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MORPHOMETRICAL FEATURES OF THE HEAD SKELETON IN BROWN BEAR (*URSUS ARCTOS*) IN BULGARIA

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Abstract

MIHAYLOV, R., R. DIMITROV, E. RAICHEV, D. KOSTOV, K. STAMATOVA-YIOVCHEVA, D. ZLATANOVA and B. BIVOLARSKI, 2013. Morphometrical features of the head skeleton in brown bear (*Ursus arctos*) in Bulgaria. *Bulg. J. Agric. Sci.,* 19: 331-337

Fifteen craniometrical indices of the head skeletons in forty brown bears (*Ursus arctos*) found in Bulgaria were studied. Data for the greatest length of the head skeleton and condylobasal length as well as the results of those motivated us to propose that the greatest length of the head skeleton in Bulgarian population of brown bears is from 280 mm to 350 mm, and the condylobasal length is from 276 mm to 304mm. Our results for length skull (cranium) and face showed that face length were 35.33% of head skeleton length. The length, rostral and caudal width of the bone palate demonstrated that the palate widened in caudal direction. The basal length of the skull was with close value to bone palate length and it could be accepted that the caudal edge of the bone palate was approximately in the middle of the ventral surface of head skeleton. The zygomatic width of the specimens was 59% from the greatest length of the head skeleton.

Key words: craniometry, osteology, craniology, brown bear

Introduction

The brown bear in the Balkans is part of the nominate subspecies *Ursus arctos arctos* L., belonging to the completely European population (Ruskov and Markov, 1984). Some craniological data of bear head skeleton from Bulgarian mountains Rila and Pirin are similar to those of the brown bears (*Ursus arctos arctos*) from the European part of Russia (Ognev, 1931).

According to Spassov (1997), the South European bears are relict from the late Pleistocene in comparison to the North-East European population, spread throughout Europe in the beginning of Holocene.

Studies on weight variation of bears from Balkan Mountains and Rodopi Mountain are carried out by (Gunchev, 1989; Kirov, 1992).

Morphometric characteristics of brown bear in Central Alaska show that zygomatic width is more

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significant sign of age that can differentiate brown bear (Glenn, 1980).

Craniometrical analysis of cave bears in Europe, Urals and Caucasus stated that the studied bears could be divided into two groups – big and small (Baryshnikov and Puzachenko, 2011). Small cave bears show an intermediate position between the brown and cave bear, and it could be assumed to have the archaic nature of their common ancestor. The big cave bears show a well-differentiated head skeleton and approach by their characteristics to the modern brown bear.

Zavatsky (1976) had done craniometrical analysis of the brown bear to determine in accuracy the age and the sex.

Ohdachi et al. (1992) are doing detailed craniometrical analysis of brown bear from the island of Hokkaido in age and gender aspect. For the purpose of the research, the authors use 11 craniometrical parameters.

Virgl et al. (2003) present morphological differences between the two populations (Newfoundland and Mainland) of North American black bear (*Ursus americanus*). The values of craniometric indices are higher in the population of bears Newfoundland and more variable in the female bears, compared to the male.

Meijaard (2004) present significant metric differences in the head skeleton in different populations of the Malaysian sun bear.

For the first time García et al. (2007) examined some endocraniological features (volume, surface and shape of the brain cavity, and frontal sinuses) of ancient bear (*Ursus deningeri*), with a view to use these data in the reconstruction of Ursidae phylogeny.

Few reports for of cranial cavity volume in the brown bear (*Ursus arctos* L.) were a motif to make the study that could enrich the craniological information for this species.

Material and Methods

Fifteen craniometrical indices of the head skeleton of fourteen brown bears (*Ursus arctos*) from Bulgarian mountains – Balkan Mountains and Rodopi Mountain were examined. They were owned by the craniological collections of the Department of Animal Morphology, Physiology and Nutrition and the Department of Animal breeding - non-ruminants and other animals in Faculty of Agriculture and the Department of Veterinary Anatomy, Histology and Embryology in Faculty of Veterinary Medicine, Trakia University, as well as private collections.

