper lip area (*Os incisivum*). It was determined by means of a tape measure. **Ear length (EL):** It is the surface distance from the base of the ear to the tip of the ear on the interior part where the two ears face each other. It was measured by means of a tape measure [16]. The body measurements collected from the donkeys are shown in Figure 1. The body measurements, withers height (WH), rump height (RH) and body length (BL) were measured by means of a measuring stick but chest circumference (CC), chest depth (CD), front shank circumference (FSC), head length (HL) and ear length (EL) by means of a tape measure [16–18].

2.4. Methods and statistical analysis

In the study, the classical method (CM) and the fixed object photo (FOP) method were employed to determine the body measurements of the animals. The 500 donkeys whose body measurements were collected were photographed at the same time; additionally, some 40 head of donkeys out of the animals photographed so were used and compared by means of the fixed object photo (FOP) method out of the computerized “image processing methods” besides the classical method. The length measurements were computed by using Image-Pro Pplus 4.5 software [19].

Classical method (CM): The method provides the data of body measurement by collecting via measuring stick and tape measure. [17]. They are shown in Figure 2. The measurement points on a donkey reported by Kök [20] and Doğaroğlu [21].

Fixed object photo (FOP) method: In the fixed object photo (FOP) method, in which a digital camera was used as an imaging apparatus, the reference source used and the position of the imaging apparatus were set to cover the lateral and posterior parts of the animal (Figure 3). The process steps of the image processing methods are shown in Figure 4. A camera was used to obtain the images in the FOP method. The images were taken at a distance of 700 cm from the animal (Figure 5). The images obtained from the lateral and posterior views by using a camera with a pixel size of “1280 × 720” and in the “jpeg” format in the FOP method were digitized and evaluated. All images under evaluation were taken when the imaging apparatuses were in the manual use position, when the AutoCorrect options were off, and without using the zoom option. Image-Pro Plus 4.5 (Media Cybernetics, Inc., Rockville, MD, USA, 1995–2001) software Grashorn and Komender [19] was used to process and evaluate the digital images obtained with the FOP method in the study.

In the research, the body measurements and live weights collected from the donkeys with the classical method were grouped according to the factors of age, sex, color, and province. Since their subgroup numbers were different, the effects of these factors were calculated

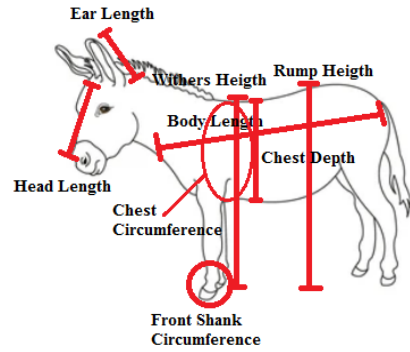


Figure 1. Body measurements of donkey.



Figure 2. Classical method equipment (CM).

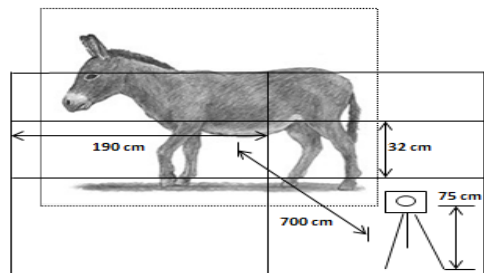


Figure 3. Fixed object photo methods (FOP).

according to the least squares analysis method and their least squares means and standard errors were provided. Furthermore, the means, standard errors and coefficients of variation for the body measurements obtained with the

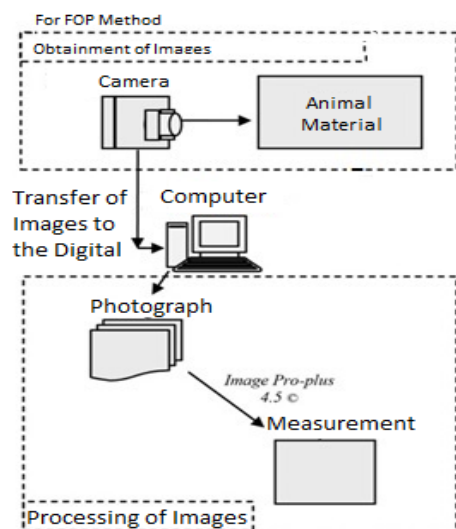


Figure 4. The steps of FOP methods.

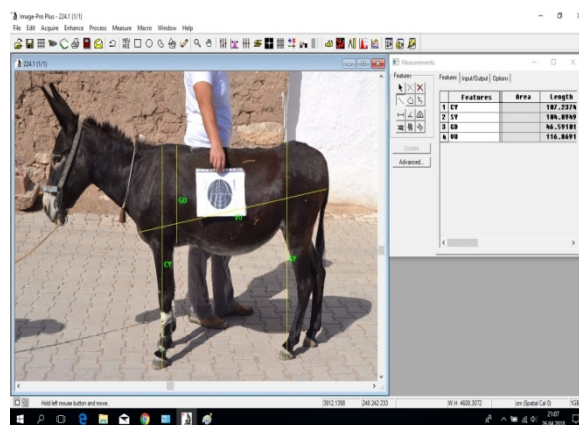


Figure 5. Body measurement points and measurement with Image-Pro Plus 4.5 program.

classical method (CM) and the fixed object photo (FOP) method were calculated.

