MORPHOMETRIC MEASUREMENTS OF RED FOXES (*Vulpes vulpes*) IN SOMOGY COUNTY, HUNGARY

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ABSTRACT

CSÁNYI, E., SÁNDOR, B. & SÁNDOR, GY. (2023): MORPHOMETRIC MEASUREMENTS OF RED FOXES (*Vulpes vulpes*) IN SOMOGY COUNTY, HUNGARY. *Hungarian Small Game Bulletin* **15**: 11–21. http://dx.doi.org/10.17243/mavk.2023.011
The red fox (*Vulpes vulpes*) has the widest natural distribution of any terrestrial carnivore. Sexual dimorphism in this species is well known and is frequently observed in body and skull measurements. Morphological analysis is essential because the skull and body morphologies reflect many population/individual characteristics, genetic distances, environmental effects, and growth-affecting factors. Our study presents the first comprehensive analysis of red fox body and skull morphometry in Hungary. We performed morphometric measurements on 200 red foxes at two developmental stages, juvenile and adult, of different sexes, male and female, from Somogy County, Hungary, between January 2021 and January 2022.
Statistical tests showed significant differences in all seven body measurements (body weight, total body length, tail length, head length, wither height, hind leg (left) length, and neck circumference of **adult** red foxes between the sexes, being significantly lower in the case of females than males. Significant differences were also found between the sexes in adult red fox skull measurements (total skull length, zygomatic width, and mandible length).

In the case of **juvenile** red foxes, not all body dimensions differed significantly between the sexes (body weight, head length, and neck circumference did not differ significantly). We also found significant differences between the sexes in skull dimensions, except for zygomatic width. Regarding significant differences, the values for females were lower than those for males.

Concerning the red foxes in Hungary, we found evidence of sexual dimorphism in all body and skull measurements in adult red foxes, which were larger in males, but not in all of the dimensions in juveniles.

KEYWORDS: red fox, morphology, sexual dimorphism, skull size, body size

KIVONAT

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A vörös róka (*Vulpes vulpes*) a legelterjedtebb szárazföldi húsevő faj. Az ivari dimorfizmus a faj esetében jól ismert, amely a test és koponya mérések eredményeivel bizonyíthatóak. A morfológiai elemzések fontos információk, mert a koponya és a test morfológiája számos populációs/egyedi jellemzőt, genetikai távolságot, környezeti hatást és növekedést befolyásoló tényezőt tükröz. Kutatásunk a vörös róka test és koponya morfometriájának első átfogó elemzését mutatja be Magyarországon. 2021. január – 2022. január között 200 fiatal és felnőtt vörös róka morfometriai mérését végeztük el Somogy megyében.

A statisztikai tesztek az ivarok között szignifikáns különbséget mutattak ki a felnőtt vörös rókák hét mért testméretében (testtömeg, teljes testhossz, farokhossz, fejhossz, marmagasság, bal hátsó lábhossz és nyakkörméret) amelyek szignifikánsan kisebbek voltak szukák esetében. Szintén szignifikáns különbséget igazoltunk az ivarok között a felnőtt vörös róka koponya méreteiben (teljes koponyahossz, járomszélesség és mandibula hossz).

A fiatal rókák esetében az ivarok között a testtömeg, a fejhossz és a nyakkörméret kivételével a többi test méret szintén szignifikánsan különbözött. A koponya méretek esetében a járomszélesség kivételével az ivarok között az szignifikáns különbséget igazoltunk, amelyek a szukák esetében kisebbek voltak.

A felnőtt és fiatal vörös rókák test- és koponya mérete alapján ivari dimorfizmust bizonyítottunk; a kanok esetében nagyobb méreteket rögzítettünk, mint a szukáknál. A felnőtt egyedek minden vizsgált mérete szignifikáns különbséget mutatott, míg a fiatal korosztályú egyedeknél nem minden méretben igazoltunk szignfikáns különbséget. Ennek valószínű oka, hogy a korcsoport kora heterogén abban a korosztályban ahol a test és koponyaméretek intenzíven nőnek.