Bone objects were processed by method of Sarma (2006). Linear values of the head skeleton parameters were measured using calipers to the nearest 0.1mm (Petrov et al., 1990; Yamaguchi et al., 2009).

The studied metrical parameters of the scull and facial skeleton were as following:

1. VCC - volume of the cranial cavity, which was measured by filling with sand through the foramen magnum, calibrated at 3 mm. The scull openings were covered with cotton in advance. The sand from the scull cavity was emptied into measuring cylinder and the cavity volume quantity was indicated (Sarma, 2006; Yamaguchi et al., 2009; Mihaylov and Dimitrov, 2010).
2. GL - greatest length of the head skeleton (the distance from the rostral surface of the upper medial incisors to the caudal part of the occipital ridge) (Gunchev, 1989; Ohdachi et al., 1992) (Figure 1).
3. ILCC - inner length of the cranial cavity (the distance from *lamina cribrosa* to the middle of the dorsal edge of *foramen magnum*) (Sarma, 2006; Mihaylov and Dimitrov, 2010) (Figure 3).
4. LHP - length of the palate bone (the distance from the caudal surface of the upper first incisive to the caudal edge of the hard palate) (Gunchev, 1989; Ohdachi et al., 1992) (Figure 2).
5. CBL – condylobasal length of the head skeleton (the distance from the cranial surface of the upper first incisive to the caudal surface of the occipital condyles) (Gunchev, 1989) (Figure 2).
6. BLCC- basal length of the cranium (the length from the caudal edge of the hard palate to the caudal surface of the occipital condyles) (Petrov et al., 1990) (Figure 2).
7. DLFS – dorsal length of the face (the distance from the cranial surface of the upper first incisive to the caudal end of the nasal bones) (Petrov et al., 1990) (Figure 1).
8. DLCS – dorsal skull length (the distance from the caudal end of the nasal bones to the caudal part of the occipital edge) (Petrov et al., 1990) (Figure 1).

9. RWHP – rostral width of the bone palate (the distance between the medial surfaces of the upper canines) (Petrov et al., 1990) (Figure 2).

10. CWHP – caudal width of the bone palate (the distance between the caudomedial surfaces of the last upper molars) (Petrov et al., 1990) (Figure 2).

11. ZW – zygomatic width of the head skeleton (the distance between the lateral surface of the zygomatic arches) (Petrov et al., 1990; Ohdachi et al., 1992) (Figure 1).

12. WMOA – width between medial eye angles (the distance between the orbital edges of the lacrimal bones) (Petrov et al., 1990) (Figure 1).

13. WCC – skull width (the distance between the prominating surfaces of *squama temporalis*) (Petrov et al., 1990; Ohdachi et al., 1992) (Figure 1).

14. HCC – skull height (the distance from the ventral surface of the body of sphenoid to external sagittal crest) (Sarma, 2006; Mihaylov and Dimitrov, 2010) (Figure 3).

15. IS – Index of Schauenberg (the ratio of the greatest length of the head skeleton GL to the volume of the cranial cavity VCC) (Schauenberg, 1971; Mihaylov and Dimitrov, 2010).

The terminology used was consistent with the Nomina Anatomica Veterinaria (2005).

Statistics have processed the data using software Date Analysis of the StatMost for Windows (1994).

Results and Discussion

The greatest length of the head skeleton had an average of 319.05±13.08 mm (Figure 1, Table 1). This corresponded to the data of Kirov (1992) who found that the length of the head skeleton was 348 mm in male and 306 mm in female bears from Rhodope Mountains, and Gunchev (1989) presenting data on the length of the head skeleton of brown bear in the Balkan Mountains (329 mm in males and 281 mm in females).

The condylobasal length of was 292.83±9.03 mm and resembled the obtained by Gunchev (1989) for the brown bear in the Balkan Mountains (304mm in males and 276 mm in females) (Figure 2, Table 1).