The student t-test was used to determine the difference between the two methods employed [22]. Additionally, the multivariate regression model was employed to estimate live weight from the data on the body circumference characteristics obtained by using the CM and the FOP Method.

For this purpose, correlation coefficients (r) and coefficients of determination (R^2) were calculated for the abovementioned data groups. The SPSS package program [23] was utilized in data analysis in the research.

The ethic permission for the realization of the study was obtained by the Ethics Committee of Namık Kemal University by 2015/08 meeting on 03.09.2015.

3. Results

Some 500 donkeys were measured to determine the morphometric characteristics of the diminishing and endangered Anatolian donkey in Turkey. The least squares means, standard errors and significance test results for the live weights and body measurements of the donkeys by province, age, sex, and color are presented in Tables 1.1 and 1.2.

When the least squares means and significance test results for the chest circumferences of the donkeys by province, age, color, and sex were evaluated, significant differences were seen among both the provinces and the age groups ($p < 0.01$ and $p < 0.05$). The least squares means of the animals in the age groups of 1–3 years and 9–13 years were 109.88 cm and 128.84 cm, respectively, with the difference being significant ($p < 0.05$). Regarding body length, however, significant differences were seen among

both the age groups and the color groups ($p < 0.01$ and $p < 0.05$). Accordingly, the least squares means of the animals aged 1–3 years, 4–5 years, and 9–13 years were 99.16 cm, 107.28 cm, and 111.02 cm, respectively, with the differences being significant ($p < 0.01$). Regarding color, a significant difference was found between the white and brown color groups ($p < 0.05$). The withers height was evaluated, significant differences were seen in terms of all factors. The highest and lowest least squares means by province were calculated as 114.07 cm and 95.71 cm in Mardin and Kırklareli provinces, respectively. Whilst Mardin Province was significantly different from the provinces other than Şanlıurfa and Kahramanmaraş ($p < 0.01$), no difference was seen among these three provinces. Regarding color, the white donkeys were found significantly different from the grey and black ones ($p < 0.05$). Significant differences were found by sex as well ($p < 0.05$).

In terms of the rump heights of the donkeys, significant differences were seen for all factors. Regarding age, however, the differences among the age groups were found significant ($p < 0.01$). In terms of color, the white donkeys were significantly different from the brown and black ones ($p < 0.05$), whereas no significant difference was found between the white ones and the grey ones or between the black ones and the brown ones. On the other hand, significant differences were found by sex ($p < 0.05$).

The chest depth was evaluated, significant differences were seen by province and sex ($p < 0.01$ and $p < 0.05$). Given sex, the females were 48.40 cm and the males were 52.28 cm, with significant differences found between them ($p < 0.05$).

The highest least squares mean by province was calculated as 52.30 cm in Mardin Province but the lowest least squares mean by province as 41.40 cm in Muğla and Aydın provinces. The head length was evaluated, significant

Table 1.1. Least square means, standard errors and significance test results of body measurements in donkeys according to province, sex, age and color group.