KULCSSZAVAK: vörös róka, morfológia, ivari dimorfizmus, testméret, koponya méret

1. INTRODUCTION

Predatory mammalian species play essential roles in the food chain. Therefore, they are important from the perspective of wildlife management and nature conservation (SMEE 2010, STIER *et al*. 2016).

The red fox is the most adaptable and representative of the genus *Vulpes* (*Vulpes vulpes* Linnaeus, 1758) (LLOYD 1980, MACDONALD 1987). The fossil record indicates that red foxes evolved somewhere in Eurasia (STATHAM *et al.* 2014). It has spread across the Northern Hemisphere, from the Arctic Circle to North Africa, Central America, and Asia. It was introduced to Australasia in the 19th century and is now found on every continent except Antarctica (MACDONALD & REYNOLDS 2004, CASTELLÓ 2018). Owing to its large population size, the red fox is one of the most significant carnivores worldwide (DOHERTY *et al*. 2016, LLOYD 1980, SOE *et al*. 2017). As an opportunistic predator, the red fox prefers food sources that occur at the highest density and can be utilized with the most minor energy investment (LANSZKI 2002, DÍAZ-RUIZ *et al.* 2013, SCHOLZ *et al.* 2020). The red fox has adapted to life in different habitats and climates and can be seen in urban and suburban areas, which has led to partial changes in behavior, manner, and diet (GLOOR *et al*. 2001, DÍAZ-RUIZ *et al*. 2016).

Fifteen predatory mammalian species have been reported in Hungary (HELTAI 2002). One of them is the red fox, the presence and distribution of which require scientifically based measures in small game management. In addition to deterioration in habitat quality, predatory species' role in controlling small game populations is an important wildlife management issue (HELTAI *et al*. 2004, FARAGÓ 2010). However, managing fox populations is difficult, because little data are available on their population sizes, densities, and reproduction. Knowledge of individual morphological and biometric data is essential for understanding the red fox's population dynamics and behavioral interactions. The dimensions of the body and skull of red foxes vary geographically; therefore, data related to location must be examined. Morphometric data indicate an intricate interplay between various factors, including age and sex, which may be influenced by genetic factors, population density, food abundance, pathogen prevalence, and climatic conditions (LLOYDS 1980, ENGLUND 2006, SOULSBURY *et al.* 2008).

Body size variation is probably one of the most significant traits in any animal (GORTÁZAR *et al.* 2000, CALDER 2001). The skull has also been referred to as a structure that presents variation between sexes and across geographical distribution in carnivores (MEIRI *et al.* 2005b) and is used at several levels as a complete source of information to distinguish carnivores' morphometric measurements of the body and skull, which are crucial for species identification. In canids, body size affects several traits, including basal metabolism, communication, social dominance, reproductive attributes, reproductive success, attendant hunting tactics, and effectiveness (GEFFEN *et al*. 1996, HARRINGTON & ASA 2003, MACNULTY *et al.* 2009, 2020) Examining red fox skull and body measurements is a valuable scientific practice contributing to species identification, taxonomy, morphological studies, population monitoring, and comparative research. It helps to understand species' biology, adaptability, and ecological roles, which are crucial for effective conservation and management strategies (SIMONSEN *et al.* 2003).

Sexual size dimorphism is common among mammalian carnivores and is manifested in differences in body size and corresponding measurements. Sexual dimorphism in body and skull dimensions, with males being usually larger than females, has been shown in several canid taxa, including red foxes (KOLB & HEWSON 1974, 1983, HELL *et al.* 1989, LABHARDT 1990, WANDELER & LÜPS 1993, SZUMA 2000, 2008, MACDONALD & SILLERO-ZUBIRI 2004, JOJIĆ *et al*. 2017), coyotes (*Canis latrans*) (KENNEDY *et al*. 2003, MORRIS & BRANDT 2014), and grey wolves (*Canis lupus*) (MILENKOVIC *et al.* 2010).

Skull data can be found in previous studies (FARAGÓ 2015), but no large-scale study of the red fox's body size has been carried out in Hungary. The present study aimed to analyze the skull, body weight, and body dimensions to appraise the differences between the sexes and among different ages of red foxes in Hungary.

