

## Body mass and measurements of the European bison during postnatal development

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Kraśińska M. and Kraśiński Z. A. 2002. Body mass and measurements of the European bison during postnatal development. *Acta Theriologica* 47: 85–106.

Body mass of the European bison *Bison bonasus* (Linnaeus, 1758) was determined for 152 animals (86 males, 66 females) from captive breeding centre in Białowieża and for 492 (248, 244) animals from the free-ranging herd in the Białowieża Forest. Body measurements were taken for a total of 472 bison (204, 268). Age-related changes in body mass and measurements of 375 bison (165, 210) were analysed. Bison body mass was significantly correlated with age. Captive bison were heavier than those from a free-ranging herd. Measurements showed the changes in bison body structure in the postnatal development. All measurements were highly correlated with age and mass of the animals and increased most intensively during the first year of life. Sex-related differences in body mass and measurements were most pronounced in bison 3 years old. Physical development of females ends at the age of 5 years, and that of males at the age of 7 years.

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*Key words:* *Bison bonasus*, growth, changes of body mass, dimensions

### Introduction

The earliest information on body mass of European bison *Bison bonasus* (Linnaeus, 1758) can be found in the paper by Bojanus (1827). Relatively extensive data concerning body mass and measurements of bison from the last free-ranging population in the Białowieża Forest at the beginning of the 20th century were presented by Wróblewski (1927). Other publications referring to *B. bonasus* have provided data on body mass and selected measurements of single specimens, particularly adults (Flerov 1932, Mohr 1952, Heptner *et al.* 1966). Data concerning body mass and measurements of bison from different age-sex groups living in captivity can be found in a number of reports of the European Bison Research Centre in the Department of Animal Anatomy of Warsaw Agricultural University (Empel and Roskosz 1963, Pytel 1969, Roskosz *et al.* 1979, 1980, Kobryńczuk and Kobryń 1981, Pucek 1986). The documentation has been collected during numerous studies on bison anatomy, as in the case of captive bison from Russia (Sablina 1975).

Capturing bison from the population of the Białowieża Forest followed by annual culling allowed us to gather information about body mass and measurements

of the animals in different age-sex groups. It was thus possible to analyse age-related changes in the specimens from a free-ranging population in the Białowieża Forest (BF) and to compare them with data obtained for bison living in a captive breeding centre in Białowieża.

### Material and methods

Data referring to body mass and measurements of the bison living in captive breeding centres and of those from a free-ranging herd caught to send to other centres, as well as of dead animals, were collected by the Białowieża National Park (BNP). From the beginning of the 1980s, the animals were weighed and measured by the workers of the Białowieża National Park and the Mammal Research Institute PAS in Białowieża. The data analysed in this paper cover the years 1961–2000. Bison living in the free-ranging herd feed on natural food, from spring to late autumn, moving freely within the Białowieża Forest. During winter, they use hay left for them in permanent feeding sites. In captive breeding centres, bison are fed on crushed oats with the addition of corn and hay given *ad libitum*, and a small amount of fodder beet in winter. In captive breeding, they can also graze on large feeding glades covered with grass. Once a week they receive willow (*Salix caprea*) twigs.

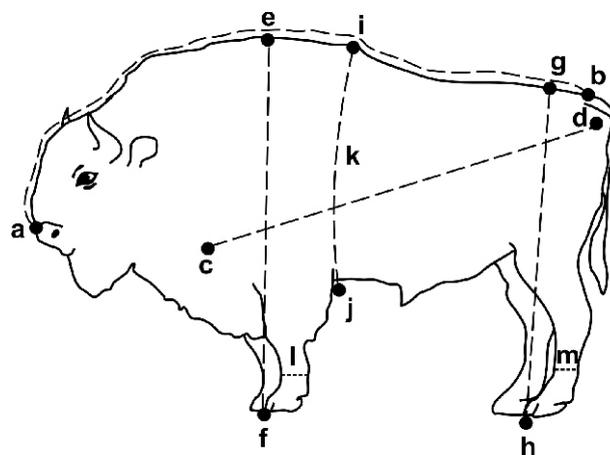
Body mass was determined for 152 bison (86 males, 66 females) coming from the Białowieża breeding centres (C), and for 492 (248, 244) animals from a free-ranging herd (F) in the Białowieża Forest. Measurements were taken of 472 (204, 268) bison of all age classes, from the free-ranging herd and captive bison. Body mass was determined separately for the free-ranging and captive bison. Body measurements were analysed jointly for the two groups, as the number of young bison in both groups was small, and in those over the age of 1 year no significant differences were found between the two groups. Data on body mass for 152 captive bison and 492 animal from the free-ranging population and measurements of 472 bison were used for calculations. Age-related changes of body mass and measurements were calculated only for 375 (165, 210) with full data available on body mass and measurements. The studied bison ranged from new-born animals to 23-year-old females and 17-year-old males. Animals in age class 0 (new-born) came exclusively from captive breeding centres and were either stillborn or those that died within 0–3 days after birth. Data on 12 dead bison (in good condition), and 21 males from the age class 6-years weighed alive, were also included in the analysed sample. Culling (for limiting population numbers) was carried out in the Białowieża Forest mainly during winter from December to March, and only occasionally at other times. Therefore, data concerning the first months of life and those for 10–12 months old are scarce. Only the data referring to the specimens found in good condition (non-emaciated) were analysed. The animals were divided into age classes starting from 0 (at birth) at monthly intervals up to the age of 12 months, then yearly. Adult animals (6-years old) were pooled into one class, because there were no significant differences in the mean body mass and measurements of females 4 years old, and males 6 years old.

Age of the captive bison was precisely determined on the basis of breeding documentation. Age of the bison from free-ranging herd could have been precisely determined only up to 4 years old on a basis of body structure and development of horns and teeth. Age of bison 6 years old was estimated with lower degree of accuracy. Age of bison is given in months in tables and figures, but in the text we used years for animals older than 12 months. Body mass of the culled animals was determined on a cart-weighing scale, and of the calves on a special weighing scale (up to 200 kg). The bison to be transported were weighed alive in a previously tared, wooden cage on a cart-weighing scale with an accuracy to 1 kg. Body measurements were taken only of dead animals according to the rules accepted for domestic cattle (Ruszczyc 1955, Weber 1957, Olbrycht and Nowicki 1961) with the use of Lidtin rod and tape measure to the nearest cm.