Data for the greatest length of the head skeleton of and condylobasal length, and the results for the same

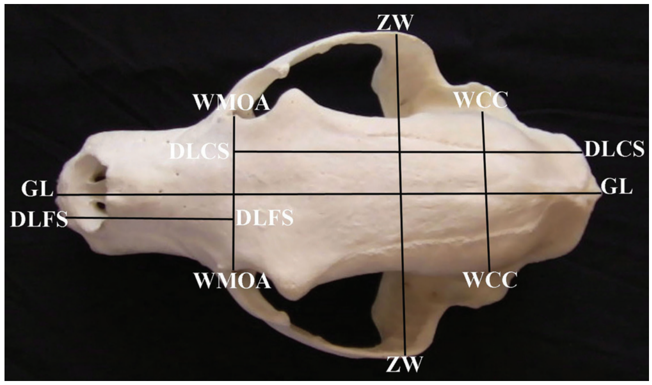

Fig. 1. Studied craniometrical parameters:
GL - greatest length of the head skeleton; WCC - width of the skull; ZW - zygomatic width; DLFS – dorsal length of the face; DLCS – dorsal length of the skull; WMOA - width between the medial eye angles. (Dorsal aspect)

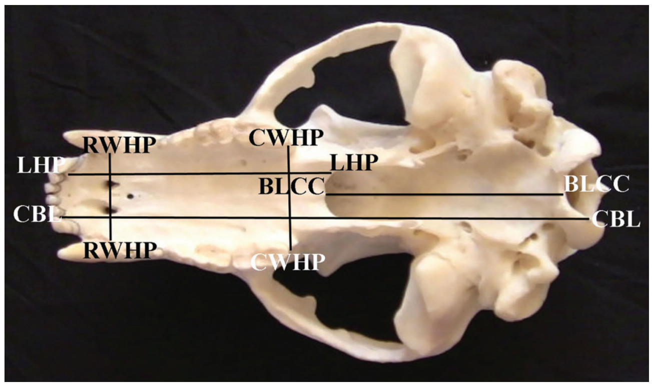

Fig. 2. Studied craniometrical parameters:
RWHP - rostral width of palate bone; CWHP - caudal width of the palate bone; LHP - length of the palate bone; CBL - condylobasal length of the head skeleton; BLCC - basal length of skull. (Ventral aspect)

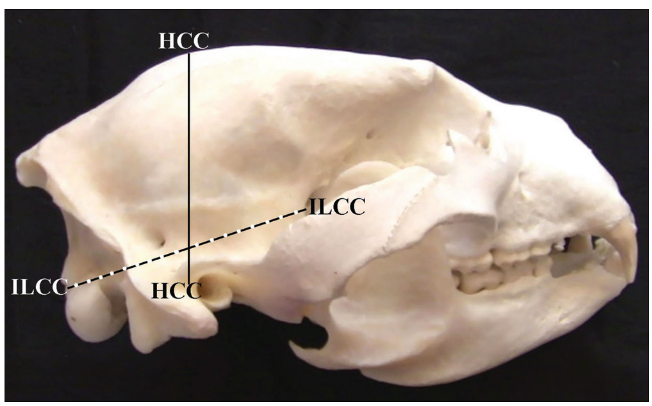

Fig. 3. Studied craniometrical parameters:
HCC - height of the skull; ILCC - inner length of the cranial (skull) cavity. (Lateral aspect)

items presented by Gunchev (1989) and Kirov (1992) gave us grounds to suppose that the greatest length of the head skeleton of Bulgarian population brown bears ranged from 280 mm to 350 mm, and condylobasal length ranged from 276 to 304 mm (Figures 1 and 2, Table 1). These parameters were closest to data (from 279 mm to 322 mm for the greatest head skeleton length and from 258 mm to 295 mm for condylobasal length) submitted by Ognev (1931) for brown bears living in the Kuban, Western Transcaucasia and Small Caucasus, presented by him as *Ursus arctos caucasicus dinnik*.

Our results for the greatest length of the head skeleton (319.05±13.08 mm) (Table 1) differed from the Glenn (1980), who had found a value of 473 mm for length in male and 403mm for the female brown bears from Central Alaska, as well as Ohdachi et al. (1992) who determined measurements of 374 mm for the head skeleton length in male and 292 mm in female brown bears in the island of Hokkaido.