2. MATERIAL AND METHODS

2.1. STUDY AREA

The unfenced study area is located in the Pannonian biogeographical region of South-West Hungary in Somogy County (Lábod region; center: 46°11' N, 17°30' E, **Fig. S1**) operated by two hunting management units, SEFAG ZRT., and Nagy Tölgyfa Vt. (**Fig. 1**). The study area has a level of high forest cover (53.5 %), consisting primarily of English oak (*Quercus robur*), willow (*Salix* sp.), as well as alder (*Alnus* sp.), linden (*Tilia* sp.), and alien black locusts (*Robinia pseudo-acacia*), interspersed with agricultural fields and small settlements. This flat, lowland area has dunes (125–190 m above sea level). Forestry, wildlife management, and crop cultivation are the predominant land uses in the region. In the arable areas (36.7 %), row crops, oilseed rape, and cereals dominate, but pastures (7.5 %), ponds and wetlands (1.1 %), human settlements, and orchards (1.2 %) also occur. The continental climate has sub-Mediterranean features.

The South Transdanubian region is characteristically a big game area, where red deer (*Cervus elaphus*), fallow deer (*Dama dama*), roe deer (*Capreolus capreolus*), and wild boar (*Sus scrofa*) occur in very high populations. The size of the moufflon (*Ovis ammon*) population is also significant. In Somogy County, 4 328 red foxes were culled in 2020 and 4 201 in 2021.

2.2. DATA COLLECTION

Foxes are not a threatened species in Hungary and were legally hunted during the 2020–2021 hunting seasons (all year) under the rules of the Hungarian Hunting Law (LV. 1996). No animals were killed specifically for this study, and no government approval or licenses were required for sampling legally hunted animals. A total of 200 foxes (96 females and 104 males) were collected (**Fig. 1**).

After biometrical characterization, we recorded their weight and sex and removed their heads for cleaning. To clean the head, we first removed most of the soft tissues, and then boiled the skulls to remove the remaining tissues, taking care not to cause any damage (SULLIVAN & ROMNEY 1999). We divided the individuals into two age categories: juvenile (younger than one year) and adult (older than one year).