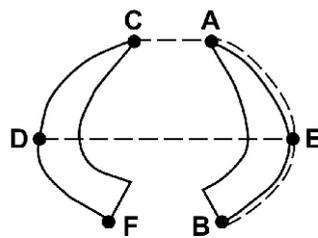
The following body measurements were taken:

1. Body length – distance from the top margin of the muzzle to tail base, measured with a tape along the spine (Fig. 1: a–b);
2. Oblique body length – distance from shoulder joint to *tuber ischiadicum* (measured with a rod) (Fig. 1: c–d);

3. Heart girth – measured with a tape immediately behind the *scapula* (Fig. 1: k);
  4. Withers height – vertical distance from the top of the withers to *facies solearis capsula unguiae* of the fore leg (measured with a rod) (Fig. 1: e-f);
  5. Sacral region height – measured by a rod along the perpendicular line passing through the middle of the *articulatio genus* to *facies solearis capsula unguiae* of the hind leg (Fig. 1: g-h);
  6. Thorax depth – distance from the dorsal line (immediately behind the rear angle of shoulder blade) to the point at the level of the medial line of the sternum (measured with a rod) (Fig. 1: i-j);
  7. Fore cannon girth – measured with a tape measure at the narrowest plane of the metacarpus (Fig. 1: l);
  8. Hind cannon girth – measured with a tape measure at the narrowest plane of the metatarsus (Fig. 1: m).
- Six horn measurements were taken from 277 bison (119 males and 158 females) with properly developed horns:
1. Breadth between horns – distance between horn bases at upper points (Fig. 1: F-B);
  2. Length of horns – measured with a tape along the external curve of the horn from basis to end (Fig. 1: A-B);
  3. Distance between horn ends (Fig. 1: A-C);
  4. Maximum distance between horn curves (Fig. 1: D-E);



Body measurements



Measurements of horns

Fig. 1. The main measurement points in the study on European bison body size. Explanation of lettering and description of measurements are given in the text.

5. Circumference of the horn at its base;
6. Circumference of the horn in the middle of its curve.

## Results

### Body mass

The mean body mass of male bison at birth was 28 kg (SD  $\pm$  6), and that of females 24 kg  $\pm$  4, but the difference was not statistically significant (Table 1). Body mass of bison of both sexes was significantly correlated with age and

Table 1. Body mass (in kg) of European bison during postnatal development (total  $n = 640$ ). F – animals from free-ranging herd, C – animals from captive breeding centres. Statistical differences between male and female groups: \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ , ns – non-significant (Student  $t$ -test:  $t = 3.185$  to  $17.559$ ); “–” – not tested

Age (months)	Origin	Males					Females					Statistical difference
		$n$	Mean	SD	Min	Max	$n$	Mean	SD	Min	Max	
0	C	18	28	6	16	35	16	24	4	15	33	ns
1	C	4	52	29	32	83	1	30	–	–	–	–
2	F	2	41	–	35	48	–	–	–	–	–	–
3	F	10	53	13	32	70	8	47	14	32	70	ns
4	F	9	76	17	46	96	8	66	14	43	81	ns
4	C	2	83	–	82	84	2	66	–	65	67	–
5	F	11	82	15	48	108	16	72	16	48	100	ns
6	F	6	99	13	90	160	23	91	20	52	120	ns
6	C	3	143	15	131	160	2	111	–	105	118	–
7	F	14	101	15	78	140	18	97	16	62	148	ns
7	C	1	150	–	–	–	3	129	16	120	148	–
8	F	9	103	15	70	180	24	111	26	70	190	ns
8	C	2	170	–	130	180	2	159	–	148	170	–
9	F	12	109	15	80	140	9	124	20	96	146	ns
11	C	2	187	–	155	220	1	200	–	–	–	–
12	F	7	124	38	80	170	5	119	17	96	140	ns
12	C	2	175	–	130	220	3	190	26	170	220	ns
24	F	40	220	49	130	300	25	213	42	170	280	ns
24	C	10	331	74	220	453	7	228	64	170	306	**
36	F	18	303	50	240	390	14	252	37	150	310	**
36	C	9	387	71	310	502	3	227	11	220	240	**
48	F	14	366	74	260	430	10	341	89	260	458	ns
48	C	6	502	97	380	609	3	400	28	378	432	ns
60	F	15	467	77	345	660	8	407	44	340	460	ns
60	C	2	591	–	572	610	2	439	–	420	458	–
72	F	79	634	95	436	840	76	424	44	340	540	***
72	C	25	747	59	580	920	19	460	82	320	640	***

increased proportionally to ageing ( $p < 0.0005$ , Fig. 2). To find out when the growth of bison ends, we compared mean body masses of females 3 to 6 years old and males 5 to 8 years old. The mean body mass of 4-years-of females was significantly bigger than that of females 3 years old (Student  $t$ -test:  $t = 9.806$ ,  $p = 0.001$  for animals from captive breeding and  $t = 3.390$ ,  $p = 0.003$  for free-living). The mean body mass of 5-year-old females from free-ranging herd did not differ from those 4 years old ( $t = 1.934$ ,  $p = 0.071$ ). The mean body mass of females 6 years old of groups (C and F) did not differ significantly from those 5 years old ( $t = 0.370$ ,  $p = 0.715$  and  $t = 1.000$ ,  $p = 0.320$ , respectively). Also, Fig. 2 shows that the most intensive increase of female body mass took place until the age of 5 years, and it was very slow later on.

The mean body mass of bulls 6 years old from both captive breeding centres and free-ranging herd was significantly bigger than those of 5-year-old males ( $t = 6.484$ ,  $p < 0.001$ ,  $t = 3.069$ ,  $p = 0.005$ ), but it did not differ from those of males 7 and 8 years old ( $t = 0.677$ ,  $p = 0.506$  and  $t = 1.158$ ,  $p = 0.255$ , respectively). Body mass of males increased up to the age of 7 years and did not grow further (Fig. 2). Interestingly, however, body mass of captive bison grew slowly almost to the end of their life, whereas body mass in some old males from the free-ranging population (estimated age 13–17 years) decreased compared to younger adult males (Table 1).

European bison doubled their body mass at the age of about 3 months (Table 1). In young bison under the age of 2 years, the mean body mass of males and females did not differ significantly. The first significant differences between of the mean body masses of males and females were observed in captive bison at the age of 2-year, and in free-ranging bison at 3 years of age. The most pronounced sexual dimorphism was observed in bison 6 years old (Table 1).

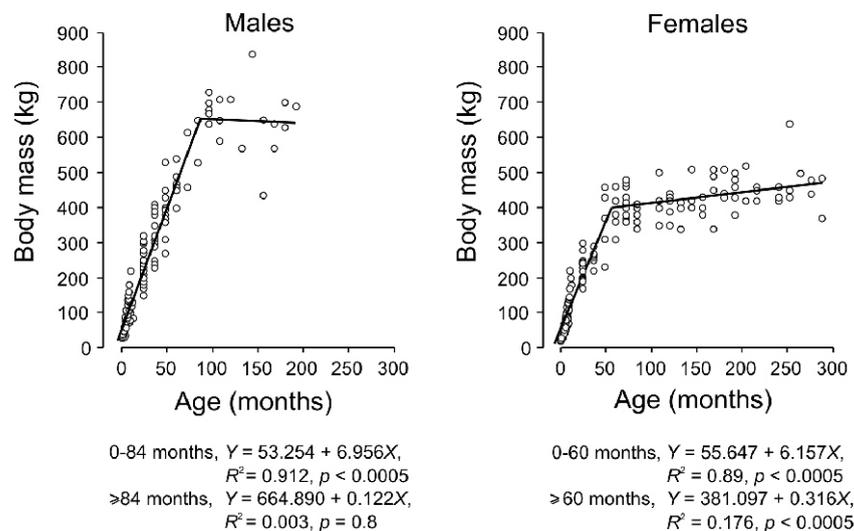


Fig. 2. Body mass of European bison (165 males and 210 females) in relation to age.

