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Reference Values for Dog Sagittal and Transverse Cephalic Indices in Different Skull Types and Their Importance

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Abstract: The study was developed in 69 canine adult skulls (n = 69), divided into three groups according to type of skull: Brachi (B), Dolicho (D) and Mesaticephalic (M) (n = 23 each) and aimed: to quantify the average values for two novel Cephalic Indices (CIs) the Sagittal (SCI) and the Transverse (TCI) cephalic indices and to describe the relationships amongst the three main CIs. Neurocranium maximum length, width and height distances were measured using a digital caliper and for statistical analysis, $p<0.05$ were considered significant. For the three groups the work presents reference values for the SCI of 56.4% for the B group, 41.7% for the D group and 58.9% for the M group and for the TCI which presented a wide variation with reference values of 63.1% for the B group, 95.1% for the D and 87.5% for the M group. Relationship between the SCI and TCI was strong in B (R = 0.85) and M (R = 0.95) but weak in D (R = 0.16). Relationship registered between the HCI and SCI was strong only for D (R = 0.96) and between the HCI and TCI was weak in all groups. The CIs provide a simple, highly repetitive and uniform method for identifying dog head types as B, D and M.

Key words: Dog, cephalic indices, skull, brachycephalic, dolichocephalic, mesaticephalic

INTRODUCTION

The high variability of dog skull morphology far exceeds that of other species, suggesting that it is the result of a functional adaptation influenced by the constant interplay of heredity and environmental factors (Lieberman *et al*., 2008; Helton, 2009; Drake and Klingenberg, 2010; Carreira *et al*., 2011; Wikswo *et al*., 2013). To minimize this phenotype variability, reference measurements are needed to standardize assays and eventually harmonize patient procedures such as cranial neurosurgical techniques (Carreira, 2011). Standardization means creating uniform pattern across structures with different aspects, minimizing the differences, allowing a well-defined practice, reducing the risks of failure and expecting better results (Carreira, 2011). By relating the neurocranium measurements such as maximum length (maxlgt), maximum width (maxwdh) and maximum height (maxhgt) in each skull, it is possible to achieve the Cephalic Indices (CIs) which provide a simple description of the geometric shape of the cranium and exclude the dimensions of the snout or face and thus being distinct from the craniofacial ratio. The neurocranium maxlgt is the distance from the glabella to inion (the most posterior point at the back of the head), the neurocranium maxwdh is the maximum transverse skull diameter measured between the left and right porions (the most projecting points at both sides of the head, behind and above the ears) and the neurocranium maxhgt is the distance from porion to vertex (the top most point of the skull) (Rhoton, 2003; Marcus *et al*., 2008; Greenberg, 2010; Carreira, 2011) (Fig. 1). In human anatomy reference to CIs is common but not in veterinary anatomy. The CIs allows to identify three different head categories which are Brachy (B), Dolicho (D) and Mesaticephalic (M), promoting a greater uniformity of the skull and minimizing the effect of it anatomical variability in the specie (Drake and Klingenberg, 2010; Armstrong *et al*., 2012). According to the literature only reference values are described for the Horizontal CI (HCI) in the dog,

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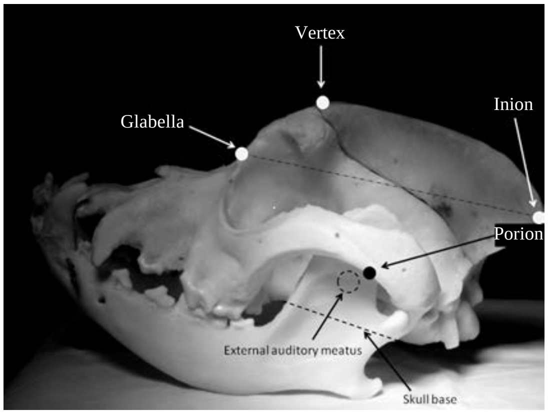