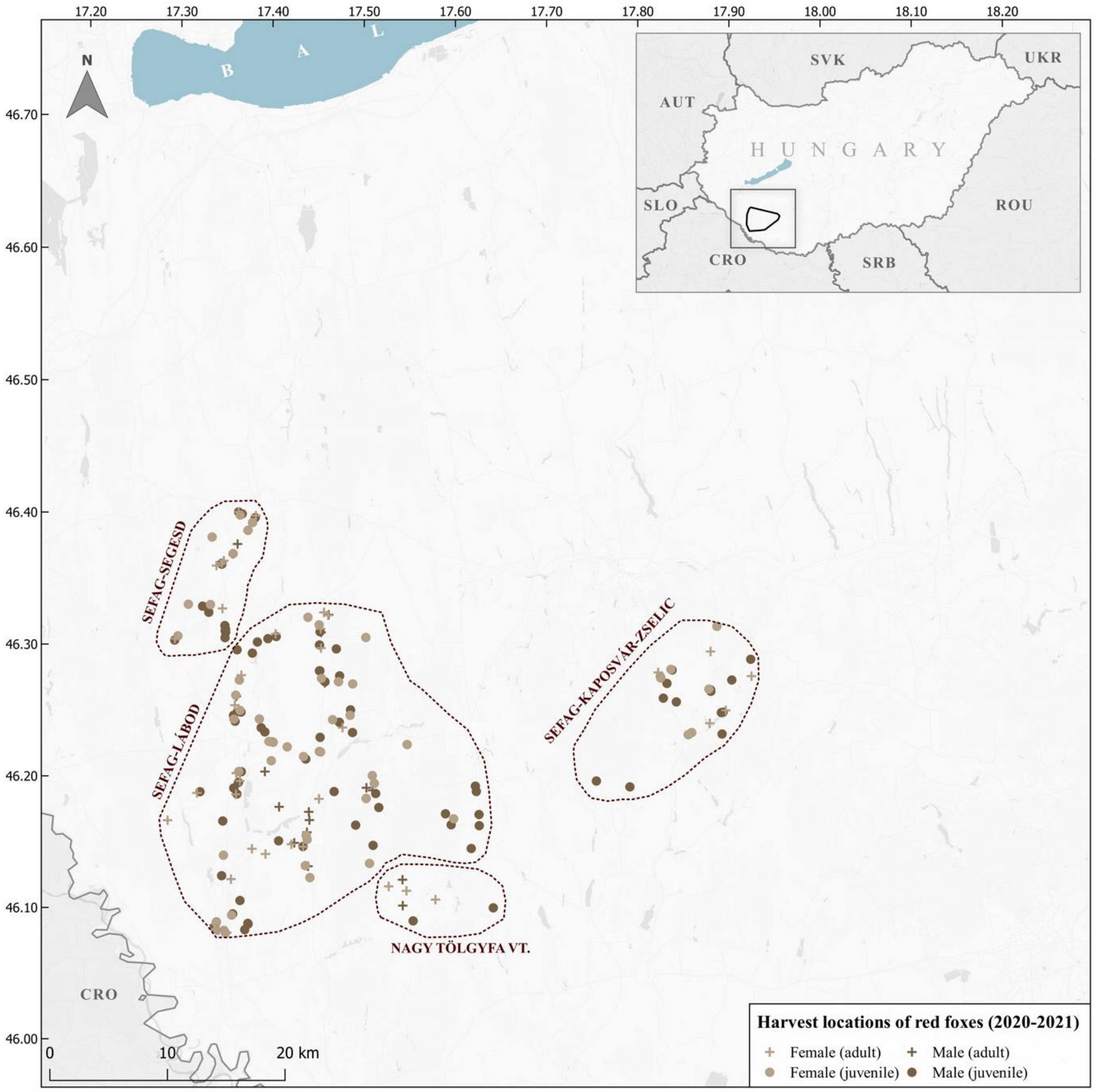

Figure 1. Study area – Hungary, Somogy County – showing the culling locations of red foxes in 2020 and 2021)

We determined the body weight of each fox in kilograms. We measured six additional body dimensions using a measuring tape to the nearest millimeter: body length from the anterior tip of the nose pad to the end of the tail (cm), tail length (cm), head length (cm), wither height (cm), hind foot (left) length (cm), and neck circumference (cm) (**Fig. 2**).

Two cranial and one mandibular dimensions were obtained from each skull using an INSIZE digital calliper at 0.01 mm precision. The total skull length (TSL), zygomatic width (ZM), and total mandible length (TML) were measured (**Fig. 3**).

