ZOOMETRIC MEASUREMENTS OF CEPHALIC CONFORMATION IN ADULT BOVINE MALES AND FEMALES (*Bos taurus*)

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Summary. A sample of 578 bovine whole, fresh adult skulls (sample of 76 adult males and 502 adult females) belonging to 16 different domestic cattle breeds from Spain and France was examined. The studied breeds descend from different European ancestral trunks. The heads were obtained from slaughtered animals and in all cases were from pure-bred animals according to their racial standard. A total of 9 cephalic lineal measurements and 7 derived indices were obtained from each skull. The values between sexes were compared in order to distinguish measurements and differentiate between male and female skulls.

Given their number-based nature, cephalic measurements and indices allow comparisons between breeds from very different geographical areas as well as permitting the development of research into breeds using exclusively bone material. Moreover, the statistics presented could act as reference values for further morphological craniological studies on sexual dimorphism.

Key words: skull measurements, domestic cattle breeds, sexual dimorphism.

OSTEOMETRINIAI SUAUGUSIŲ BULIŲ IR KARVIŲ KAUKOLIŲ MATAVIMŲ YPATUMAI

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Santrauka. Ištirtos 578 sveikos suaugusių galvijų, priklausančių 16-ai Ispanijos ir Prancūzijos veislių, išvestų skirtingose vietovėse, kaukolės (76 bulių ir 502 karvių). Jos, atitikusios grynų veislių standartus, surinktos skerdyklose. Kiekvienai kaukolei atlikti 9 matavimai ir apskaičiuoti 7 indeksai. Norint išskirti matmenis bei diferencijuoti bulių ir karvių kaukoles, duomenys buvo lyginami.

Pagal kiekybinį duomenų pobūdį kaukolių matmenys ir indeksai leidžia palyginti veisles, išvestas labai skirtingose geografinėse vietovėse, tirti jas naudojant išimtinai tik kaulinę medžiagą. Be to, pateikti statistiniai duomenys gali būti naudojami kaip atskaitos kriterijai tiriant kaukolių lytinį dimorfizmą.

Raktažodžiai: kaukolių matavimai, galvijų veislės, lytinis dimorfizmas.

Introduction. After the initiation of domestication, not only did cattle body size decrease but so did the difference in size between genders. Nevertheless, in modern domestic cattle, sexual dimorphism between bulls and cows still exists. Such difference in size is not just confined to certain parts of the body; it can also be present in any bone, such as the horns and the head.

The goals of this research are:

1) to obtain some values (lineal measurements and indices) of the skull from several domestic bovine breeds; these values are normally used in veterinary ethnology, easily taken *in vivo*, and they allow the comparison with extinct breeds or species (such *Bos primigenius*). We think our results will be particularly useful to determine the range of variation in a given breed.

2) to determine the cephalic values that distinguish and differentiate sexes in modern cattle.

Given their number-based nature, these cephalic measurements and indices allow comparisons between breeds from very distant geographical areas, and permit research into breeds using bone material only. In addition, our results could be used as reference values for further morphologic craniological studies on sexual dimorphism.

Material and Methods

A total of 578 whole, fresh skulls from 76 adult males and 502 adult females (>2,5 yr), belonging to 16 modern domestic breeds, were used (Table 1). No castrated animal was included. The heads were obtained from slaughtered animals and in all cases were from pure-bred animals according to the racial standard. A problem with the use of measurements as criteria for distinguishing between the sexes is that an observed difference in a measurement is not necessarily caused by a difference in sex, but can be explained by a difference in breed. For this reason, and for further information and particularly to allow comparison of values, the measurements for each breed have been classified separately (Table 2). It should be noted that it was not possible to measure horn variables in all skulls, because some animals had had their horns cut. The following 9 measurements were obtained (Pares, 2006a):

Cephalic length	CefL
Cranial length	CrL
Facial length	FacL
Cephalic width	CefW
Cranial width	CrW
Facial width	FacW
Horn perimeter	HP
Cephalic depth	CefD
Horn length	HL (along the outer curvature).

