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Femoral Osteometry of the Edible Dormouse, *Glis glis* (L., 1766): an Indicative Basis for Specificity of Its Sex and Age

Georgi G. Markov

Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, 2 Gagarin Str., 1113 Sofia, Bulgaria;
E-mail:georgimar@gmail.com

Abstract: Osteometric features of the femur both in adult males and females, as well as in adolescent males of the edible dormouse, *Glis glis* (L., 1766) were evaluated. Seven morphometric characters of the femur and its angular configuration were measured on electronic pictures of the femurs of dead specimens without any developmental bone abnormality. In addition to the actual bone measurements of the edible dormice, 12 indices were calculated from the linear measurements. The examination and statistical analysis of defined femoral features established a primary norm of the variation in male and female femurs in *Glis glis*. The obtained results indicated that femoral osteometric measurements of the edible dormouse allow identification of the sex and age of the studied specimens; moreover, as the femoral osteometric characters are likely to be affected by the population variations in heredity and geographical factors related to the life style, the femur's structure can be analyzed and interpreted to reveal interpopulation differences in this species.

Key words: edible dormouse, *Glis glis*, femur, osteometric measurements, skeleton

Introduction

The edible dormouse, *Glis glis* (L., 1766) is widely distributed in European deciduous or mixed forests (Kryštufek 2010). The adaptability of this species has allowed it to spread across Europe and through northern Turkey to the Caucasus, northern Iran and Turkmenistan (Amori *et al.* 2010).

The search for anatomical structures of the edible dormouse reflecting age and sex was stimulated by the necessity to find some morphological tools for assessment of its population variation in the Palearctic, where: (i) subspecific morphological variation has still not been assessed (Kryštufek 2010); (ii) the significance of geographical variation within *G. glis*, in the context of the subspecific level of differentiation among populations, has not been investigated in detail throughout its range (Holden 2005), (iii) there seems to be too many named races of *G. glis* (Ellerman, Morrison-Scott 1951), (iv) a number of these synonyms remain without a clear and exact indication of their morphological discrimination (Corbet 1978, Holden 2005) and (v) the geographical boundaries of 10 tentatively recognized subspecies have not been determined (Corbet 1978).

The femur is a unique, very solid, inflexible and dense bone among the long single bones in the mammals' body (Description of the Femur Bone: eHow.com). As the femoral osteometric measurements are likely to be affected by population variations in heredity and geographical factors related to life style (Birdsell 1972, Ferembach 1966), the aim of the present study was to examine the morphology of edible dormouse femurs and to establish a representative picture of its osteometric features related to sex and age. Thus, a database for further work would be provided, which would contribute to elucidation of the intraspecies taxonomic structure of *G. glis* within its range.

Material and Methods

The samples analysed consisted of edible dormouse specimens (*G. glis*) that belong to the subspecies *G. g. glis* (L., 1766), which has a range covering France, Germany, Austria, Italy, Switzerland, former Yugoslavia, Romania and Russia (Ellerman, Morrison-Scott 1951). The specimens were kept in the mammals' collection of the Hungarian Natural History Museum in Budapest. They came from a contemporary population in Hungary, which inhabits natural or semi-natural forests (sessile oak, turkey oak and beech), bushes and orchards, where the animals have an optimal food supply (Bakó, Gál 1999), mainly in or at the boundary of mid-mountainous and hilly areas with bushy or woodland coverage (Bakó *et al*. 1998, Hecker *et al*. 2003).

The age determination of the animals was based on the dental development and the state of dental attrition: class 1 – adolescent (1-2 years); class 2 – adult animals (over 3 years) (Gaisler *et al*. 1977). The sex and locality of the specimens were described in the biological data of each collection.

The following 8 morphometric measurements of the femur and its angular configuration (Fig. 1) were measured: V1 – Vertical maximum length; V2 – Vertical length to the head; V3 – Collo-diaphyseal angle; V4 – Proximal breadth; V5 –Head vertical diameter; V6 – Neck vertical diameter; V7 – Maximum mid-shaft antero-posterior diameter and V8 – Distal breadth. Measurements were taken from 18 femurs of the dead specimens (10 adult males, 4 adult females and 4 adolescent males) without any developmental bone abnormality.