Table 2. Statistical significance of differences in mean body mass of European bison originating from free-ranging population (F) and captive breeding centres (C). Calculations based on data shown in Table 1. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ , ns – non-significant (Student  $t$ -test:  $t = 2.208$  to  $5.777$ ); “–” – not tested.

Age (months)	Males F versus C	Females F versus C
6	**	ns
7	–	**
8	***	*
12	ns	**
24	***	ns
36	***	ns
48	**	ns
60	*	ns
72	***	*

Furthermore, males living in captivity had significantly greater body mass compared to males of the same age originating from the free-ranging herd (Table 2). In females, significantly bigger body mass of captive-bred individuals was observed in young (7–12 months) and adult (6-years) animals only (Table 2).

The maximum body masses recorded were 920 and 840 kg for males (C and F, respectively) and 640 and 540 kg for females (C and F). It cannot be excluded, however, that still larger animals may be found in the free-ranging population.

### Body measurements

Changes in the proportions of bison body structure during the postnatal development were described based on the changes in body measurements from birth to 6 years of age. All values of bison body measurements analysed were significantly correlated with age ( $p < 0.0005$ , Fig. 3). The increase in dimensions with age showed non-linear correlations. The highest rate of the increase occurred during the first 12 months of life (Fig. 3). In later years, growth rate was slower and

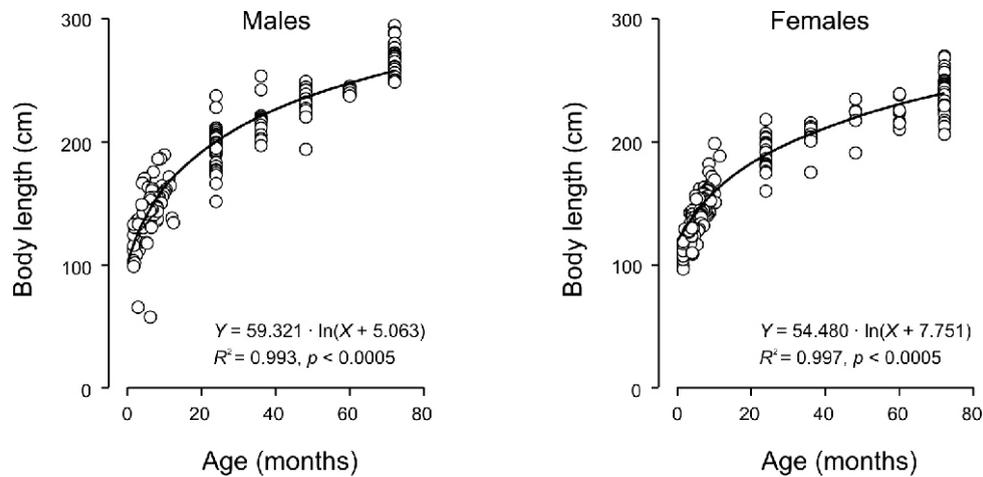


Fig. 3. Body measurements of European bison (165 males and 210 females) in relation to age.

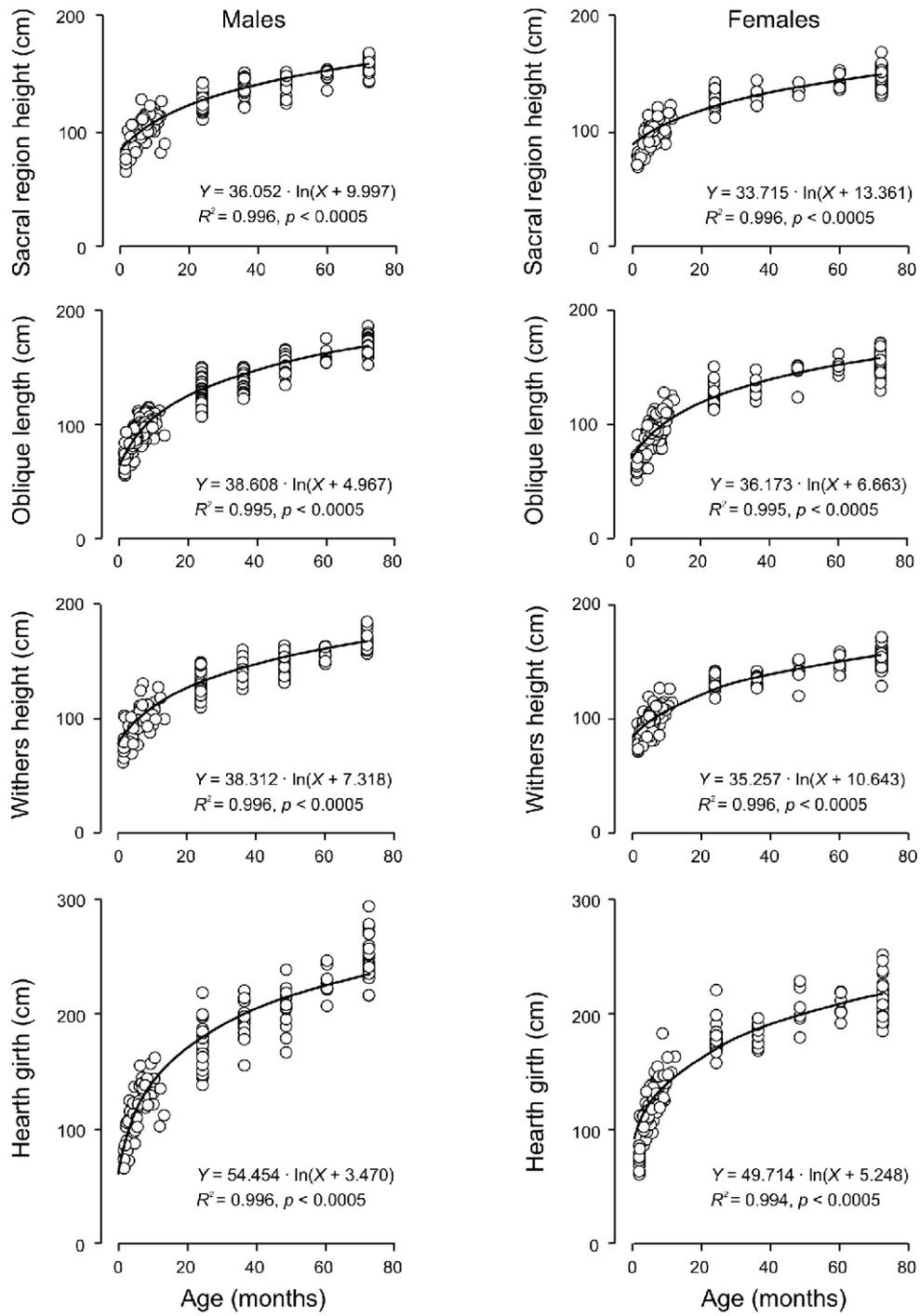


Fig. 3 – concluded.