Factor	CC (cm) ($\bar{X} \pm S$)	BL (cm) ($\bar{X} \pm S$)	WH (cm) ($\bar{X} \pm S$)	RH (cm) ($\bar{X} \pm S$)
Province (N)				
Muğla-Aydın (39)	113.92 ± 8.34 ^B	103.67 ± 1.37 ^{CDE}	94.67 ± 7.27 ^B	98.87 ± 0.98 ^F
Antalya (47)	112.22 ± 7.38 ^B	103.13 ± 1.21 ^{DE}	97.47 ± 6.44 ^B	99.63 ± 0.87 ^{EF}
Isparta (15)	114.87 ± 12.89 ^{AB}	109.19 ± 2.13 ^{ABCD}	95.41 ± 11.24 ^B	100.93 ± 1.52 ^{DEF}
Konya (17)	123.99 ± 12.29 ^{AB}	111.39 ± 2.03 ^{ABC}	97.97 ± 10.72 ^B	104.16 ± 1.45 ^{BCDEF}
Kütahya (15)	120.07 ± 12.77 ^{AB}	110.04 ± 2.11 ^{ABCD}	102.14 ± 11.14 ^B	102.75 ± 1.50 ^{BCDEF}
Kastamonu-Cide (20)	109.48 ± 11.15 ^B	102.47 ± 1.84 ^{CDE}	97.81 ± 9.72 ^B	99.96 ± 1.31 ^{EF}
Tokat (31)	110.16 ± 9.13 ^B	102.91 ± 1.50 ^{DE}	99.04 ± 7.96 ^B	99.83 ± 1.07 ^{EF}
Amasya-Merzifon (49)	120.41 ± 7.47 ^B	107.82 ± 1.23 ^{ABCD}	102.01 ± 6.51 ^B	105.94 ± 0.88 ^{BCD}
İstanbul-Çatalca (27)	131.18 ± 9.90 ^A	110.98 ± 1.63 ^{AB}	97.26 ± 8.63 ^B	103.88 ± 1.16 ^{BCDE}
Kırklareli (52)	130.27 ± 7.94 ^A	108.15 ± 1.31 ^{ABCD}	95.71 ± 6.92 ^B	103.74 ± 0.93 ^{CDE}
Kars (57)	111.63 ± 6.79 ^B	101.21 ± 1.12 ^E	96.78 ± 5.92 ^B	100.30 ± 0.80 ^{EF}
Mardin (48)	121.16 ± 7.66 ^{AB}	113.93 ± 1.26 ^A	114.07 ± 6.68 ^A	113.50 ± 0.90 ^A
Tekirdağ-Malkara (21)	115.84 ± 10.95 ^{AB}	105.82 ± 1.81 ^{BCDE}	104.26 ± 9.55 ^B	108.76 ± 1.29 ^{ABC}
Şanlıurfa (42)	120.13 ± 7.49 ^{AB}	105.94 ± 1.23 ^{BCDE}	106.29 ± 6.53 ^{AB}	107.72 ± 0.88 ^{BC}
Kahramanmaraş (20)	115.96 ± 11.13 ^{AB}	109.01 ± 1.84 ^{ABCD}	107.25 ± 9.71 ^{AB}	109.28 ± 1.31 ^{AB}
p	**	**	**	**
Age (N)				
1-3 (89)	109.88 ± 5.95 ^B	99.16 ± 0.98 ^C	98.30 ± 5.19 ^B	99.93 ± 0.70 ^C
4-5 (110)	122.77 ± 5.28 ^{AB}	107.28 ± 0.87 ^B	104.81 ± 4.61 ^{AB}	105.80 ± 0.52 ^B
6-8 (148)	124.19 ± 4.63 ^{AB}	110.71 ± 0.76 ^A	110.25 ± 4.03 ^A	110.02 ± 0.54 ^A
9-13 (148)	128.84 ± 4.48 ^A	111.02 ± 0.74 ^A	107.75 ± 3.90 ^A	107.79 ± 0.52 ^{AB}
p	*	**	*	**
Sex (N)				
Female (286)	121.47 ± 3.74	107.29 ± 0.61	106.77 ± 3.26	107.85 ± 0.44
Male (214)	121.96 ± 4.31	107.96 ± 0.71	107.80 ± 3.76	108.92 ± 0.50
p	n.s.	n.s.	*	*
Color (N)				
Grey (183)	120.34 ± 3.92	105.56 ± 0.64 ^{AB}	102.65 ± 3.42 ^B	103.04 ± 0.46 ^{AB}
Brown (194)	123.45 ± 3.63	105.18 ± 0.60 ^B	106.28 ± 3.17 ^A	102.62 ± 0.42 ^B
Black (73)	120.09 ± 6.15	108.07 ± 1.01 ^{AB}	102.11 ± 5.36 ^B	104.21 ± 0.72 ^{AB}
White (50)	121.80 ± 8.60	109.36 ± 1.42 ^A	107.09 ± 7.30 ^A	105.66 ± 1.01 ^A
p	n.s.	*	*	*

No statistical difference between the ^{A,B...}averages shown with the same letter, n.s. = not significant, $p > 0.05$; **: $p < 0.01$; *: $p < 0.05$; CC: Chest Circumference; BL: Body Length; WH: Withers Height; RH: Rump Height.

differences were seen by province and age group ($p < 0.01$ and $p < 0.05$), whereas no significant difference was seen by sex or color group. When the LW of the donkeys were evaluated, significant differences were seen in terms of all factors. The least squares means of the animals aged 1-3

years, 4-5 years, 6-8 years, and 9-13 years for LW were found as 112.10 kg, 141.54 kg, 153.98 kg, and 152.95 kg, respectively ($p < 0.01$). The brown donkeys were lighter (134.34 kg) than the other color groups, whereas the white donkeys were found the heaviest (145.97 kg) ($p < 0.05$).

Table 1.2. Least square means, standard errors and significance test results of body measurements in donkeys according to province, sex, age and color group.