Table 1. **Animals studied and breed**

		Females	Males
Asturiana de los Valles	AS	17	0
Aubrac	AU	9	1
Avileña	AV	9	0
Blanca del Pallars	BL	10	0
Bruna dels Pirineus	BP	260	20
Fleckvieh	FL	5	0
Friesian (black and white)	BW	38	24
Friesian (red and white)	RW	16	1
Gasconne	GS	7	0
Limousin	LI	9	10
Pardo Alpina	PA	19	1
Parda de Montaña	PM	19	0
Pyrenean	PY	17	1
Blonde d'Aquitanie	BA	7	3
Salers	SA	34	1
Charolais	CH	26	14
TOTAL		502	76

We also have included an analysis in the form of indices. The advantage of the use of indices is that it is not so much the difference in the size of the bones that is expressed but rather the differences in measurement ratios. So, starting from these values we have derived the following 7 indexes which are very widespread in veterinary ethnology:

Cephalic index (CefI): (CefW/CefL) x 100

Cranial index (CrI): (CrW/CrL) x 100

Facial index (FacI): (FacW/FacL) x 100

Depth index (DI): (CefL/CefD) x 100

Skorkowski's W1 index (W1)= (CefW/FacL) x 100

Skorkowski's W2 index (W2)= (FacL/CrL) x 100

Horn length: horn perimeter = (HL/HP) x 100.

Calculus and figures were obtained using the statistical software PAST (*PALEONTOLOGICAL STATISTICS SOFTWARE*, by Hammer *et al.*, 2001).

Results and Discussion

The results of this study are presented in Table 2 and Table 3.

Generally, measurements are statistically larger in males, except LH (Table 1). The female skulls are shorter and narrower, their orbits are less protruding and their horns are smaller in perimeter, but horn length in both sexes is similar. The fairly high variation in CrL could be explained by the protruding occipital part of the head, especially in males. Overall, the sex dimorphism in prehistoric cattle could be considerably larger than in modern breeds. All of the indices present statistical differences except FacI and W2, thus indicating a similar conformation in the facial region of both sexes.

All indexes are statistically different, except FacI and W2, therefore indicating a similar conformation in the facial region of both sexes.

Table 4 shows the canonical analysis for each sex. Horn data have been excluded (some animals were hornless). The most discriminating variables are CefW, CrW and CrL and their derived indexes CrI and W1 (Figure 1).

Conclusion

The lineal measurements related to cephalic width and length show statistically significant differences between sexes, independent of the breed. Moreover, most indexes present differences between sexes, and this could allow the evaluation of skulls of different sizes.

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Table 2. **Average values of lineal measurements (cm ± standard deviation).** Statistical analysis only established globally