The measurements of the different features were taken according to the method described by Noble *et al*. (1988). The morphometric characters were measured on the photographs using the software Image J, ver. 1.44, with 0.01 mm accuracy. Twelve logical indices characterizing the femur shape were calculated from the linear measurements, namely: i1=V5/V4; i2=V6/V4; i3=V5/V6; i4=V4/V8; i5=V4/V7; i6=V8/V7; i7=V5/V7; i8=V2/V1; i9=V8/V1; i10=V4/V1; i11=V5/V1 and i12=V6/V1.

All these osteometric data were used for the statistical calculations. Data were tested for normality using Kolmogorov-Smirnov D-statistics, and for homogeneity of variances using Levene's test. The osteometric differences between the groups of the investigated animals were checked on the basis of the univariate and multivariate description of the femur. Basic statistical parameters: mean (X), standard deviation (SD) and standard error of mean (SE) were calculated for each group of the investigated animals. For all the osteometric characteristics studied the 95% confidence limits of their mean values were calculated.

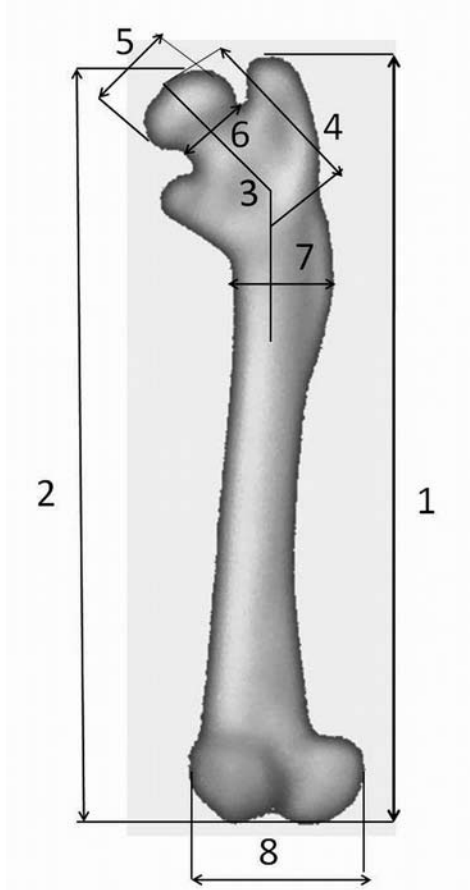

Fig. 1. Morphometric measurements taken on the posterior surface of the femur of edible dormouse, *Glis glis glis* (L., 1766): 1 – Maximum length; 2 – Length to the head; 3 – Collo-diaphyseal angle; 4 – Proximal breadth; 5 –Vertical diameter of the head; 6 – Vertical diameter of the neck; 7 – Mid-shaft antero-posterior diameter; 8 – Distal breadth

The following statistics were computed for each parameter:

Coefficient of sexual dimorphism $CD_{sex} = [(X_{male} - X_{female}) / X_{female}]*100$;

Coefficient of age dimorphism $CD_{age} = [(X_{adult} - X_{adolescent}) / X_{adolescent}] *100$;

Coefficient of variation CV=SD / X, as estimation of variability;

Student's t-test for comparison of the mean values.

The multidimensional osteometric differentiation among the femurs in the groups of the studied animals was studied using Discriminant analysis (Stepwise Discriminant Function Analysis with Model Definition – Forward Stepwise). The univariate and multivariate analyses were conducted by means of the statistical package StatSoft (1993).

Results

The measurements of the femurs from the *G. glis* groups made are given in Table 1.

The average values of the osteometric parameters analyzed in the three groups of the studied animals were of sufficient accuracy, and the errors of the arithmetic means of analogous parameters were of the same, not very high, order and their absolute variation was at similar levels. The relative variation of those osteometric parameters in the three groups of animals, on estimating it through the Coefficient of variation, was also of low grade and at similar levels, with a trend towards higher values of some parameters in the adult males.

Comparison of the mean values ($p < 0.05$) of the osteometric parameters between the different groups of animals indicated: (i) significant differences between the adult and adolescent males in 50% of the linear measurements and 50% of the computed indices; (ii) significant differences between the adult males and females in 37.5% of femoral linear measurements and 50% of the computed indices; (iii) significant differences between the adult females and adolescent males in 25% of the femoral linear measurements and 8.3% of the computed indices (Table 1).