Factor	CD (cm) ($\bar{X} \pm S_e$)	FSC (cm) ($\bar{X} \pm S_e$)	HL (cm) ($\bar{X} \pm S_e$)	EL (cm) ($\bar{X} \pm S_e$)	LW (kg) ($\bar{X} \pm S_e$)
Province (N)					
Muğla-Aydın (39)	41.40 ± 6.35 ^{BC}	13.67 ± 0.19	43.04 ± 3.33 ^B	26.17 ± 0.33 ^{ABCD}	138.47 ± 4.36 ^{BCDE}
Antalya (47)	42.36 ± 5.62 ^{BC}	13.59 ± 0.16	43.59 ± 2.95 ^B	25.90 ± 0.30 ^{ABCD}	130.97 ± 3.86 ^{DE}
Isparta (15)	44.60 ± 9.83 ^{BC}	14.38 ± 0.29	42.97 ± 5.16 ^B	25.70 ± 0.52 ^{ABCDE}	139.79 ± 6.74 ^{ABCDE}
Konya (17)	46.80 ± 9.37 ^{AB}	15.36 ± 0.28	45.01 ± 4.92 ^B	27.24 ± 0.49 ^{AB}	159.52 ± 6.43 ^{ABC}
Kütahya (15)	43.74 ± 9.73 ^{ABC}	14.23 ± 0.29	46.74 ± 5.11 ^B	26.10 ± 0.51 ^{ABCDE}	148.35 ± 6.68 ^{ABCDE}
Kastamonu-Cide (20)	41.73 ± 8.50 ^{BC}	12.80 ± 0.25	43.40 ± 4.46 ^B	24.61 ± 0.45 ^{DEFG}	126.97 ± 5.83 ^{DE}
Tokat (31)	40.43 ± 6.96 ^{BC}	12.73 ± 0.20	43.95 ± 3.65 ^B	24.23 ± 0.37 ^{EFG}	124.11 ± 4.77 ^{DE}
Amasya-Merzifon (49)	45.29 ± 5.69 ^{AB}	13.50 ± 0.17	45.02 ± 2.99 ^B	25.25 ± 0.30 ^{CDEF}	151.77 ± 3.90 ^{ABC}
İstanbul-Çatalca (27)	47.67 ± 7.55 ^{AB}	13.20 ± 0.22	42.79 ± 3.96 ^B	22.91 ± 0.40 ^G	163.62 ± 5.18 ^A
Kırklareli (52)	48.31 ± 6.05 ^{AB}	13.74 ± 0.18	47.37 ± 3.18 ^{AB}	23.94 ± 0.32 ^{FG}	138.57 ± 4.15 ^{BCDE}
Kars (57)	47.06 ± 5.18 ^{AB}	13.11 ± 0.15	44.46 ± 2.71 ^B	25.37 ± 0.27 ^{BCDE}	122.11 ± 3.55 ^E
Mardin (48)	52.30 ± 5.84 ^A	13.58 ± 0.17	46.72 ± 3.06 ^{AB}	26.02 ± 0.31 ^{ABCD}	165.19 ± 4.01 ^A
Tekirdağ-Malkara (21)	46.66 ± 8.35 ^{AB}	13.76 ± 0.25	44.41 ± 4.38 ^B	26.16 ± 0.44 ^{ABCD}	126.96 ± 5.73 ^{DE}
Şanlıurfa (42)	49.77 ± 5.71 ^A	13.73 ± 0.17	49.01 ± 3.00 ^{AB}	26.65 ± 0.30 ^{ABC}	134.06 ± 3.92 ^{CDE}
Kahramanmaraş (20)	46.96 ± 8.49 ^{AB}	14.27 ± 0.25	50.59 ± 4.45 ^A	27.17 ± 0.45 ^A	138.65 ± 5.82 ^{BCDE}
p	**	n.s.	**	**	**
Age (N)					
1-3 (89)	45.03 ± 4.54	13.07 ± 0.13	44.14 ± 2.38 ^B	24.96 ± 0.24 ^B	112.10 ± 3.11 ^C
4-5 (110)	47.21 ± 4.03	13.72 ± 0.12	47.67 ± 2.11 ^{AB}	25.61 ± 0.21 ^{AB}	141.54 ± 2.76 ^B
6-8 (148)	49.95 ± 3.53	14.04 ± 0.10	50.55 ± 1.85 ^A	25.82 ± 0.18 ^A	153.98 ± 2.42 ^A
9-13 (148)	49.26 ± 3.41	14.01 ± 0.10	46.06 ± 1.79 ^B	25.86 ± 0.18 ^A	152.95 ± 2.34 ^A
p	n.s.	n.s.	*	*	**
Sex (N)					
Female (286)	48.40 ± 2.85	13.39 ± 0.08	47.55 ± 1.50	25.66 ± 0.15	138.08 ± 1.96
Male (214)	52.28 ± 3.28	14.01 ± 0.09	48.62 ± 1.72	25.88 ± 0.17	142.21 ± 2.25
p	*	n.s.	n.s.	n.s.	*
Color (N)					
Gray (183)	51.08 ± 2.99	13.50 ± 0.08	46.68 ± 1.57	25.45 ± 0.15	137.00 ± 2.05 ^{AB}
Brown (194)	47.69 ± 2.77	13.40 ± 0.08	48.51 ± 1.45	25.44 ± 0.14	134.34 ± 1.90 ^B
Black (73)	47.35 ± 4.68	13.91 ± 0.14	45.93 ± 2.46	25.68 ± 0.24	143.25 ± 3.21 ^A
White (50)	51.24 ± 6.56	14.03 ± 0.19	47.29 ± 3.44	25.68 ± 0.34	145.97 ± 4.50 ^A
p	n.s.	n.s.	n.s.	n.s.	*

No statistical difference between the ^{A,B}...averages shown with the same letter; n.s. = not significant, $p > 0.05$; **, $p < 0.01$; *, $p < 0.05$. CD: Chest Depth; FSC: Front Shank Circumference; HL: Head Length; EL: Ear Length; LW: Live Weight.

Given sex, significant differences were found between the females (138.08 kg) and the males (142.21 kg) ($p < 0.05$). When the ear lengths of the donkeys were evaluated, significant differences were seen by province and age group ($p < 0.01$ and $p < 0.05$). The front shank circumference was

evaluated no significant difference was seen in terms of any factor. The all results are presented in Tables 1.1 and 1.2.

The correlation coefficients among the LW and body characteristics of the donkeys and the significance test results are presented in Table 2. Accordingly, the highest

correlation coefficients were found between LW and BL ($r = 0.83$) and between LW and CC ($r = 0.81$). On the other hand, the lowest correlation coefficient was recorded between CC and EL ($r = 0.24$).

To compare the classical method (CM) and the fixed object photo (FOP) method in the study, the statistical values and significance test results for the body measurements obtained from the photographed donkeys are shown in Table 3.