		CrW	CefW	FacW	CrL	FacL	CefL	CefD	PH	LH
AS	Males	--	--	--	--	--	--	--	--	--
	Females	18,15± 0,77	23,35± 1,12	17,06± 0,70	15,34± 1,24	39,81± 2,01	55,15± 2,39	37,56± 2,25	17,86± 1,91	26,00[2]
AU	Males[2]	25,00	28,00	20,00	15,50	27,50	43,00	49,00	27,00	--[1]
	Females	18,46± 1,35	23,10± 1,48	16,74± 1,37	13,99± 1,44	37,81± 2,90	51,80± 3,65	36,42± 2,47	17,00± 1,98	29,50± 0,71
AV	Males	--	--	--	--	--	--	--	--	--
	Females	18,18± 1,12	23,10± 1,07	16,49± 0,95	15,60± 1,38	28,92± 5,86	44,52± 5,44	37,50± 3,91	18,17± 2,93	42,00± 9,17
BL	Males	--	--	--	--	--	--	--	--	--
	Females	19,11± 0,72	24,45± 1,01	17,54± 0,81	15,37± 1,51	38,83± 4,56	54,20± 4,67	38,16± 1,89	17,67± 1,17	31,38± 3,40
BP	Males	23,03± 1,14	27,07± 1,75	18,31± 0,89	17,32± 2,84	39,74± 3,34	57,05± 2,45	38,38± 2,09	22,13± 1,99	27,83± 7,32
	Females	18,70± 1,19	23,55± 1,52	16,94± 1,11	15,43± 1,94	37,87± 3,88	53,31± 3,55	35,28± 2,74	16,81± 2,94	27,60± 4,31
FL	Males	--	--	--	--	--	--	--	--	--
	Females	19,21± 0,86	24,04± 0,46	18,07± 0,58	14,70± 0,91	39,68± 1,61	54,38± 1,72	36,78± 0,97	17,83± 2,02	--[1]
BW	Males	23,29± 2,08	28,23± 1,44	18,36± 1,05	18,03± 2,87	43,90± 4,34	61,93± 5,08	42,82± 1,95	24,28± 2,52	19,50± 2,78
	Females	17,90± 1,43	23,48± 1,15	16,32± 1,08	15,61± 1,78	40,00± 2,05	55,97± 2,87	36,44± 1,62	16,28± 2,06	25,75± 8,13
RW	Males[2]	19,50	27,00	18,00	17,00	29,50	46,50	43,00	23,00	22,50
	Females	17,79± 0,92	23,53± 1,10	17,23± 1,21	14,65± 1,11	38,81± 4,47	53,46± 4,76	40,41± 1,95	16,33± 2,52	25,25± 10,96
GS	Males	--	--	--	--	--	--	--	--	--
	Females	18,34± 0,71	23,10± 0,58	17,09± 0,70	14,29± 1,07	39,64± 1,83	53,93± 2,30	38,01± 2,09	17,50± 1,78	33,00± 5,20
LI	Males	23,12± 1,23	25,85± 1,43	18,43± 0,91	15,67± 2,14	39,26± 1,97	54,93± 2,58	39,68± 2,35	22,28± 1,01	32,50± 5,07
	Females	18,91± 1,26	22,76± 1,13	17,08± 0,50	14,11± 0,82	38,83± 1,60	52,94± 1,53	37,89± 1,24	17,17± 1,39	38,19± 3,26
PA	Males[2]	23,00	28,60	19,20	17,50	41,30	58,80	37,00	22,00	--[1]
	Females	18,86± 0,82	24,07± 0,97	17,44± 0,95	16,67± 1,80	36,67± 3,83	53,34± 3,42	35,06± 1,66	17,31± 1,86	26,00± 2,62
PM	Males	--	--	--	--	--	--	--	--	--
	Females	19,22± 1,20	24,16± 1,27	17,26± 1,00	15,26± 1,37	40,35± 2,01	55,61± 2,02	38,77± 2,05	17,53± 1,92	32,36± 7,54
PY	Males	23,00	26,70	19,50	16,60	40,10	56,70	35,40	25,00	41,20
	Females	18,57± 0,89	23,17± 0,86	17,04± 1,03	14,66± 1,56	37,75± 1,95	52,41± 2,56	36,45± 2,24	18,07± 1,94	34,78± 6,24
BA	Males	23,23± 2,44	26,50± 2,50	18,23± 0,25	16,50± 3,12	42,80± 3,81	59,30± 6,88	41,57± 2,54	18,17± 2,75	31,00± 7,07
	Females	18,86± 0,75	22,81± 0,37	17,11± 0,76	14,14± 0,75	38,59± 4,49	52,73± 4,07	37,90± 2,49	16,81± 0,97	27,38± 3,09
SA	Males[2]	24,50	28,20	20,20	16,20	40,50	56,70	45,20	23,00	45,50
	Females	18,62± 0,64	23,01± 0,76	16,93± 0,73	14,79± 1,85	36,65± 2,99	51,44± 3,13	35,91± 2,38	19,48± 2,63	40,67± 8,96
CH	Males	22,88± 1,36	26,84± 1,37	19,59± 2,85	16,09± 1,97	39,97± 2,04	56,06± 2,02	39,10± 2,97	23,47± 1,81	34,38[2]
	Females	19,41± 1,06	23,92± 2,37	18,23± 1,59	15,13± 1,37	38,46± 2,47	53,58± 2,80	36,98± 1,73	17,77± 2,15	33,66± 7,80
Global	Males	23,10± 1,61***	27,25± 1,68***	18,64± 1,54***	17,02± 2,62***	40,89± 4,27***	57,91± 4,92***	40,44± 3,15***	22,67± 2,36***	30,13± 7,61
	Females	18,64± 1,16	23,53± 1,42	17,04± 1,12	15,28± 1,79	38,01± 3,81	53,30± 3,71	36,17± 2,76	17,28± 2,68	30,26± 8,30

Statistical significance: *** P < 0,01 1: cut horns 2: only 1 sample

Table 3. **Average values of indexes** (± standard deviation)