Fig. 1: Photo of laterolateral projection of a brachycephalic dog skull for the identification of craniometric points used for the determination of neurocranium maximum length is the distance from the glabella to inion (the most posterior point at the back of the head), the neurocranium maximum width is the maximum transverse skull diameter measured between the left and right porions (the most projecting points at both sides of the head, behind and above the ears) and the neurocranium maximum height is the distance from porion to vertex (the top most point of the skull), required to achieve the calculations of the cephalic index

relating the neurocranium maxlgt with the maxwdh (Regodon *et al*., 1991; Onar and Pazvant, 2001).

MATERIALS AND METHODS

Study was performed in 69 adult dog cadavers (n = 69) obtained after death verification by a veterinary surgeon, permission from the ethical committee and signed consent forms from owners. All individuals without head injuries, regardless of breed and gender were accepted in the study. The sample was divided in three groups of 23 individuals each, according to skull type: B, D and M. Considering four human classic craniometric points: glabella, inion, porion and vertex and using a digital caliper (SXG-Model 110) the skulls' maxlgt, maxhgt and maxwdh measurements were obtained to calculate the three main CIs using the formulas described for man (Table 1). For statistical analysis the SPSS® Software was used. The Kolgomorv-Smirnoff test (KS) was used to test the normality assumption and in order to test if CIs differed among B, D and M breeds we used ANOVA followed by a post-hoc Bonferoni correction to test for significant pair-wise differences. The Pearson product-moment correlation coefficient was used to measure the strength of the relationship between two variables. A $p<0.05$ was considered statistically significant.

Table 1: Descriptive statistics with mean, standard deviation, minimum and maximum values, sigma and t, regarding the parameters of neurocranium maximum width, length and height and breeds in Brachy (B), Dolicho (D) and Mesaticephalic (M) dogs. Mathematical equations for calculate the three main Cephalic Indices (CIs) are also represented

				95% CI			
Groups	Parameters	n	$\bar{X}\pm SD$	Min.	Max.	σ for p>0.05	t-values
B	maxwdt	23	79.98±10.57	75.40	84.55	σ = 0.19	36.26
	maxlgt	23	89.80±14.32	83.60	95.99	σ = 0.11	30.05
	maxhgt	23	49.90±5.58	47.48	52.31	σ = 0.17	42.83
	Breed (23)	8	French bulldog	-	-	-	-
		7	Boxer	-	-	-	-
		4	Pekingese	-	-	-	-
		2	Pug carlin	-	-	-	-
		2	Shitzu	-	-	-	-
	Age (years)		8.00±1.65	-	-	-	-
	BW (kg)		15.79±6.46	-	-	-	-
	Brain (g)		84.91±31.29	-	-	-	-
D	maxwdt	23	69.36±4.13	67.57	71.15	σ = 0.11	80.43
	maxlgt	23	160.41±22.85	150.54	170.30	σ = 0.13	33.66
	maxhgt	23	65.94±2.75	64.74	67.13	σ = 0.15	114.64
	Breed (23)	11	Doberman pinsher	-	-	-	-
		5	Rough collie	-	-	-	-
		4	Whippet	-	-	-	-
		3	Miniature bull terrier	-	-	-	-
	Age (years)		8.70±2.40	-	-	-	-
	BW (kg)		23.63±2.59	-	-	-	-
	Brain (g)		92.50±8.60	-	-	-	-
M	maxwdt	23	62.86±5.59	60.44	65.28	σ = 0.15	53.91
	maxlgt	23	93.63±10.95	88.89	98.37	σ = 0.14	40.98
	maxhgt	23	55.08±7.19	51.97	58.19	σ = 0.09	36.71
	Breed (23)	7	Beagle	-	-	-	-