As a result of the t-test done to determine in terms of which characteristics the CM and the FOP method caused statistical differences, significant differences were found in terms of BL and EL ($p < 0.01$), whereas no difference in WH, RH, CD or HL was found between the two methods. Moreover, mean squared error (MSE) values and coefficients of determination (R^2) were calculated by means of the multivariate regression equations formulated

to estimate live weight by making use of the body measurements and the results are provided in Table 4.

When Table 4 is examined, it is seen that the highest coefficient of determination was found as 69.02% in the equation where WH, RH, BL, CD, HL and EL were used as independent variables to estimate LW in the multivariate regression equation obtained with the CM. On the other hand, the highest coefficient of determination was found as 43.04% in the equation where WHI, RHI, BLI, CDI, HLI, and ELI were used as independent variables to estimate LW in the multivariate regression equation obtained with the FOP method. Accordingly, when the classical method (CM) and the fixed object photo (FOP) method were compared, it was seen that the classical method (CM) had higher coefficients of determination than the fixed object photo (FOP) method in all equations in order to estimate LW.

Table 2. Correlation coefficients and significance test results between body weight and body measurements in donkey.

	LW	WH	RH	BL	CC	CD	FSC	HL
WH	0.55**							
RH	0.60**	0.81**						
BL	0.83**	0.64**	0.71**					
CC	0.81**	0.49**	0.55**	0.72**				
CD	0.65**	0.72**	0.76**	0.68**	0.59**			
FSC	0.55**	0.48**	0.52**	0.60**	0.43**	0.50**		
HL	0.47**	0.56**	0.60**	0.60**	0.59**	0.56**	0.51**	
EL	0.37**	0.37**	0.41**	0.42**	0.24**	0.41**	0.49**	0.44**

** $: p < 0.01$, LW: Live Weight; WH: Withers Height; RH: Rump Height; BL: Body Length; CC: Chest Circumference; CD: Chest Depth; FSC: Front Shank Circumference; HL: Head Length; EL: Ear Length.

Table 3. Descriptive statistics and significance test results of body measurements obtained by classical methods (CM) and fixed object photo (FOP) methods.

	$\bar{X} \pm Se$	t	p		$\bar{X} \pm S_e$	t	p
WH (CM)	98.80 ± 0.42	1,68	0.12	CD (CM)	43.32 ± 0.48	0.89	0.37
WH (FOP)	96.28 ± 1.44			CD (FOP)	42.63 ± 0.61		
RH (CM)	102.40 ± 0.77	1,00	0.32	HL (CM)	45.48 ± 0.38	0.99	0.32
RH (FOP)	100.52 ± 1.72			HL (FOP)	46.26 ± 0.67		
BL (CM)	106.44 ± 1.05	3,86	0.01**	EL (CM)	25.95 ± 0.36	5.95	0.01**
BL (FOP)	102.36 ± 1.18			EL (FOP)	22.66 ± 0.41		
LW	146.69 ± 3.99						

** $: p < 0.01$. LW: Live Weight; WH: Withers Height; RH: Rump Height; BL: Body Length; CC: Chest Circumference; CD: Chest Depth; FSC: Front Shank Circumference; HL: Head Length; EL: Ear Length.

Table 4. Multivariate regression equations obtained by classical method (CM) and fixed object photo (FOP) method.

Multivariate regression equations by classical method (CM)	MSE	R ² (%)	p
$LW = -199.3 + 0.66 \times WH - 0.41 \times RH + 3.02 \times BL$	232.0	66.41	0.000
$LW = -190.8 + 0.46 \times WH - 0.75 \times RH + 2.83 \times BL + 1.50 \times CD$	228.5	67.85	0.000
$LW = -190.1 + 0.80 \times WH - 0.64 \times RH + 2.95 \times BL + 1.33 \times CD - 1.12 \times HL$	231.9	68.30	0.000
$LW = -181.0 + 0.56 \times WH - 0.43 \times RH + 2.85 \times BL + 1.32 \times CD - 1.79 \times HL + 1.32 \times EL$	233.5	69.02	0.000
Multivariate regression equations by fixed object photo (FOP)			
$LW = -57.1 + 1.93 \times WHI - 1.61 \times RHI + 1.79 \times BLI$	442.2	36.00	0.001
$LW = -57.1 + 1.65 \times WHI - 1.65 \times RHI + 1.61 \times BLI + 1.13 \times CDI$	450.6	36.60	0.003
$LW = -141.4 + 2.45 \times WHI - 2.39 \times RHI + 1.76 \times BLI + 0.89 \times CDI + 1.68 \times HLI$	417.1	42.98	0.001
$LW = -141.3 + 2.41 \times WHI + 2.33 \times RHI + 1.75 \times BLI + 0.81 \times CDI + 1.58 \times HLI + 0.28 \times ELI$	429.3	43.04	0.003

LW: Live Weight; WH: Withers Height; RH: Rump Height; BL: Body Length; CC: Chest Circumference; CD: Chest Depth; FSC: Front Shank Circumference; HL: Head Length; EL: Ear Length are measured by CM and WHI, RHI, BLI, CDI, HLI, ELI are measured by FOP method.