The coefficient of sexual dimorphism in the femoral linear measurements of the adult males and females (Fig. 2a) had their highest values at V7, V1and V2 and reached negative values at V6 and V3. Indices i3 and i4 showed the highest positive values of the coefficient of sexual dimorphism, while i6 and i12 – the highest negative values.

The coefficient of age dimorphism in the femoral linear measurements and indices followed the same pattern in the adult and adolescent males (Fig 2b): high positive values at V7, V1 and V2; the highest positive values at i3 and i4 and the highest negative value at i6.

The results of the Discriminant Function Analysis concerning the femoral osteometric features of the studied groups of animals showed that:

(i) on the analysis of the largest linear characters V1, V2 and V7 in the groups of adult and adolescent males (Wilks' Lambda: 0.2939; approx. F (1, 12) = 28.8338; $p < 0.0002$) a correct assignment of 92.86% of the specimens to their known age was achieved. The classification functions that were worked out for age discrimination included only one character (V7), namely:

$Y_{adult} = V7 * 103.285 - 205.105$

$Y_{adolescent} = V7 * 87.072 - 146.779$

(ii) on the analysis of the same linear characters in the groups of adult males and females (Wilks' Lambda: 0.1679; approx. F (1, 12) = 59.4696; $p < 0.0000$) correct determination of the sex was achieved in 100% of the specimens. The classification functions that were worked out for sex discrimination included the same variable V7, namely:

$Y_{male} = V7 * 90.6200 - 179.9546$

$Y_{female} = V7 * 68.7915 - 104.8068$

According to the algorithm of the discrimina-

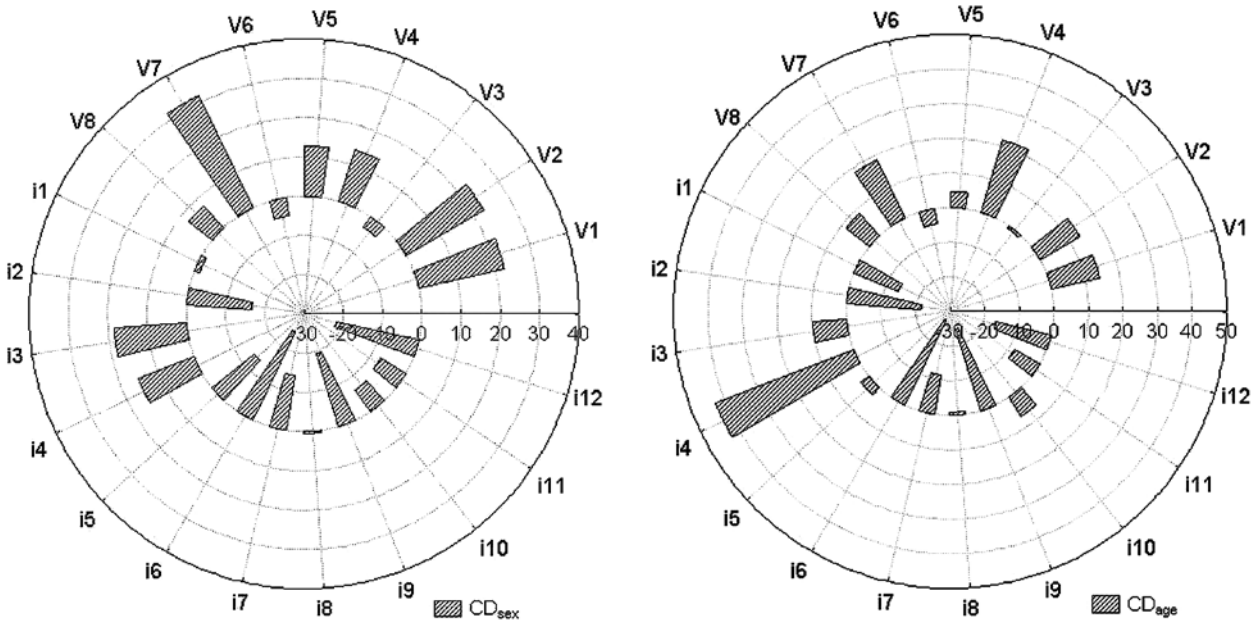

Fig. 2. Coefficient of sexual dimorphism in adult males and females (a) and Coefficient of age dimorphism in individual adult and adolescent males (b) in femoral linear measurements of the edible dormouse (*Glis glis glis* L., 1766). Explanations of the osteometric measurements are given in Fig. 1