		CefI	CrI	FacI	DI	W1	W2	HL:HP
AS	Males	--	--	--	--	--	--	--
	Females	42,36± 1,80	118,97± 9,69	42,98± 3,00	147,14± 8,11	58,75± 3,51	261,20± 24,48	152,94
AU	Males	65,12	161,29	72,73	142,57	101,82	177,42	--
	Females	44,65± 1,76	132,99± 15,36	44,32± 2,27	87,76± 11,24	61,19± 2,58	272,10± 28,57	171,01± 0,59
AV	Males	--	--	--	--	--	--	--
	Females	52,54± 6,43	117,60± 15,01	58,87± 10,78	119,42± 15,60	82,75± 16,24	187,76± 45,42	231,93± 43,39
BL	Males	--	--	--	--	--	--	--
	Females	45,49± 5,30	125,26± 11,19	45,94± 7,61	142,66± 17,05	64,01± 10,31	255,02± 41,15	181,29± 34,82
BP	Males	47,44± 2,22	135,81± 19,07	46,33± 3,84	149,00± 9,29	68,45± 5,98	236,65± 49,33	124,88± 18,59
	Females	44,30± 3,42	123,06± 16,57	45,14± 4,99	151,82± 13,35	62,76± 7,09	250,17± 45,47	165,38± 32,64
FL	Males	--	--	--	--	--	--	--
	Females	44,25± 1,91	131,13± 10,67	45,61± 2,69	147,98± 7,33	60,67± 2,93	270,87± 21,76	--
BW	Males	45,78± 3,18	132,59± 24,73	42,18± 4,51	144,83± 12,46	64,80± 6,02	249,42± 45,41	82,10± 10,80
	Females	42,00± 1,94	116,21± 16,38	40,86± 2,75	153,72± 6,91	58,81± 3,31	253,99± 34,56	148,21± 46,59
RW	Males	58,06	114,71	61,02	108,14	91,53	173,53	97,83
	Females	44,36± 4,85	121,88± 8,53	45,05± 7,03	132,63± 13,70	61,54± 9,20	266,08± 34,65	149,34± 34,42
GS	Males	--	--	--	--	--	--	--
	Females	42,88± 1,44	129,02± 10,81	43,17± 2,40	142,02± 5,31	58,35± 2,28	278,63± 21,62	185,57± 24,67
LI	Males	47,14± 3,19	149,86± 21,39	47,02± 2,87	138,73± 8,14	66,00± 5,02	254,44± 33,39	145,15± 17,54
	Females	43,01± 2,50	134,48± 12,99	44,07± 2,75	139,88± 6,31	58,72± 4,36	276,25± 22,99	216,72± 17,37
PA	Males	48,64	131,43	46,49	158,92	69,25	236,00	--
	Females	45,27± 2,97	114,54± 14,25	47,96± 4,80	152,29± 9,97	66,35± 7,74	223,57± 40,08	153,96± 12,38
PM	Males	--	--	--	--	--	--	--
	Females	43,46± 2,16	126,54± 9,02	42,89± 3,40	143,72± 7,15	60,02± 4,62	266,99± 31,86	186,82± 56,98
PY	Males	47,09	138,55	48,63	160,17	66,58	241,57	164,80
	Females	44,28± 2,02	127,62± 10,92	45,19± 2,81	144,07± 7,67	61,51± 3,20	259,96± 28,75	192,20± 30,21
BA	Males	44,80± 2,19	142,49± 13,36	42,81± 3,54	142,77± 16,19	61,94± 2,82	263,12± 29,73	188,35± 62,09
	Females	43,57± 4,55	133,74± 10,43	45,22± 8,85	140,06± 17,64	60,09± 9,73	274,38± 41,28	167,27± 23,03
SA	Males	49,74	151,23	49,88	125,44	69,63	250,00	197,83
	Females	44,89± 3,10	127,62± 14,97	46,52± 4,60	143,93± 13,17	63,23± 6,11	251,78± 38,70	210,00± 42,75
CH	Males	47,90± 2,14	144,17± 18,43	49,16± 7,99	144,07± 11,29	67,32± 4,91	252,88± 40,52	143,51± 36,13
	Females	44,70± 4,40	129,09± 10,42	47,64± 5,83	145,12± 8,72	62,32± 6,31	256,32± 29,27	187,79± 34,54
GLOBAL	Males	47,27± 3,67***	138,69± 21,27***	46,11± 6,50	143,80± 13,69***	67,25± 7,43***	245,68± 43,39	134,18± 34,73***
	Females	44,30± 3,61	123,59± 15,33	45,29± 5,49	148,06± 13,56	62,52± 7,53	252,63± 42,05	175,46± 38,27

Statistical significance: *** $P < 0,01$

Table 4. **Correlations between zoometrical variables and canonical variables**

Females	Can1	Can2	Males	Can1	Can2
CefI	-1,1152	-1,7739	CefI	-0,7159	0,6807
CefL	-0,5097	-0,9575	CefL	-1,1156	-1,5509
CefW	-1,1136	-2,0571	CefW	-2,8237	-1,0478
CrI	2,0535	-0,6871	CrI	1,5650	-0,8465
CrL	-1,0996	0,3211	CrL	-2,0625	-0,6788
CrW	4,2693	-1,3665	CrW	1,8517	-1,2669
DI	-0,7502	0,7505	DI	-0,7595	-0,3139
FacI	-0,0464	2,0739	FacI	-0,2330	2,5135
FacL	-0,2723	-1,4720	FacL	-0,7217	-1,9138
FacW	0,2091	-1,4135	FacW	-0,4782	-0,3795
PCefD	-0,2704	0,2264	PCefD	-0,7698	0,0964
W1	-1,4141	-1,2470	W1	-1,1287	1,0141
W2	0,2296	0,6108	W2	0,7405	0,5254