4. Discussion

The morphological characteristics of 25 male (3–13 years of age) and 44 female (3–17 years of age) donkeys were determined in a study on the endangered Catalan donkey of Spain. The HL, EL, WH, and RH of the male and female donkeys were reported as 61.24–58.25 cm, 32.45–33.81 cm, 142.20–136.29 cm and 139.88–135.79 cm, respectively and it was expressed that the morphological characteristics did not differ greatly by sex [24]. These body measurements were found quite high compared to the donkeys in our country.

In a study carried out in Ethiopia, 12 morphometric measurements were collected from 289 male and 280 female donkeys. All breeds were expressed to have originated from a common ancestor. Of the five breeds studied, the Harar and Afar breeds were discovered to be the closest breeds, while the Sinnar breed was reported to have the most different morphological structure among all breeds [25].

Yılmaz and Ertuğrul [12] reported that WH, RH, BL, and CD were significantly different by sex in 124 female and 70 male donkeys ($p < 0.05$). In a study where the morphological characteristics of the Amiata donkey out of the endangered native breeds in Italy were investigated, Cecchi et al. [26] reported that the WH and the CC were 129.0–131.8 cm and 148.4–150.8 cm in 60 female and 75 male animals, respectively and that no significant difference was found by sex.

In another study where the morphological characteristics of the Amiata donkey were investigated in Italy, morphometric measurements were collected by using 67 donkeys. This breed was reported to reach its adult body weight and composition at 3 to 4 years of age. They found the WH, the RH, and the CC as 129.8–125.8

cm, 133.0–129.0 cm, and 145.6–145.0 cm in the adult male and female Amiata donkeys, respectively. Furthermore, in the measurements they carried out among the female donkeys, they grouped the animals by age as 3–4 years of age, 5–6 years of age, and 6 years of age and over. The WH were recorded as 122.2 cm, 127.9 cm, and 126.1 cm, the RH as 126.1 cm, 131.5 cm, and 128.7 cm, and the CC as 139.4 cm, 146.7 cm, and 147.0 cm according to these groups, respectively, with the differences among the groups found significant ($p < 0.01$) [27]. The Amiata donkeys were discovered to be higher and larger in terms of body than the donkeys in this study; moreover, the significant differences in the WH, RH, and CC of the Amiata donkeys by age group were found significant, as in present study ($p < 0.05$).

In present study 286 female and 214 male donkeys were evaluated and while no significant difference in EL, HL, FSC, BL or CC was found depending on the sex factor of the animals, significant differences were found in terms of LW, WH, RH, and CD ($p < 0.05$).

Body colors and measurements were determined in a study carried out to determine the morphological characteristics of donkeys in Iğdır. Some 56 male and 38 female donkeys divided into four age groups as 1–3 years, 4–5 years, 6–7 years, and 8–13 years of age were used in the study. The descriptive statistical values of the donkeys under examination were generally found as follows: WH, 99.1 cm; RH, 101.0 cm; BL, 103.0 cm; CC, 111.5 cm; CD, 45.4 cm; chest width, 29.1 cm; rump width, 34.8 cm; tail length, 48.3 cm; leg length, 53.7 cm; FSC, 13.4 cm; HL, 48.4 cm; and EL, 21.8 cm. It was reported that the donkeys reared in Iğdır reached their adult body sizes at two years of age and that these donkeys were small-sized [10]. In present study, some 50 head of donkeys were sampled in

Kars Province and the least squares means of the donkeys were calculated as 96.78 cm for WH, 100.30 cm for RH, 101.2 cm for BL, 111.63 cm for CC, 47.06 cm for CD, 44.46 cm for HL, 25.37 cm for EL, and 122.11 kg for LW. It was seen that the results of this study were similar to the results in the study carried out in 2011 by Yılmaz and Ertuğrul [10] on the donkeys in Kars Province considering age groups. In addition, it was reported that the donkeys reared in Kars Province were smaller-sized than the donkeys reared in other countries.

A total of 194 donkeys were used in another study where some morphological characteristics of the Anatolian donkey were determined. The WH, RH, BL, CC, CD, FSC, HL, and EL of the Anatolian donkey were determined as 102.3 cm, 104.3 cm, 105.2 cm, 113.5 cm, 45.7 cm, 13.6 cm, 48.7 cm, and 21.9 cm, respectively [12].

Stanisic et al. [28] collected 18 different body measurements from some 74 head of Balkan donkeys. They grouped the donkeys as those under and over 3 years of age and reported significant differences in BL, HL, CC, and LW by age group. They reported the body measurements of the Balkan donkeys under and over 3 years of age as follows: WH 103.3–104.0 cm; CH, 46.5–47.3 cm; BL, 111.5–117.2 cm; HL, 48.0–49.6 cm; EL, 26.1–25.6 cm; CC, 114.2–119.6 cm; and LW, 122–143.4 kg. They expressed that the Balkan donkey differed morphologically from Catalan, Croatian, and Albanian donkeys. These data and the body measurements of the donkeys measured in present study are similar.

John et al. [29] reported LW as 114.3 kg, BL as 92 cm, CC as 94.3 cm, WH as 92.8 cm, withers width as 17.5 cm, neck circumference as 50 cm, neck length as 38.6 cm, HL as 39.9 cm, head width as 12.3 cm, EL as 22.9 cm, and tail length as 45.9 cm in some 210 head of donkeys reared in north-western Nigeria. The researchers accounted for the morphometric differences they found considering the other breeds by the difference in the genetic lines of the donkeys. It was seen that since the donkeys were small (6–12 months of age), all their measurements were lower than the measurements reported in the present study.