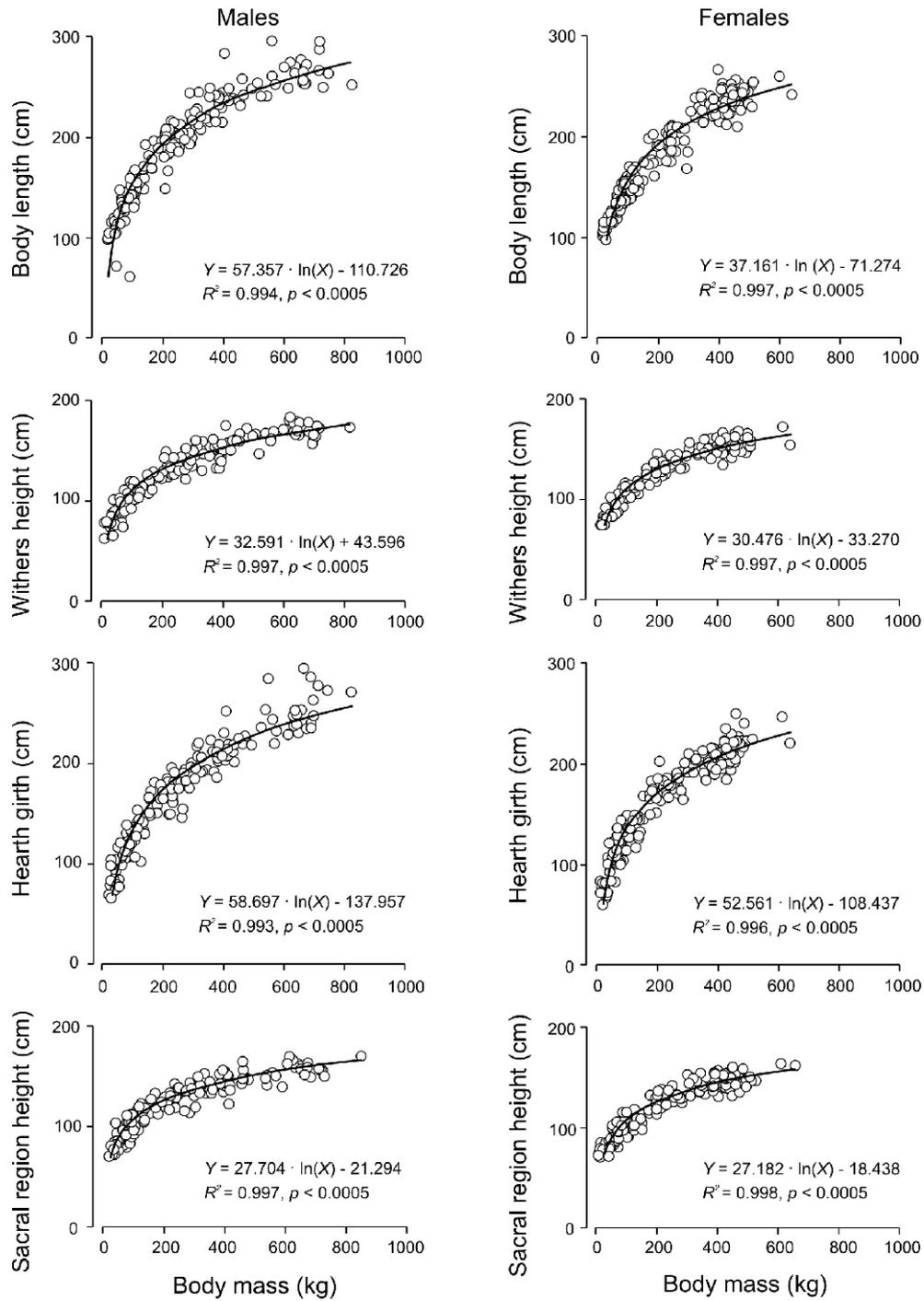


Fig. 4. Body measurements of European bison (165 males and 210 females) in relation to body mass.