Table 1: Continue

Groups	Parameters	n	X̄±SD	95% CI Min.	95% CI Max.	σ for p>0.05	t-values
		6	Golden retriever	-	-	-	-
		5	Yorkshire terrier	-	-	-	-
		3	Border collie	-	-	-	-
		2	Dalmatian	-	-	-	-
	Age (years)		9.50±2.50	-	-	-	-
	BW (kg)		13.80±7.20	-	-	-	-
	Brain (g)		69.90±28.70	-	-	-	-

Minimum (Min.); maximum (Max.); Confidence Interval (CI); maximum width (maxwdt); maximum length (maxlgt); maximum height (maxhgt). Cephalic Indices (Cis); measurements are in millimetres. Body Weight (BW); Mathematical equations for CIs; Horizontal CI (HCI = maxwdh/maxlgt×100) Sagittal CI (SCI = maxhdh/maxlgt×100); Transverse CI (TCI = maxhdh/maxwdh×100)

Table 2: ANOVA and Post-Hoc Bonferroni corrected tests for differences in neurocranium maximum width, length and height between the Brachy (B), Dolicho (D) and Mesaticephalic (M) dogs. The difference was significant at p<0.05. The comparison between groups was made with an n = 46 (23 specimens within each group). After the blank line it is the descriptive statistics with mean, standard deviation, minimum and maximum values, p and t for the parameters of horizontal, sagittal and transverse cephalic indices and the Pearson coefficients to characterize the relationship between the 3 cephalic indices in B, D and M dogs

Neurocranium

Parameters	Type of test	Diferences between groups		N	EP	SS	MS	F-values	p-values	CI 95% Min.	CI 95% Max.
maxwdt	ANOVA	-	-	69	-	6959	1716	32.13	0.00	-	-
	Bonferroni	B	D	46	6.96	-	-	-	<0.00	5.44	15.79
		B	M	46	11.23	-	-	-	<0.00	11.94	22.28
		D	M	46	4.26	-	-	-	0.04	1.32	11.67
maxlgt	ANOVA	-	-	69	-	9118	3626	128.30	<0.00	-	-
	Bonferroni	B	D	46	20.14	-	-	-	<0.00	-82.51	-58.71
		B	M	46	1.09	-	-	-	1.00	-15.73	8.06
		D	M	46	19.05	-	-	-	<0.00	54.88	78.68
maxhgt	ANOVA	-	-	69	-	5074	1540	51.01	<0.00	-	-
	Bonferroni	B	D	46	13.99	-	-	-	<0.00	-19.92	-12.05
		B	M	46	4.52	-	-	-	<0.01	-9.07	-1.29
		D	M	46	9.47	-	-	-	<0.00	6.96	14.74

Cephalic indices

Groups	Indices	CIs	n	X̄±SD (%)	Min. (%)	Max. (%)	p-values	t-values	R
B	Cephalic indices	HCI	23	89.65±6.39	74.96	105.30	>0.10	67.28	-
		SCI	23	56.45±7.60	43.64	67.73	>0.10	35.59	-
		TCI	23	63.19±9.09	49.10	80.69	0.08	33.33	-
	Relationship	HCI:SCI	23	-	-	-	-	-	0.19
	between cephalic	HCI:TCI	23	-	-	-	-	-	-0.36
	indices	SCI:TCI	23	-	-	-	-	-	0.85
D	Cephalic indices	HCI	23	43.87±5.13	35.88	53.61	0.00	40.99	-
		SCI	23	41.74±4.89	33.19	50.55	>0.10	40.85	-
		TCI	23	95.19±3.25	87.21	98.83	0.03	140.38	-
	Relationship	HCI:SCI	23	-	-	-	-	-	0.96
	between cephalic	HCI:TCI	23	-	-	-	-	-	-0.11
	indices	SCI:TCI	23	-	-	-	-	-	0.16
M	Cephalic indices	HCI	23	67.33±1.85	63.28	69.62	0.01	174.19	-
		SCI	23	58.91±5.12	48.65	67.97	>0.10	55.16	-
		TCI	23	87.53±7.65	69.88	98.07	>0.10	54.85	-
	Relationship	HCI:SCI	23	-	-	-	-	-	0.10
	between cephalic	HCI:TCI	23	-	-	-	-	-	-0.22
	indices	SCI:TCI	23	-	-	-	-	-	0.95