Labbaci et al. [30] collected 11 different body measurements from 30 male and 31 female donkeys reared in two different regions in Algeria. They reported the body length of the donkeys as 157.26 cm, their WH as 116.16 cm, their CC as 124.26 cm, their rump width as 37.15 cm, their HL as 52.39 cm, their EL as 30.15 cm, their head width as 23.01 cm, their LW as 161.81–194.78 kg, and their tail length as 41.42 cm. They could not find any significant difference in live weight or in any of the body measurements by sex. Contrary to these researchers, the effect of sex was found significant in terms of WH, RH, CD, and LW in the present study. In present study, the least squares means of the male donkeys were 107.96

cm for body length, 107.80 cm for WH, 121.96 cm for CC, 48.62 cm for HL, 25.88 cm for EL, and 142.21 kg for LW and it was seen that the Algerian donkeys were larger-sized. Ayad et al. [31] collected 17 body measurements from some 126 donkeys reared in Algeria. They estimated that the LW of the donkeys were between 144.3 and 171.5 kg. They reported the BL of the donkeys as 110.1 cm, their CC as 118.5 cm, their CD as 48.8 cm, their WH as 106.9 cm, their rump width as 33.2 cm, their withers width as 25.6 cm, their fore leg length as 73.5 cm, their FSC as 14.7 cm, their neck length as 46 cm, their HL as 48.5 cm, their EL as 24.4 cm, and their back height as 107.2 cm. Given the age factor, they found significant differences in HL, chest width, back length, rump width, back height, CC, CD, fore leg length, and FSC among the young (5 years of age and under), adult (6–10 years of age), and old (11 years of age and over) donkeys ($p < 0.05$). In the present study, however, significant differences in HL, EL, LW, CC, BL, WH, and RH were found for 4 different age groups (1–3, 4–5, 6–8, and 9–13 years of age) ($p < 0.05$). In the present study carried out, the least squares means of the donkeys aged 6–8 years were found similar, namely 110.71 cm for BL, 124.19 cm for CC, 49.95 cm for CD, 110.25 cm for WH, 14.04 cm for FSC, 50.55 cm for HL, and 25.82 cm for EL.

Mostafa et al. [32] collected various measurements from the fore and hind feet of some 20 donkeys used in transportation at a brickkiln in Egypt and compared them. They compared the fore and hind feet of the donkeys in terms of hoof width, heel width, dorsal hoof wall length, lateral and medial heel lengths, toe angle, and hoof angle and found significant differences in hoof width, heel angle, and lateral and medial heel lengths ($p < 0.01$). The researchers reported that the live weights of the donkeys ranged from 150 to 241 kg, their withers heights from 110 to 122 cm, and their chest circumferences from 113 to 134 cm. It was striking that although the donkeys used in the field of work resembled the Anatolian donkeys in terms of live weight and chest circumference, their withers heights were greater than those of the Anatolian donkeys.

Hannani et al. [33] collected 16 body measurements from some 65 donkeys aged 3–16 years in Algeria. In their study, they found significant differences in chest circumference, withers height, shank length, shank circumference, rump height, and live weight by sex ($p < 0.05$). They measured the body length of the donkeys as 115.76 cm, their withers height as 110.15 cm, their chest circumference as 114.94 cm, their neck length as 36.62 cm, their right ear length as 26.06 cm, their left ear length as 25.88 cm, their head length as 40.79 cm, their shank length as 14.07 cm, their shank circumference as 13.93 cm, their back length as 69.95 cm, their rump width as 32.76 cm, and their rump height as 114.02 cm and reported that their live weights

varied between 151.30 and 158.83 kg. In the present study performed, the least squares means of the donkeys aged 9–13 years were calculated as 111.02 cm for body length, 107.75 cm for withers height, 128.84 cm for chest circumference, 25.86 cm for ear length, 46.06 cm for head length, 14.01 cm for shank circumference, and 107.79 cm for rump height and live weight was found as 152.95 kg. Khaleel et al. [34] investigated the morphometric characteristics in the Kano donkeys reared in Nigeria. They used 144 male donkeys of 2 years of age and over in their study. They divided the donkeys into 4 different groups according to the age factor and into 7 different groups by body color. They grouped the donkeys by age as 2–4 years, 5–7 years, 8–10 years, and 11 years of age and over and found significant differences in HL, EL, CC, and BL ($p < 0.01$). In the present study too, significant differences in LW, BL, RH ($p < 0.01$), WH, CC, HL, and EL ($p < 0.05$) were found according to the age groups. Furthermore, they found significant differences by color among the Kano donkeys ($p < 0.01$). Considering color, they found significant differences in HL, EL, CC, and BL ($p < 0.01$). In the present study too, significant differences in LW, BL, RH, and WH ($p < 0.05$) were found according to the color groups. The researchers reported body length as 64 cm, chest circumference as 113.2 cm, withers height as 102.4 cm, neck length as 31.1 cm, head length as 44.0 cm, ear length as 26.7 cm, and tail length as 60.7 cm in the male donkeys. On the other hand, the least squares means of the male animals were found higher 107.96 cm for body length, 121.96 cm for chest circumference, 107.8 cm for withers height, 48.62 cm for head length, and 25.88 cm for ear length in the present study.