Table 1. Basic descriptive statistics (mean (X), standard deviation (SD), standard error of mean (SE) and coefficient of variation (CV)) of femur measurements (mm) of the edible dormouse (*Glis glis glis* L., 1766) and comparison of mean values (T-test value) of analyzed osteometric parameters between the different groups of animals (G1_ male adult, G2_ male adolescent and G3_ female adult individuals). Osteomethric parameters with significant statistical difference ($p<0.05$) in their average value between the different groups of animals are marked with asterisk (*). Description of ostemetric parameters is given in Material and Methods and Fig. 1

Osteo-metric param-eters	Basic descriptive statistics												Student's test		
	Male animals								Female animals				t- value		
	G1 (N=10)				G2 (N=4)				G3 (N=4)				G1/G2	G1/G3	G2/G3
	X	SD	SE	CV	X	SD	SE	CV	X	SD	SE	CV			
V1	29.4429	1.564857	0.494851	5.31489	25.7687	0.665664	0.332832	2.58323	24.0873	1.417155	0.708578	5.88341	4.45 *	5.91 *	2.14 *
V2	28.8063	1.533818	0.485036	5.32459	25.4437	0.908702	0.454351	3.57143	23.4587	1.173261	0.586631	5.00140	4.04 *	6.22 *	2.67
V3	143.2398	6.663129	2.107066	4.65173	144.3557	2.252086	1.126043	1.56010	147.9450	3.726908	1.863454	2.51912	-0.32	-1.31	-1.64
V4	6.3001	0.525724	0.166249	8.34470	5.1723	0.084685	0.042343	1.63727	5.5393	0.804249	0.402125	14.51888	4.16 *	2.11	-0.90
V5	3.0691	0.357289	0.112985	11.64149	2.9320	0.155437	0.077719	5.30140	2.7207	0.321586	0.160793	11.82012	0.72	1.68	1.18
V6	2.1930	0.265774	0.084045	12.11921	2.2940	0.148209	0.074105	6.46074	2.3003	0.344097	0.172049	14.95858	-0.70	-0.63	0.03381
V7	3.9651	0.222065	0.070223	5.60050	3.3427	0.074968	0.037484	2.24276	3.0107	0.164686	0.082343	5.47009	5.36 *	7.71 *	3.66 *
V8	5.4521	0.579411	0.183226	10.62729	5.0220	0.734489	0.367244	14.62543	5.0697	0.377297	0.188648	7.44224	1.16	1.20	-0.11
i1	0.4874	0.048253	0.015259	9.89904	0.5666	0.022653	0.011326	3.99804	0.4939	0.027153	0.013577	5.49814	-3.09 *	-0.24	4.11 *
i2	0.3484	0.035186	0.011127	10.09942	0.4439	0.032987	0.016494	7.43195	0.4176	0.042767	0.021384	10.24174	-4.65 *	-3.14 *	0.97
i3	1.4094	0.174271	0.055109	12.36468	1.2829	0.101272	0.050636	7.89391	1.1891	0.065400	0.032700	5.50005	1.34	2.41 *	1.55
i 4	13.0427	1.687067	0.533497	12.93492	9.1393	0.289103	0.144552	3.16328	11.3156	2.131162	1.065581	18.83377	4.49	1.61	-2.02
i 5	1.5921	0.147807	0.046741	9.28358	1.5480	0.036222	0.018111	2.33994	1.8447	0.289871	0.144935	15.71402	0.57	-2.20 *	-2.03
i 6	0.1234	0.014799	0.004680	11.99548	0.1695	0.003801	0.001900	2.24299	0.1642	0.007249	0.003624	4.41501	-6.01 *	-5.17 *	1.28
i 7	0.7762	0.102769	0.032498	13.23987	0.8768	0.033761	0.016880	3.85052	0.9039	0.098204	0.049102	10.86471	-1.87	-2.12	-0.52
i 8	0.9784	0.011804	0.003733	1.20638	0.9872	0.011112	0.005556	1.12563	0.9745	0.015434	0.007717	1.58380	-1.26	0.52378	1.33
i 9	0.0166	0.001700	0.000538	10.25292	0.0220	0.000556	0.000278	2.52731	0.0206	0.001688	0.000844	8.20350	-6.09 *	-3.97 *	1.58
i 10	0.2140	0.014680	0.004642	6.85926	0.2008	0.001963	0.000981	0.97765	0.2293	0.026805	0.013402	11.68776	1.75	-1.40171	-2.12
i 11	0.1042	0.010901	0.003447	10.46237	0.1137	0.003552	0.001776	3.12321	0.1126	0.008013	0.004006	7.11575	-1.67	-1.38709	0.25
i 12	0.0745	0.008767	0.002772	11.76377	0.0891	0.006926	0.003463	7.77002	0.0950	0.008649	0.004324	9.10480	-2.95 *	-3.95 *	-1.05