Data for the condylobasal length (292.83±9.3mm) (Figure 2, Table 1) differed from Zavatsky (1976), who gave values for the same parameters in the male brown

Table 1
Values of the investigated cranial indices

Number of skulls examined	Parameters	Range	Minimum	Maximum	Mean	Standard error	Standard deviation	Coefficient of variation
14	VCC-*Volume of the cavum cranii* (cm^3)	37	323	360	343	5.66	13.86	4.04
14	GL-*Greatest length of the head skeleton (mm)*	90	280	370	319.05	13.08	32.03	10.04
14	ILCC-*Internal lenght of the cavum cranii (mm)*	27	125.4	152.4	138.73	4.19	10.26	7.4
14	LHP-*Length of the palatum osseum (mm)*	33.4	141	174.4	152.75	6.09	14.86	9.73
14	CBL-*Condylobasal length (mm)*	60	270	330	292.83	9.3	30.11	10.28
14	BLCC-*Basal length of the cranium (mm)*	40	132	172	145.23	6.07	14.86	8.75
14	DLFS-*length of the facial skeleton (mm)*	33.1	87.3	120.4	112.75	6.12	14.98	14.4
14	DLCS-*length of the cranial skeleton (mm)*	65.6	189.4	255	207	8.66	28.56	9.8
14	RWHP-*Rostral width of the palatum osseum (mm)*	22.7	62.3	85	71.27	3.51	8.6	12.07
14	CWHP-*Caudal width of the palatum osseum (mm)*	18.07	76.9	95.6	82.22	2.81	6.87	8.36
14	ZW-*Zygomatic width (mm)*	62.6	161.2	223.8	189.5	9.54	13.37	9.54
14	WMOA-*Width between medial ocular angles(mm)*	16	69	85	78.45	2.47	10.96	9.34
14	WCC-*Width of the cranium (mm)*	66.9	93.2	160.1	107.23	5.65	26.09	24.33
14	HCC-*Height of the cranium (mm)*	10.6	85.4	96	91.23	1.6	3.91	4.29
14	IS-*Iindex of Schauenberg*	0.02	0.94	0.96	0.95	0.01	0.01	0.14

VCC - volume of cranial cavity; GL - greatest length of the head skeleton; WCC - width of the skull; ZW - zygomatic width of the head skeleton; DLFS – dorsal length of the face; DLCS – dorsal length of skull; WMOA - width between the medial eye angles; RWHP - rostral width of the bone palate; CWHP - caudal width of bone palate; LHP - length of the palate bone; CL - condylobasal length of the head skeleton; BLCC - basal length of skull; HCC - height of the skull; ILCC - inner length of the cranial cavity; IS-index of Schauenberg bears 15 to 18 years of age from the middle Yenisei region in Russia (from 333 mm to 349 mm).

The results for the length of the cranium (207±8.66 mm) and the length of the face (112.75±6.12 mm) (Figures 1 and 2, Table 1) showed that the length of the face is 35.33% of the head skeleton length (Figure 1). The data differed from the one published from Gunchev (1989) which show the length of the cranium 182.12 mm, and the length of the face 164.94 mm. According to the author, the length of the face was 50% of the head skeleton length.

Length (152.75±6.09 mm), rostral width (71.27±3.51 mm) and caudal width (82.22±2.81 mm) of the bone palate (Figure 2, Table 1) demonstrated that the palate was extending to caudal direction with 10 mm. Our result for the bone palate corresponded to the one from Gunchev (1989) (156.71 mm). That differed from the results of Ohdachi et al. (1992), which showed the length of the bone palate in the male brown bears from the island of Hokkaido was 192.7 mm and in the females 157 mm. It is naturally to be accepted as with the account to the greater values in length of the head skeleton and the condilobasal length of the bears in the island of Hokkaido, compared to the Bulgarian ones.

Basal skull length was 145.23±6.07 mm (Figure 2, Table 1). It was close in value to the length of the bone palate (152.75±6.09mm) and could be assumed that the caudal edge of the bone palate was approximately in the middle of the ventral surface of the head skeleton (Figure 2).