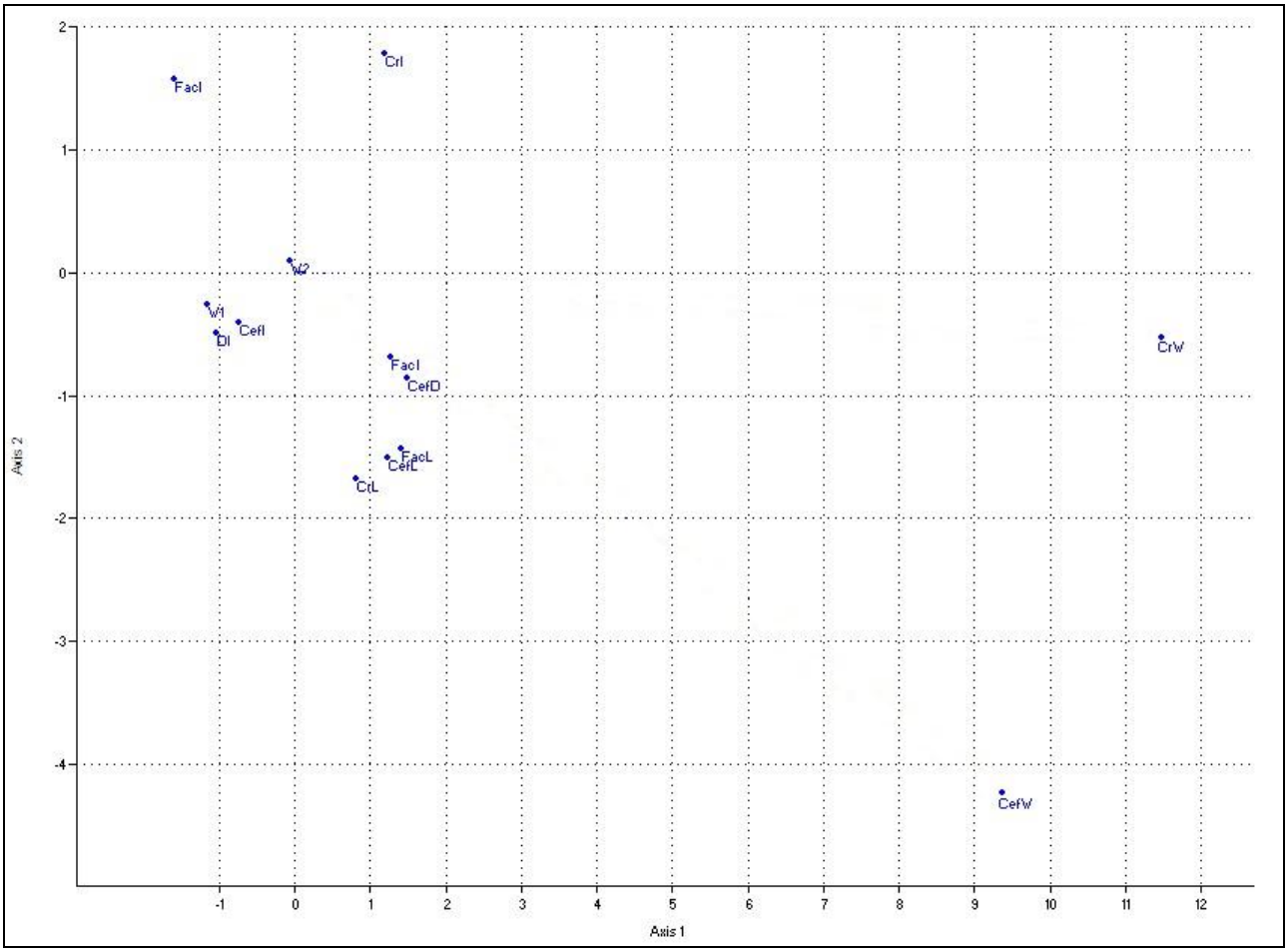

Figure 1. **PCA Analysis**

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