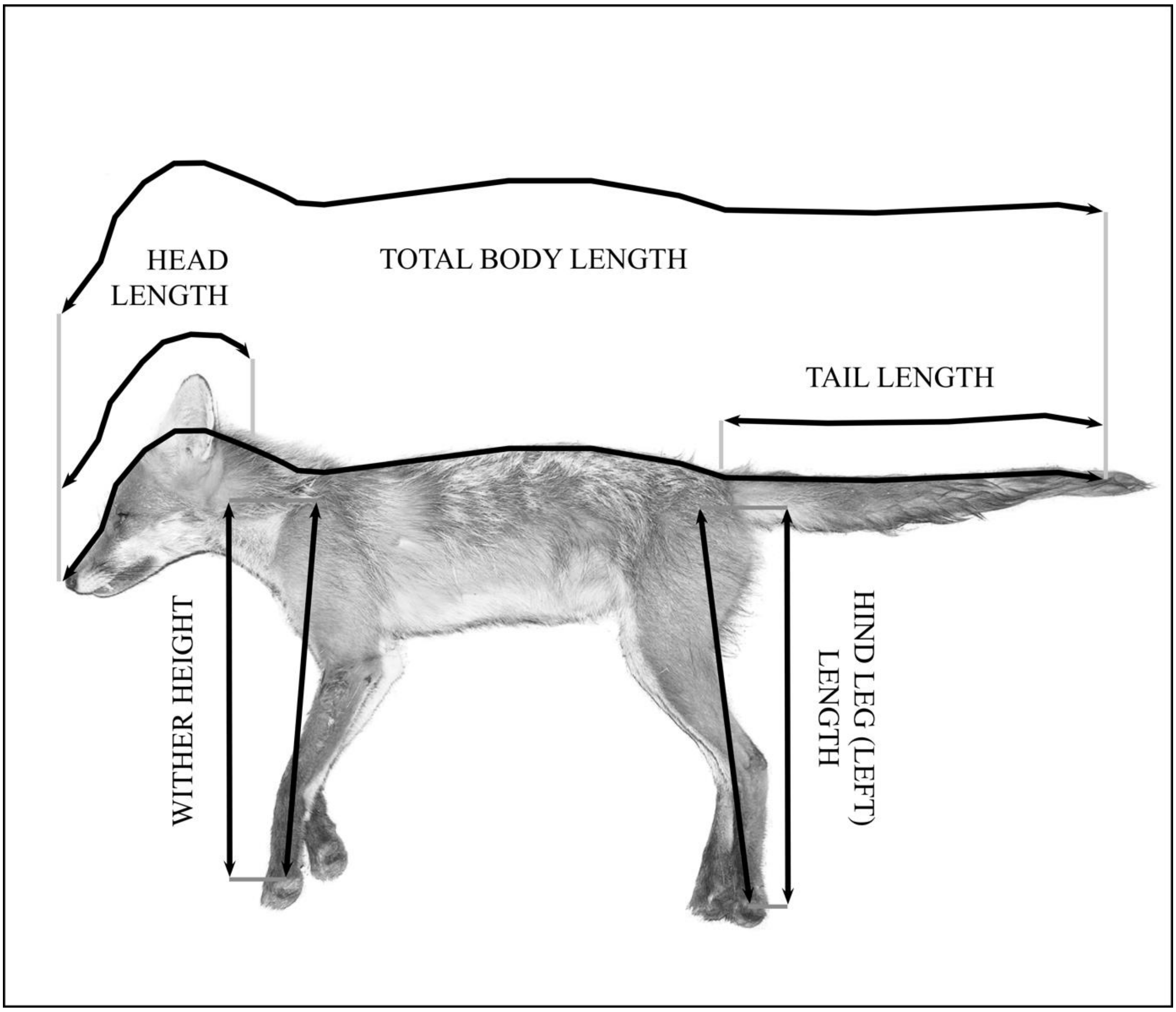

Figure 2. Body measurements of the red fox: total body length, head length, tail length, wither height, hind leg (left) length

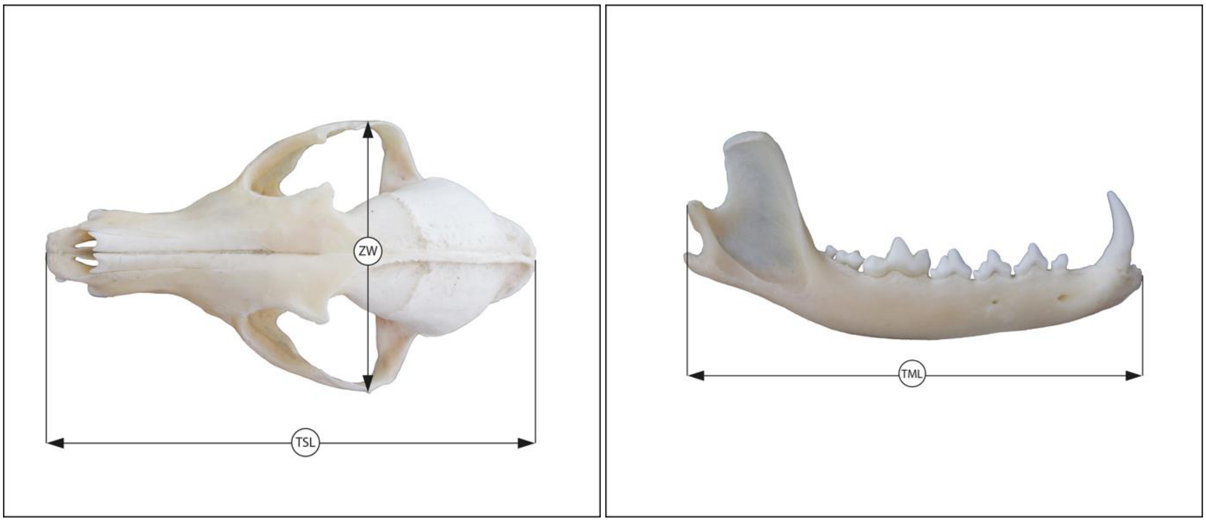

Figure 3. TSL: total skull length, ZW: zygomatic width, TML: total mandible length