Zygomatic width was 189.5±9.54 mm and represented 59% of the greatest length of the head skeleton (Figure 1, Table 1). According to Glenn (1980), it is a very significant feature in comparison to the length of head skeleton, which with aging could differentiate the brown bear. According to us, the ratio of zygomatic width and the greatest length of the head skeleton determined the bear head skeleton shape (long or oval). According Ohdachi et al. (1992), this ratio of the head skeleton in bears from the island of Hokkaido is 60%, and according to Glenn (1980) for bears in Central Alaska, it is 66%. Therefore, we propose the Bulgarian brown bears and those from the island of Hokkaido were with nearly equal proportions and elongated skeleton head than these from Central Alaska.

Width measured between the medial eye angles was 78.45±2.47 mm. Bearing in mind that this distance is in the base of the nose and comparing it with the length of face, length, rostral and caudal width of the bone palate, it can be assumed that nose bone base in Bulgarian bear is approximately equally wide at the top and the base (Figure 1).

The width of the cranium was 107.23±5.65 mm and represented 56.59% of the zygomatic width (Figure 1, Table 1). The height of the cranium was 91.23±1.6 mm (Figure 3) (Table 1). The internal length of the cranium was 138.73±4.19 mm (Figure 3, Table 1). The above parameters with dorsal length of skull and its basal length determined the volumetric capacity of the cranial cavity. The volume of the cranial cavity was 343±5.66 cm^3 (Table 1). This is an important indicator because the cranial cavity fits brain. It is known that the bigger the brain cavity, the brain is bigger, as a relatively bigger brain to the body size could give to the individual's advances as behavior adaptability (Sol et al., 2008).

Such advanced behavioral adaptability is being predicted to function in physical favor of the individuals when exposed to new or changing conditions of the environment. The link between the size of the brain and the survival rate of the mammals in new environment proved that the mammals with larger brains to the body weight are predetermined to success than those with smaller brains. Sol et al. (2008) defended the hypothesis that the brain growth could provide an advantage for survival in new environments. The hypothesis underscores the asset of the larger brains when forming adaptive responses to new ecological challenges and future revealing of those mechanisms would give opportunities for further investigations.

The submissions done by Mihaylov and Dimitrov (2010) showed the tiger (*Panthera tigris*) had a bigger volume of cranial cavity (360 cm^3) compared to the brown bear (*Ursus arctos* L.) (343 cm^3). The volume of the brown bear cranial cavity was 36% greater than the volume of cranial cavity (220 cm^3) in lions (*Panthera leo*). The bigger volume of the brown bear cranial cavity, as compared to the lion, was probably the reason for the prevalence of brown bear in geographical terms. This fact supports the hypothesis of Sol et al. (2008) for the benefit of big brain in the construction of adapted responses to new environmental challenges.

Index of Schauenberg (Schauenberg, 1971; Mihaylov and Dimitrov, 2010) was with a value of 0.95 (Table 1). It was extremely important to us, as it would have an effect in determining of brown bear's belonging to different populations.

Our results of the studied fifteen metric parameters of the cranial and facial skeleton of the brown bear in Bulgaria showed and added the existing information for the craniological specifics of this species and could be of help when performing reconstruction and identification of the head skeleton.

Conclusion

The results for the greatest and condylobasal length of the head skeleton, gave us the base to presume our data are closest to those for brown bears living in Kuban, Western Transcaucasia and Small Caucasus.

Head skeleton in brown bear in Bulgaria is relatively elongated, narrow and low and with more significant development of cranial skeleton.

Basal length of skull and the inner length of the cranial cavity are close craniometrical indices with close values.

Head skeleton in brown bear is almost with the same length in dorsal and ventral aspect.

Zygomatic arches in brown bears are relatively well developed and highly prominent in lateral aspect.

Brain portion of the brown bear head skeleton is almost twice more developed than the face part.

The bone palate of the brown bear in Bulgaria is long and narrow, extended in the caudal direction.

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