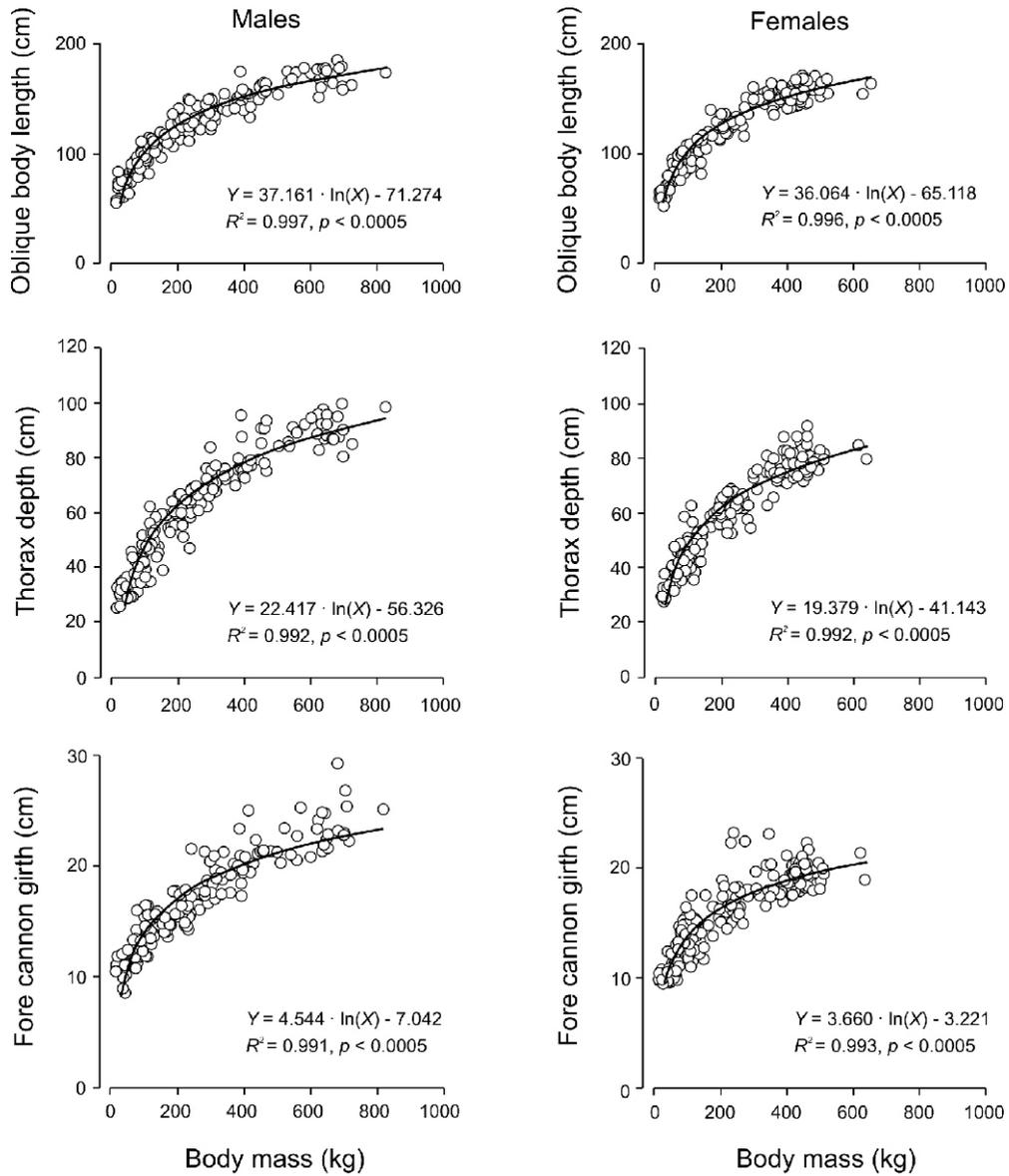


Fig. 4 – concluded.

ended at the age of 5–6 years. The rate of increase in body dimensions was higher in males than in females after the first year of age.

The body measurements of bison were also significantly correlated with their body mass ( $p < 0.0005$ ). All measurements showed non-linear correlations (Fig. 4). The greatest increase in body measurements was observed until bison attained

200 kg. The maximum values of body measurements were obtained at the age of 5–6 years.

The European bison silhouette is characterised by the huge forequarters and relatively small rump. The hump, formed by the elongated spinal processes of the thoracic vertebrae surrounded with powerful muscles, gives adult bulls an impressive appearance. The hump in cows is smaller, and adult cows are slighter built than bulls.

At birth, bison of both sexes were characterised by short and high trunk. At the age of 8–10 months the height and length of the trunk were similar in size. The trunk of females was short throughout the development (approximating withers height), while males had a relatively longer trunk.

The maximum body measurements of 6-year-old bulls were 188 cm for withers height, 300 cm for body length, 193 cm for oblique body length and 280 cm for hearth girth. In adult cows the corresponding maximal measurements were 167 cm (withers height), 270 cm (body length), 172 cm (oblique body length), and 246 cm (hearth girth) (Table 3\*).

At birth, body measurements of bison males were larger than those of females, but the differences were not statistically significant (Table 3\*), suggesting that sex-related differences in bison structure were not pronounced at birth. Statistically significant sexual dimorphism in body sizes of bison was observed from the age of 2 to 5, most frequently 3 years (Table 3). All body measurements of male bison 6 years old were significantly greater than those of females, just like horn measurements (Tables 3 and 4\*).

Calves were born with traces of horn buds, which grew fast reaching about 2 cm by the age of 2 months. Sex-related differences in both size and shape of horns were pronounced earlier than in the body structure. Most measurements of horns in 2-year-old bulls were significantly larger than in 2-year females, and differed in shape (Table 4\*). The maximum male horn sizes were: length 65 cm, distance between ends 75 cm, the maximum breadth 79 cm and circumference at horn base 36 cm, for female the respective measurements being 52, 55, 70, and 28 cm (Table 4\*). The horns of adult bulls were longer, thicker and set wider apart than those of females. Horn curves of bulls were sickle-shaped and perpendicular to the *planum frontalis* of the skull, while in females horn ends bended backwards. Horns are usually black, however, specimens with ivory colour at tips can be encountered in the free-ranging herd in the Białowieża Forest.

## Discussion

The available literature contains little information on body mass of European bison from the historical free-rangigng population. Data usually refer to single specimens, but sometimes provide no reference to their sex or age (Bojanus 1827,

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\* Tables 3 and 4 are placed at the end of the paper (pages 102–106).

Łoziński 1878 cited in Roskosz *et al.* 1980, Kartsov 1903, Flerov 1932, Mohr 1952, Heptner *et al.* 1966). Unfortunately, the data on body mass of a few dozen of male and female bison of different age provided by Wróblewski (1927), cannot be considered because – as the author wrote in the first chapter of his monograph – body mass was estimated based on body measurements. The fact that the values reported by Wróblewski (1927) differ significantly from those we found in the corresponding age-sex class, may be the result of incorrect estimation of age and body mass. Also it is rather unlikely that bison living in the Białowieża Forest at the beginning of the 20th century were considerably smaller than at present.

Whenever possible we compared our data with other information on body mass and measurements of European bison as well as American bison *Bison bison* (Tables 5–10). The mean and maximal body masses of new-born captive bison are representative for this species despite the fact that the data come from stillborn or dead calves. With the exception of two calves (with low body masses) all new-born were well developed. Moreover, 40% of 18 males calves were large (29–34 kg) and died in effect of a difficult and complicated parturition. In addition, 4 new-borns (3 males and 2 females) were killed by other bison just after birth. The body masses of new-born American bison ranged from 13 to 32 kg (Table 6), so it was similar to or even lower than that of European bison. Thus, the small size of new-borns (3–5.5% of adult body mass) seems typical for the two species of *Bison*. The fact that adult captive bison attained higher body masses than free-living animals and slow increase of their mass lasted throughout the whole life of captive bison may be explained by the abundant supply of high quality food in captivity.

Abundant earlier documentation on body mass of bison living in various reserves can be found in publications on European bison's anatomy (Pytel 1969,

Table 5. Earlier literature data on body masses of European bison. All data from free-ranging bison from Białowieża Forest. ? – no data.

Age	n	Body mass (kg)		Source
		Mean	Min–Max	
Males				
0–3 days	2	23	20–25	Wróblewski 1927
Adult	?		480–720	Łoziński 1878 cited in Roskosz <i>et al.</i> 1980
Adult	3	664	524–778	Flerov 1932
Old			–850	Mohr 1952
Adult	?	500–515	–850	Heptner <i>et al.</i> 1966
Females				
Adult	1	540		Flerov 1932
Sex and age unknown				
Adult ?	3	569	403–717	Bojanus 1827

Sablina 1975, Roskosz *et al.* 1980, Kobryńczuk and Kobryń 1981, Pucek 1986). The results are similar to those on body mass of bison living in reserves in Białowieża in the second half of the 20th century, the values being much higher compared to the body mass of free ranging bison in the corresponding age-sex class (Tables 5).