2.3. DATA ANALYSIS

For body dimensions and skull measurements of each red fox sample, descriptive statistics (mean, standard deviation [SD], standard error [SE], and minimum and maximum values) were calculated. Red fox biometric and skull measurements were analyzed to assess differences and variations among sexes and ages. The data were first tested to confirm the normality of the distribution. We followed the central limit theorem for samples with more than 50 individuals; for groups with fewer than 50 individuals, we tested normality using the Shapiro-Wilk test (SHAPIRO & WILK 1965). The homogeneity of variances was tested using Levene's test (LEVENE 1961). Most of our craniometric data followed a normal distribution ($p > 0.05$, in the Shapiro-Wilk test for all groups with $n < 50$), but the same was not verified for biometric measures (in the age analysis). Most data presented homogenized variance ($p > 0.05$, Levene's test), with some exceptions. All the analyses were performed based on these results.

The mean values of each dimension were then compared between sexes (females and males) and age categories (adults and juveniles) using the Student's t-test (ZAR 1999). When the assumption of homogeneity of variances was not confirmed, we used Student's t-test, considering no equal variances. When normality was not confirmed, the Mann-Whitney U test was used. JASP (version 0.14.1) (JASP Team 2020) was used for all statistical analyses.

3. RESULTS

The calculated basic statistical parameters (mean, SD, minimum, and maximum) for all studied morphometric characteristics (body and skull) in both sexes and the two age categories in Hungary are presented in **Tab. 1**.

Table 1. The sample size (n), mean, and standard deviation for body measurements and skull parameters, presented separately for both sexes (female and male) and age groups (juvenile and adult) of red foxes.

		Body measurements							Skull measurements		
	Descriptive statistics	Body weight (kg)	Body length from nose to end of tail (cm)	Tail length (cm)	Head length (cm)	Wither height (cm)	Hind leg (left) length cm	Neck circumference (cm)	Total skull length (cm) (TSL)	Zygomatic width (cm) (ZW)	Total mandible length (cm) (TML)
Female adult red fox	n	43	43	43	43	43	43	43	40	41	43
	Mean	5.560	101.791	36.628	16.791	40.930	35.767	21.349	144.036	76.738	103.815
	Standard deviation	0.521	4.464	3.599	0.742	1.696	1.556	1.646	4.126	2.328	2.952
	Minimum	4.340	80.000	17.000	15.000	38.000	33.000	19.000	136.800	72.610	98.370
	Maximum	6.800	110.000	41.000	19.000	45.000	39.000	27.000	154.140	82.820	111.360
Male adult red fox	n	77	77	77	77	77	77	77	72	72	75
	Mean	6.478	107.312	38.649	17.766	43.571	37.662	22.571	152.281	81.217	108.711
	Standard deviation	0.799	5.447	3.538	1.075	1.976	2.043	1.650	5.312	4.670	11.997
	Minimum	5.210	90.000	29.000	15.000	39.000	34.000	19.000	140.820	49.980	11.630
	Maximum	9.130	118.000	47.000	20.000	48.000	42.000	29.000	166.210	87.320	119.740
Female juvenile red fox	n	53	53	53	53	53	53	53	50	46	53
	Mean	4.874	99.755	35.170	16.113	39.434	33.868	20.038	141.313	74.829	101.508
	Standard deviation	0.624	6.578	3.361	1.171	1.956	2.489	1.519	4.387	3.140	4.623
	Minimum	3.000	73.000	23.000	13.000	34.000	27.000	15.000	127.770	64.870	80.680
	Maximum	6.700	113.000	42.000	18.000	44.000	39.000	23.000	151.300	82.300	109.620
Male juvenile red fox	n	27	27	27	27	27	27	27	22	21	27
	Mean	5.132	101.407	36.741	16.519	41.037	36.259	20.370	144.413	75.984	102.980
	Standard deviation	1.088	8.706	3.696	1.252	3.264	5.654	3.002	9.211	4.836	8.416
	Minimum	2.200	76.000	28.000	14.000	31.000	26.000	13.000	118.930	63.450	78.940
	Maximum	6.660	113.000	43.000	18.000	46.000	60.000	25.000	159.300	85.160	114.810