Table 2. 95 % confidence interval of mean values of osteometric features on the femur of the edible dormouse (*Glis glis glis* L., 1766) from the different groups of animals (G1_ male adult, G2_ male adolescent and G3_ female adult individuals). Description of ostemetric parameters is given in Material and Methods and Fig. 1

Osteometric parameters	95% confidence interval of the mean values					
	Male animals				Female animals	
	G_1		G_2		G_3	
	Confidence -95.00%	Confidence 95.00%	Confidence -95.00%	Confidence 95.00%	Confidence -95.00%	Confidence 95.00%
V1	28.3235	30.5623	24.7094	26.8279	21.8323	26.3423
V2	27.7091	29.9035	23.9977	26.8896	21.5917	25.3256
V3	138.4733	148.0063	140.7721	147.9392	142.0147	153.8753
V4	5.9240	6.6762	5.0376	5.3071	4.2596	6.8191
V5	2.8135	3.3247	2.6847	3.1793	2.2090	3.2324
V6	2.0029	2.3831	2.0582	2.5298	1.7528	2.8479
V7	3.8062	4.1240	3.2234	3.4620	2.7486	3.2727
V8	5.0376	5.8666	3.8533	6.1907	4.4693	5.6700
i1	0.4529	0.5220	0.5306	0.6026	0.4507	0.5371
i2	0.3232	0.3736	0.3914	0.4963	0.3495	0.4856
i3	1.2848	1.5341	1.1218	1.4441	1.0850	1.2931
i 4	11.8359	14.2496	8.6793	9.5994	7.9245	14.7068
i 5	1.4864	1.6979	1.4903	1.6056	1.3834	2.3059
i 6	0.1128	0.1340	0.1634	0.1755	0.1526	0.1757
i 7	0.7027	0.8497	0.8231	0.9305	0.7476	1.0601
i 8	0.9700	0.9869	0.9695	1.0048	0.9499	0.9990
i 9	0.0154	0.0178	0.0211	0.0229	0.0179	0.0233
i 10	0.2035	0.2245	0.1976	0.2039	0.1867	0.2720
i 11	0.0964	0.1120	0.1081	0.1194	0.0999	0.1254
i 12	0.0683	0.0808	0.0781	0.1002	0.0812	0.1088

tion analysis applied, when the classification scores for the femur of a single specimen are computed, it should be classified as belonging to the group for which it has the highest classification score.

Discussion

The studies of skeletal (postcranial) bones, and particularly of the femur, in different animal species, including morphological examination and evaluation of quantitative and qualitative data about osteometric features, has led to the identification of the sex and age of the mammals studied (Onar *et al*. 2005, Vignc *et al*. 2000, Alpak *et al*. 2009, Jambresic, Paunovic 2002). The results obtained from the present evaluation of the femur variation in the edible dormouse strongly confirm that the development of its visible anatomy shows considerable variation and the evaluation of osteometric measurements provides morphological information about the sex and age of the animals. They also comply with the results of the morphometric studies of human femurs, which revealed racial and morphological differences between different human populations (Birdsell 1972, Ferembach 1966), and the variations in the upper femoral morphology between the racial groups may be significant in describing some morphometric modifications of their hip design (Atilla *et al*. 2007).

The present examination and statistical analysis of defined femoral features has established the initial norm of their variation described by the 95% confidence interval of their mean values in males (adult and adolescent) and females (adult) (Table 2).

The femoral osteometric characters are likely to be affected by the population variations in heredity and geographical factors related to the life style of *G. g. glis* from Central Europe, therefore, they can specify the animal population and allow comparison with other, different populations from areas where the species occurs. The results obtained indicate that femoral osteometric measurements in the edible dormouse provide a proper anatomical basis for examination of sexual and age dimorphism and population differentiation of this species within its range.

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