Changes in body mass of European bison (free-living animals from Białowieża Forest) were compared with those of the free-ranging American bison (Table 6). During the first years of life, American bison of both sexes grow markedly faster than European bison. One-year-old males of American bison attained, on average, 43% of adult body mass, 2-year-old males 60%, and 30-year-old males 67%, whereas the corresponding figures for male European bison were 20, 35, 48% (based on data from Table 6). The final body mass of adult males was similar in both species, although maximal recorded values were markedly higher in the European bison (Table 6).

Table 6. Comparison of changes in body mass (in kg) during postnatal development in European bison (data from this paper) and American bison. Sources: <sup>a</sup> Mc Hugh (1972), <sup>b</sup> Park (1969 cited in Meagher 1973), <sup>c</sup> Meagher (1973) from Yellowstone National Park, USA, <sup>d</sup> Halloran (1960) from Wichita Mountains Refuge of Southwestern, Oklahoma, <sup>e</sup> Halloran (1961), <sup>f</sup> Banfield (1974). In both species data for animals from free-ranging populations. *n* – number of individuals, ? – no information given.

Age (years)	European bison			American bison		
	<i>n</i>	Mean	Min–Max	<i>n</i>	Mean	Min–Max
			Both sexes			
Newborn	34	26	15–35	?	?	14–18 <sup>a</sup>
				?	?	14–32 <sup>b</sup>
1	12	122	80–170	?	?	227–318 <sup>c</sup>
			Males			
1	7	124	80–170	5	281	261–287 <sup>d</sup>
2	40	220	130–300	18	393	361–451 <sup>e</sup>
3	18	303	240–390	49	437	343–556 <sup>f</sup>
4	14	366	260–430	19	511	420–590 <sup>d</sup>
5	15	467	345–660	15	531	390–624 <sup>d</sup>
6	79	634	436–840	40	656	461–769 <sup>d</sup>
					570	460–720 <sup>f</sup>
			Females			
2	25	213	170–280	5	387	354–447 <sup>d</sup>
3	14	252	150–310	22	367	336–449 <sup>d</sup>
4	10	341	260–458	21	386	329–465 <sup>d</sup>
5	8	407	340–458	19	387	343–440 <sup>d</sup>
6	76	424	340–540	77	393	334–488 <sup>d</sup>
				?	?	363–500 <sup>c</sup>
				?	?	360–460 <sup>f</sup>

Faster rate of growth in American bison was even more manifest in females, which already at the age of 2–3 years attained the same body mass as individuals 5 years old (Table 6). Females European bison continued growth until 5 years old. Body mass of 2-year old females was only 50% of adult body mass, that 3-year old females 60% and 4-years old females 80%. Moreover, the final body mass attained by adult females of European bison (mean 424 kg, range 340–540 kg) was higher than that of American bison (mean 393 kg, range 334–500 kg) (Table 6).

Documentation on body measurements during the postnatal development is available for 50 bison from the last free-ranging population living in the Białowieża Forest at the beginning of the 20th century (Wróblewski 1927). Body measurements of dead or culled specimens were probably taken using similar methods and with the same instruments as in the present study (Lidtin rod and tape measure). In Wróblewski's (1927) study, all mean measurements were smaller at birth, but still within the range we found. Also in the postnatal development, body measurements of bison described by Wróblewski are smaller than those we found. In adult animals (aged 6 years and older) body measurements fall within our range of measurements. Smaller sizes of bison living in the last free-ranging population may be associated with the fact that Wróblewski measured mainly specimens, which died due to diseases. In addition, age determination might not have been precise, since

Table 7. Earlier literature data on body measurements (in cm) of European bison. BF – Białowieża Forest, C – captive bison, ? – *n* unknown.

Age	Locality and origin	<i>n</i>	Measurements		Source
			Mean	Min–Max	
Body length					
Males					
0–5 days	BF	2	74	68–81	Wróblewski 1927
0–7 days	C	4	105	85–107	Pytel 1969
6 years	C	15	250	228–290	Pytel 1969
Females					
0–7 days	C	3	105	103–106	Pytel 1969
6 years	C	6	249	235–267	Pytel 1969
Withers height					
Males					
0–5 days	BF	2	73	73–74	Wróblewski 1927
0 days	C	1	86		Pytel 1969
Adult	BF	?	185		Flerov 1932, Heptner <i>et al.</i> 1966
6 years	C	15	185	166–204	Pytel 1969
Females					
0–7 days	C	3	70	78–90	Pytel 1969
6 years	C	6	172	161–197	Pytel 1969



values than in the material analysed (Pucek 1986). The horn size and shape of bison aged 1, 2 and 3 differ considerably, thus allowing precise determination of their age (Wróblewski 1927, Krasinski *et al.* 1982). At the older age this method is also helpful although not so precise.

Body measurements of European bison from reserves that were presented by Pytel (1969) and Sablina (1975) are within the ranges of variability for bison from Białowieża (Table 7). Only withers height measurements given by Pytel (1969) are larger, being taken with tape measure and not with Lydtin rod. Bison did not exhibit sex-related differences at birth (Pytel 1969, Kobryńczuk and Kobryń 1981). Sexual dimorphism increased along with age (Kobryńczuk and Kobryń 1981, Pytel 1969, this study).

A comparison made of body mass and body measurements of European bison living nowadays in Białowieża Forest with earlier data from the same locality suggest that high inbreeding of contemporary population (average inbreeding coefficient = 0.2219; Olech 1987) does not have a negative influence on the development, body structure and size of these animals. Mature bison exhibit proper development and their body mass and measurements are not smaller than those of bison living in freedom before the First World War.

Body length of the American bison is larger than in the European bison at each age class (Table 8), however the withers height does not differ much. The hump of adult European bison of both sexes is higher and the trunk is shorter than those in American bison (Table 8). Horns of the European bison are more bended inwards, but the two species have similar maximal distance between curves (Table 10). Body size of the European bison increased more slowly during postnatal development than those in the American bison. Body measurements in American bison (Berger and Peacoc 1988) are less correlated with body mass than those in the European bison.

Table 9. Earlier literature data on horn measurements (in cm) of European bison from Białowieża Forest.

Age	<i>n</i>	Horn measurements		Source
		Mean	Min-Max	
Distance between tips of horns				
Males				
6 years	11	47	38-63	Wróblewski 1927
6 years	23	55	41-70	Pucek 1986
Females				
6 years	15	32	25-42	Wróblewski 1927
Maximal distance between curves				
Males				
6 years	11	65	58-72	Wróblewski 1927
6 years	23	72	66-84	Pucek 1986
Females				
6 years	15	47	37-63	Wróblewski 1927

Table 10. Comparison of changes in horn measurements (in cm) during post-natal development in European bison (data from this paper) and American bison. Source: Halloran (1960).