The mean values of all the studied body and skull size parameters of both sexes of **adult** red foxes differed significantly ($P < 0.05$); all means were higher in males (**Tab. 2).**

Table 2. Results of the statistical analysis for body and skull measurements of adult red foxes

Red fox (*Vulpes vulpes*)		Differences between sexes						
		Adult males	Adult females	Student's t-test		Mann-Whitney test		
		mean ± SE (n)	mean ± SE (n)	t (df)	p-value	U	z	p-value
body measurements	Weight (kg)*	6.478 ± 0.091 (77) ‡	5.560 ± 0.079 (43)	-6.770 (118) †	< .001	508.501	-6,2774284	< .001
body measurements	Body length (cm)*	107.312 ± 0.621 (77) ‡	101.791 ± 0.681 (43) ‡	-5.666 (118) †	< .001	691.501	-5,2758857	< .001
body measurements	Tail length (cm)*	38.649 ± 0.403 (77)	36.628 ± 0.549 (43) ‡	-2.983 (118)	0.003	1090.501	-3,0921944	< .001
body measurements	Head length (cm)*	17.766 ± 0.122 (77) ‡	16.791 ± 0.113 (43) ‡	-5.286 (118) †	< .001	799.001	-4,6875479	< .001
body measurements	Wither height (cm)*	43.571 ± 0.225 (77) ‡	40.930 ± 0.259 (43)	-7.374 (118)	< .001	516.001	-6,2363815	< .001
body measurements	Left hind leg length (cm)*	37.662 ± 0.233 (77) ‡	35.767 ± 0.237 (43) ‡	-5.283 (118)	< .001	798.501	-4,6902843	< .001
body measurements	Neck circumference (cm)*	22.571 ± 0.188 (77) ‡	21.349 ± 0.251 (43) ‡	-3.896 (118)	< .001	943.501	-3,8967123	< .001
skull measurements	Total skull length (mm)*	152.281 ± 0.626 (72)	144.036 ± 0.652 (40)	-8.490 (110)	< .001	314.001	-6,8374403	< .001
skull measurements	Zygomatic width (mm)*	81.217 ± 0.550 (72) ‡	76.738 ± 0.364 (41)	-5.741 (111)	< .001	316.501	-6,9238998	< .001
skull measurements	Total mandible length (mm)*	108.711 ± 1.385 (75) ‡	103.815 ± 0.450 (43)	-2.626 (116)	0.006	352.001	-7,0484745	< .001

‡ Non-normal distribution;
† Non-homogeneous variance;
* Differences statistically significant.

In the case of juvenile foxes, we did not find significant differences in all body size parameters between the sexes; specifically, we did not find any significant differences in body weight, body length, head length, or neck circumference. Furthermore, among the skull measurements, the zygomatic width values also did not differ significantly (**Tab. 3**).

Table 3. Results of the statistical analysis for body and skull measurements of juvenile red foxes considering sexes