Cephalic Indices (CIs); Confiance Interval (CI); maximum width (maxwdt); maximum length (maxlgt); maximum height (maxhgt); Confiance Interval (CI); minimum (Min.); maximum (Max.); Horizontal Cephalic Index (HCI), Sagittal Cephalic Index (SCI); Transverse Cephalic Index (TCI); minimum (Min.); maximum (Max.); Standard Deviation (SD); Pearson coefficient (R) with a maximum value of 1.0

RESULTS

Sample individuals characterization for parameters of neurocranium maximum length, maximum width and maximum height measurements and breeds of the 3 groups are listed in Table 1. Based on the KS test results, normal distribution was accepted for maxlgt values for B (p = 0.19) for D (p = 0.11) and for M (p = 0.15) for maxwdt values in B (p = 0.11) in D (p = 0.13) and in M (p = 0.14) and for maxhgt values for B group (p = 0.17) for D (p = 0.15) and for M (p = 0.09) with no statistically significant differences in the 95% confidence intervals. The results of ANOVA and post-hoc Bonferroni test for comparing the three groups for each index at B, D and M groups are listed in Table 2. Using the Pearson coefficient, the relationship between the cephalic index

HCI-SCI was low for B (R = 0.19) and M (R = 0.10) but strong for D (R = 0.96); between HCI-TCI was low for B (R = 0.36), D (R = 0.11) and M (R = 0.22) and between SCI-TCI was strong for B (R = 0.85) and M (R = 0.95) but weak for D (R = 0.16) (Table 2).

DISCUSSION

The use of CIs calculated based on maxlgt, maxhgt and maxwdh parameters allowed for a more uniform description of individuals in terms of type of skull, trying to standardize the morphological diversity displayed by the dog (Carreira *et al*., 2011). Height was the most variable skull dimension between the 3 groups, similar with has been observed in humans. According to the study results from the three groups, the B presented the highest HCI value being directly related to their craniofacial complex architecture characterized by a very marked retraction of the facial region (minor length) and a very wide skull. The mean value was 89.6±6.3% being in line with the results. In man, two others CIs are used the SCI and the TCI but no references for dog were described until now. By applying the formulas, it was possible to achieve reference values for the SCI of 56.4% for the B group, 41.7% for the D group and 58.9% for the M group and for the TCI which presented a wide variation with reference values of 63.1% for the B group, 95.1% for the D and 87.5% for the M group. Although, the study point out the relationship between the SCI and TCI which present the same numerator (height) was strong in both groups B (R = 0.85) and M (R = 0.95) and may be related to the fact that in these groups the maxlgt and maxwdh dimensions presented no statistical significant differences; contrary to what was registered in the D group (R = 0.16) were the relationship was weak. A strong relationship between the HCI and SCI which share the same denominator (length) was registered in the D group (R = 0.96). This may be related to the fact that maxlgt is the main skull geometry dimension in this group, promoting a dilution of the maxwdh and maxhgt values, contrary to what was registered in the B and M groups where the relationship was weak. By not having any common dimension in the numerator or denominator the relationship between the HCI and TCI was weak in all of the groups (R = 0.36 for B, R = 0.11 for M and R = 0.22 for D). The CIs provide a simple, highly repetitive and uniform method to describe the individuals in terms of type skull in an attempt to standardize the morphological diversity displayed by the dog breeds.

CONCLUSION

The study aimed to present reference values for the sagittal CI (SCI) which relates the neurocranium maxhgt with the maxlgt and the Transverse CI (TCI) which relates the neurocranium maxhgt with the maxwdh in B, M and D dogs and to describe the relationships between the three main Cis.

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