Age (years)	European bison			American bison		
	<i>n</i>	Mean	Min-Max	<i>n</i>	Mean	Min-Max
Distance between tips of horns						
Males						
2	34	40	31–48	7	63	56–71
3	22	41	25–51	1	64	
4	14	45	30–75	3	57	46–65
5	8	39	14–48	3	51	47–54
6	31	52	39–61	7	63	46–74
Females						
2	25	33	24–43	2		41–55
3	11	29	24–34	1	41	
4	8	29	27–36	1	39	
5	8	28	22–37	4	41	30–55
6	61	29	15–55	9	36	24–44
Maximal distance between curves						
Males						
2	34	48	27–65	7	64	60–71
3	21	57	48–67	1	69	
4	14	64	54–70	3	66	63–70
5	8	64	52–70	3	60	58–62
6	32	71	63–79	7	66	66–81
Females						
2	23	41	31–46	2	51	47–55
3	11	45	43–49	1	48	
4	8	48	40–51	1	51	
5	9	51	46–55	4	48	42–55
6	57	54	47–70	9	48	47–53

American bison cows reach maximum size at about 4 years of age and bulls attain adult size at 6 years, but they continue to grow slowly through life (Banfield 1974).

Acknowledgements: We thank Dr B. Jędrzejewska for her help in statistic analysis, general suggestions, critical reading of this paper, and correcting the English. Special thanks are due to K. Zub for preparing the figures, as well as technical staff of the Mammal Research Institute PAS in Białowieża for their help with taking measurements of bison.

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Received 21 September 2000, accepted 5 December 2001.

Table 3. Body measurements (cm) of European bison during postnatal development. Statistical differences between male and female groups in each class of age: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ , ns – non-significant (Student  $t$ -test:  $t = 2.088$  to  $12.052$ ); “–” – not tested.

Age (months)	Males					Females					Statistical differences
	<i>n</i>	Mean	SD	Min	Max	<i>n</i>	Mean	SD	Min	Max	
1	2	3	4	5	6	7	8	9	10	11	12
Body length											
0	3	112	10	100	120	5	108	8	101	116	ns
2	3	112	7	105	120	2	123	–	118	129	–
3	11	124	11	108	138	11	120	9	106	126	ns
4	4	132	10	117	140	4	128	10	114	138	–
5	9	145	6	136	155	11	137	11	128	156	ns
6	9	147	12	136	169	21	145	7	126	159	ns
7	14	153	12	136	173	21	150	9	137	170	ns
8	10	155	18	139	198	15	152	8	138	171	ns
9	10	161	10	153	188	10	155	11	142	174	ns
12	2	179	–	164	195	4	182	8	174	191	–
24	42	194	14	165	230	28	185	13	155	200	**
36	22	217	21	200	248	14	205	9	191	214	ns
48	14	226	26	208	246	9	222	16	197	245	*
60	9	247	10	238	270	10	226	8	215	230	***
72	39	257	16	245	300	90	236	12	217	270	***
Oblique body length											
0	4	62	6	56	70	7	62	5	56	70	ns
1	2	76	–	70	83	1	65	–	–	–	–
2	3	65	6	59	71	2	68	–	62	72	–
3	14	74	9	69	93	10	79	9	66	91	ns
4	5	86	7	75	93	3	82	12	72	96	–
5	10	91	7	85	108	15	88	7	79	100	ns
6	8	93	8	80	102	22	95	7	82	103	ns
7	14	97	10	83	112	18	96	8	85	115	ns
8	11	100	9	88	112	14	93	2	82	107	ns
9	10	107	6	100	114	10	104	11	88	114	ns
12	2	115	–	114	116	4	118	17	93	125	–
24	35	126	10	113	145	28	124	7	104	145	ns
36	22	139	9	120	151	13	128	6	120	144	***
48	15	149	9	133	169	10	147	5	138	156	ns
60	8	160	5	155	171	10	153	5	147	161	**
72	34	173	9	157	193	87	157	8	130	172	***

Table 3 – continued.

1	2	3	4	5	6	7	8	9	10	11	12
Withers height											
0	4	73	9	59	78	7	76	3	74	82	ns
1	2	86	–	75	98	1	80	–	–	–	–
2	3	74	3	71	76	2	82	–	74	91	–
3	11	84	7	76	98	10	86	6	74	92	ns
4	5	93	8	80	100	3	87	4	83	90	–
5	11	97	4	94	100	15	93	8	85	106	ns
6	6	102	5	96	108	23	105	7	96	126	ns
7	14	106	5	98	117	19	103	7	92	118	ns
8	11	104	12	91	126	15	106	5	92	114	ns
9	10	109	5	102	120	10	108	8	99	118	ns
12	2	122	–	114	130	4	117	13	101	131	–
24	37	130	9	116	144	26	133	8	116	154	ns
36	22	142	8	131	160	13	132	5	125	139	***
48	15	150	10	136	165	10	145	4	140	150	ns
60	8	159	9	151	178	10	151	5	147	159	ns
72	39	172	8	158	188	87	152	6	134	167	***
Sacral region height											
0	4	76	5	71	81	6	77	3	73	82	ns
1	2	88	–	76	100	1	85	–	–	–	–
2	3	76	2	74	78	2	82	–	74	91	–
3	11	84	7	74	96	10	89	7	75	96	ns
4	4	95	9	84	103	3	95	7	83	97	–
5	11	99	6	92	108	14	95	9	81	100	ns
6	7	103	8	91	110	23	103	6	89	113	ns
7	12	107	5	100	118	20	105	7	94	117	ns
8	11	108	12	87	129	15	105	6	87	113	ns
9	10	110	5	102	120	10	109	7	97	117	ns
12	2	121	–	114	128	4	117	8	107	125	–
24	37	127	8	112	142	27	129	7	115	140	ns
36	20	139	6	124	149	13	131	6	125	142	**
48	13	146	7	132	155	11	140	5	135	154	ns
60	9	149	5	144	158	10	144	6	141	153	*
72	38	160	8	147	179	87	145	7	128	160	***
Hearth girth											
0	4	73	6	68	82	7	71	5	66	78	ns
1	2	96	–	80	103	1	80	–	–	–	–
2	3	84	6	78	90	2	88	–	78	98	–
3	11	101	10	88	118	10	97	10	80	110	ns
4	3	111	11	100	112	4	106	5	100	112	–
5	11	119	5	112	126	15	108	11	88	124	ns
6	6	121	14	102	136	23	124	9	108	140	ns
7	14	129	9	108	144	20	128	11	118	150	ns
8	11	132	12	112	146	15	135	12	114	150	ns
9	10	140	12	126	162	9	136	14	110	152	ns
12	2	153	–	140	166	5	161	30	118	194	–
24	36	171	18	146	212	27	172	13	146	200	ns
36	22	193	17	160	224	13	181	9	172	196	**
48	15	194	5	176	240	10	201	18	172	222	ns
60	9	231	25	210	222	10	203	10	190	218	**
72	37	247	19	206	280	85	209	12	184	246	***

Table 3 – concluded.