Red fox (*Vulpes vulpes*)		Differences between sexes						
		Juvenile males	Juvenile females	Student's t-test		Mann-Whitney test		
		mean ± SE (n)	mean ± SE (n)	t (df)	p-value	U	z	p-value
body measurements	Weight (kg)	5.132 ± 0.209 (27)	4.874 ± 0.086 (53)	-1.346 (78) †	0.091	511.000	-2,0807582	0.019
body measurements	Body length (cm)	101.407 ± 1.675 (27) ‡	99.755 ± 0.904 (53) ‡	-0.950 (78)	0.172	543.500	-1,7500753	0.039
body measurements	Tail length (cm)*	36.741 ± 0.711 (27)	35.170 ± 0.462 (53) ‡	-1.911 (78)	0.030	497.000	-2,2232062	0.013
body measurements	Head length (cm)	16.519 ± 0.241 (27) ‡	16.113 ± 0.161 (53) ‡	-1.430 (78)	0.078	576.000	-1,4193925	0.073
body measurements	Wither height (cm)*	41.037 ± 0.628 (27) ‡	39.434 ± 0.269 (53)	-2.745 (78) †	0.004	398.500	-3,2254295	< .001
body measurements	Left hind leg length (cm)*	36.259 ± 1.088 (27) ‡	33.868 ± 0.342 (53)	-2.630 (78) †	0.005	478.500	-2,411441	0.008
body measurements	Neck circumference (cm)	20.370 ± 0.578 (27)	20.038 ± 0.209 (53) ‡	-0.660 (78) †	0.256	602.500	-1,1497588	0.122
skull measurements	Total skull length (mm)*	144.413 ± 1.964 (22)	141.313 ± 0.620 (50)	-1.942 (70) †	0.028	421.000	-1,5769668	0.058
skull measurements	Zygomatic width (mm)	75.984 ± 1.055 (21)	74.829 ± 0.463 (46)	-1.171 (65)	0.123	373.000	-1,486758	0.069
skull measurements	Total mandible length (mm)*	102.980 ± 1.620 (27) ‡	101.508 ± 0.635 (53) ‡	-1.012 (78) †	0.157	547.000	-1,7144633	0.044

‡ Non-normal distribution;
† Non-homogeneous variance;
* Differences statistically significant.

4. DISCUSSION

In Hungary, no study contained data that examined both body and skull size in the case of red foxes. The present study showed sexual dimorphism, which was significant only in adults for all measurements (body, skull, and mandible dimensions). Males were larger than females in body weight (16.51 %), total body length (5.43 %), tail length (5.52 %), head length (5.87 %), wither height (6.46 %), left hind leg (5.30 %), and neck circumference (5.73 %). All the studied skull dimensions also showed significant differences between the sexes. The total skull length (5.72 %), the zygomatic width 5.83 %, and the total mandible length (4.71 %) were larger in males than females.

Red fox body size in Hungary was reported by HELTAI in 2010. Body weight - ♂ n: 266, mean (min-max) 6.3 (2.4-9.7) kg; ♀ n: 279, 5.4 (3.5-7.5) kg. Body length (without tail) - ♂ n: 478, 70.8 (54.0-89.0) cm, ♀ n: 463, 67 (54.0-79.0) cm. Tail length - ♂ n:455, 42.8 (30.0-57.0) cm; ♀ n: 442, 40,4 (21.0-52.0) cm. Left hind leg - ♂ n: 480, 40.9 (33.0-48.0) cm; ♀ n: 458, 39.1 (30.0-46.0) cm.

FARAGÓ (2015) published measurements of the skull and mandible of red foxes in Hungary. Skull length - ♂ n: 85, 152.35 (138.1-169.9), ♀ n: 90, 146.13 (124.2-162.4) mm. Zygomatic width - ♂ n: 85, 79.39 (68.9-86.8) mm; ♀ n: 90, 75.70 (66.6-84.4) mm. Mandible length - ♂ n: 85, 112.36 (99.8-125.1) mm; ♀ n: 90, 107.29 (89.9-118.7) mm.

The sexual dimorphism of the body weight and body size, and cranial measurements of the red fox, which is supported by our results, has already been confirmed in previous studies in red fox's geographical distribution area: Norway (LUND 1959) Scotland and England (KOLB & HEWSON 1974), Italy (CAVALLINI 1995), Spain (TRAVAINI & DELIBES 1995; Ireland (LYNCH 1996), GORTÁZAR *et al*. 2000), Czech Republic (HARTOVÁ-NENTVICHOVÁ *et al.* 2010b), Egypt (YOUNES 2023).

Our findings will be beneficial for managing sympatric canid populations and understanding demographic responses to density-dependent processes in red foxes. The present study provides morphometric data on Hungarian red fox bodies and skull sizes, which can be a significant resource for the taxonomy of carnivores. The body and cranial parameters measured in adult and juvenile individuals provide valuable information for ecological studies, comparative anatomy, and clinical veterinary sciences.

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