The highest correlation coefficients among live weight and various body characteristics in donkeys were found as $r = 0.83$ between live weight and body length and as $r = 0.81$ between live weight and chest circumference in the study performed. Additionally, the correlation coefficient between withers height and rump height was $r = 0.81$. Nevertheless, the lowest correlation coefficient was calculated as $r = 0.24$ between chest circumference and ear length. In their study on the donkeys reared in the south-eastern and eastern regions of Turkey, Yilmaz and Ertuğrul [12] reported the highest correlation coefficient among the body measurements as $r = 0.97$ between withers and RH but the lowest correlation coefficient as $r = 0.15$ between CD and FSC. John et al. [29] found positive and significant correlation coefficients between the morphological characteristics of the donkeys in north-western Nigeria. Accordingly, they found significant correlation coefficients between LW and BL ($r = 0.41$), between LW and CC ($r = 0.28$), and between withers width and chest circumference ($r = 0.80$). Ayad et al. [31] found significant and positively high correlation coefficients between withers height and back height ($r = 0.80$), between back and rump heights ($r = 0.72$), and between withers and rump heights ($r =$

0.72) in some 126 donkeys reared in Algeria ($p < 0.05$). In another study, head length, ear length, neck length, tail length, withers height, body length, chest circumference and body length were considered in the Kano donkeys and it was reported that there were positive and significant correlations ($r = 0.43$ – 0.91) for all characteristics other than tail length among the characteristics under consideration. In addition, the correlation coefficient between body length and chest circumference was found as $r = 0.77$ [34].

According to the CM and the FOP method, no difference in WH, RH, CD or HL was seen between the two methods, whereas differences were found in terms of BL and EL ($p < 0.01$). In the research, it was discovered that the FOP method might be substituted for the CM to determine WH, RH, CD, and HL in particular out of the body measurements in donkeys. The regression equations obtained according to the CM and the FOP Method by using all body measurements were provided. The coefficient of determination was found as 69.02% in the equation where WH, RH, BL, CD, HL and EL were used as independent variables to estimate LW in the multivariate regression equation obtained with the CM. However, the coefficient of determination was found as 43.04% in the equation where WHI, RHI, BLI, CDI, HLI, and ELI were used as independent variables to estimate LW in the multivariate regression equation obtained with the FOP method. When the CM and FOP method were compared, it was discovered that the CM had higher coefficients of determination than FOP method in all equations in order to estimate live weight. Aluja et al. [35] intended to estimate live weight by making use of body measurements in the donkeys reared in Central Mexico. The study was conducted on some 160 donkeys aged 6 years on average and two different allometric models were employed to estimate body weight, namely $LW = b_0 \times CC^{b_1}$ and $LW = b_0 \times WH^{b_1} \times CC^{b_2}$. The coefficients of determination of the first and second models for both sexes were 0.98 and 0.97, respectively and it was seen that both models were practicable. Hannani et al. [33] used equations $LW_1 = CC^{2.826} / 4434.7$ and $LW_2 = (CC^{2.575} \times WH^{0.240}) / 3968$ to estimate live weight in the Algerian donkeys. In their study on the donkeys reared in Algeria, Labbaci et al. [30] employed equations $LW_1 = (CC^{2.575} \times WH^{0.240}) / 3968$ and $LW_2 = CC^{2.65} / 2188$ to estimate live weight.

5. Conclusion

In the study, the males were found to have higher values of live weight, withers height, rump height, and chest depth than the females and the donkeys of 6–8 years of age were found to have higher values of live weight and body measurements than the other age groups. In the study, it was seen that the donkeys in the white color group had higher values of live weight and body measurements than the other color groups. In addition, when the characteristics

obtained according to the CM and the FOP method were compared, no difference in WH, RH, CD or HL was seen between the two methods, whereas differences were found in terms of BL and EL ($p < 0.01$). When the CM and the FOP method were compared in the research, the CM was found to have higher coefficients of determination than the FOP method in all equations to estimate live weight. Furthermore, the morphological measurements of the animals were collected and compared by province, age, sex, and color in the study we conducted to determine the morphological characteristics of donkeys throughout Turkey. It was expressed that intensive transitions on population basis had taken place as the donkey owners had purchased donkeys from different provinces throughout Turkey for long years and that the breed characteristics had therefore disappeared. It was seen that no clear distinction could be made among the provinces despite the quite large number of samples of the donkey populations studied. The donkey populations in Turkey were discovered to be distributed in a rather scattered way.

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Acknowledgments

We would like to thank the Scientific and Technological Research Council of Turkey (TÜBİTAK) and the relevant people working in the Provincial and District Directorates of the Ministry of Food, Agriculture and Livestock of the Republic of Turkey, who provided support for determining the breeders at the districts and in the villages affiliated to the provinces and for collecting the animal material in the research, as well as all staff members working on the Private Donkey Farms and especially the donkey owners for their cooperation.

Contribution of authors

EKG, SG, SK, FÖ, EÖÜ, HB, SY received data; FÖ, SA, MİS, EÖÜ, EKG, SG, SK planned and EKG, SG, FÖ, EÖÜ wrote the study.

Conflict of interest

All of the authors declare that they have no conflict of interest.

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