1	2	3	4	5	6	7	8	9	10	11	12
Thorax depth											
0	3	31	3	28	34	6	30	2	28	30	ns
1	2	35	–	30	41	1	38	–	–	–	–
2	3	31	2	28	32	2	32	–	30	34	–
3	11	34	3	29	35	9	36	6	31	50	ns
4	4	39	3	35	42	3	37	3	34	41	–
5	11	40	5	33	45	14	41	5	34	38	ns
6	6	44	4	41	50	24	45	5	42	63	ns
7	12	43	4	39	50	20	45	6	34	51	ns
8	11	48	6	41	61	14	48	6	39	59	ns
9	10	50	7	37	62	9	48	4	39	54	ns
12	2	59	–	58	60	4	52	7	43	53	–
24	35	63	6	47	77	26	62	5	51	69	ns
36	21	73	5	65	81	14	63	6	55	74	***
48	15	77	7	68	92	10	72	4	62	78	ns
60	8	85	6	77	93	10	76	9	72	81	ns
72	35	94	8	63	112	85	79	6	63	95	***
Fore cannon girth											
0	4	10	1	9	12.5	6	10	1	9.5	12	ns
2	3	10	1	9	11	2	10	–	10	10	–
3	10	11	1	11	13	8	11	1	10	12	ns
4	4	12	1	11	12	3	10	1	10	11	–
5	11	12	1	11	13	13	12	1	10	14	ns
6	3	14	1	14	15	20	13	2	12	15	ns
7	12	14	1	12	16	20	13	1	12	15	ns
8	10	14	2	12	16	15	14	1	12	15	ns
9	9	15	2	13	19	10	14	1	12	15	ns
12	2	16	–	16	16	4	15	2	13	16	–
24	34	17	2	14	21	26	16	3	14	19	ns
36	21	18	2	15	21	11	17	1	16	18	ns
48	14	19	3	15	20	8	18	1	18	19	*
60	8	21	1	19	24	10	18	1	18	21	***
72	35	23	3	19	27	76	19	1	17	21	***
Hind cannon girth											
0	3	11	2	9	13	7	10	1	9	12	ns
1	2	11	–	10	13	1	10	–	–	–	–
2	4	12	1	11	13	2	11	–	11	11	–
3	10	12	1	11	13	10	11	1	10	13	ns
4	4	13	1	12	14	3	12	1	11	12	–
5	11	13	1	12	15	14	13	2	11	14	ns
6	7	14	1	13	16	25	14	2	12	16	ns
7	11	14	2	13	17	20	14	1	13	16	ns
8	11	14	2	13	16	15	15	1	13	16	ns
9	9	15	2	13	19	11	15	2	15	20	ns
12	2	17	–	17	18	4	15	1	14	16	ns
24	34	18	2	16	22	26	17	3	16	21	ns
36	23	19	1	16	22	11	18	1	17	19	ns
48	14	21	2	21	26	10	20	1	19	22	ns
60	9	22	1	21	24	10	20	1	19	21	***
72	40	23	3	19	31	86	20	1	18	23	***

Table 4. Horn measurements (cm) of European bison during postnatal development. Statistical differences between males and females in each age classes: \*  $p < 0.05$ ; \*\*  $p < 0.01$ ; \*\*\*  $p < 0.001$ ; ns – non-significant (Student  $t$ -test:  $t = 2.723$  to  $15.271$ ); “–” – not tested.

Age (months)	Males					Females					Statistical difference
	<i>n</i>	Mean	SD	Min	Max	<i>n</i>	Mean	SD	Min	Max	
1	2	3	4	5	6	7	8	9	10	11	12
Distance between tips of horns											
0	1	11	–	–	–	–	–	–	–	–	–
12	2	39	–	33	45	4	36	11	23	49	–
24	34	40	4	31	48	25	33	6	24	43	ns
36	22	41	5	29	51	11	29	4	24	34	**
48	14	45	11	30	75	8	29	5	27	36	***
60	8	39	11	14	48	8	28	5	22	37	*
72	31	52	7	39	63	61	29	9	15	55	***
Maximal distance between curves of horns											
0	1	14	–	–	–	–	–	–	–	–	–
12	2	41	–	37	45	2	31	–	23	39	–
24	34	48	6	27	65	23	41	6	31	46	ns
36	21	57	6	48	67	11	45	2	43	49	**
48	14	64	5	54	70	8	48	4	40	51	***
60	8	64	6	52	70	9	51	3	46	55	***
72	32	71	4	63	79	57	54	5	47	70	***
Horn circumference at base											
0	–	–	–	–	–	–	–	–	–	–	–
12	2	18	–	15	21	4	19	8	9	29	–
24	36	23	3	15	32	25	19	2	14	23	***
36	22	28	3	24	35	12	21	1	19	22	***
48	13	29	5	24	31	9	20	1	18	22	***
60	8	28	2	26	32	10	21	2	19	22	***
72	34	31	3	29	36	82	20	2	15	28	***
Circumference in half of horn											
0	–	–	–	–	–	–	–	–	–	–	–
12	2	12	–	11	13	1	11	–	–	–	–
24	34	16	2	10	18	24	14	3	12	22	***
36	20	19	2	17	23	11	15	1	14	17	***
48	14	21	3	18	23	8	16	1	15	17	***
60	8	20	2	19	25	10	16	2	13	19	***
72	28	23	2	22	25	70	17	2	11	22	***

Table 4 – concluded.

1	2	3	4	5	6	7	8	9	10	11	12
Breadth between horns											
0	3	9	1	9	11	5	10	1	8	11	–
12	2	17	–	17	18	3	16	1	15	18	–
24	36	21	4	17	31	26	19	2	16	22	ns
36	22	26	5	16	39	12	21	1	19	23	**
48	14	29	4	22	32	12	22	2	19	26	***
60	9	29	3	26	35	10	23	3	19	27	***
72	37	29	4	23	37	83	23	3	16	29	***
Horn length											
0	3	vestige	–	–	–	4	vestige	–	–	–	–
12	2	18	–	15	21	4	20	9	7	28	–
24	36	30	5	22	46	24	27		20	31	**
36	24	39	5	35	48	11	30	4	20	35	***
48	12	43	4	32	49	9	35	2	32	37	***
60	9	47	7	42	65	10	36	2	32	38	***
72	32	44	7	25	65	83	41	6	30	52	***