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CORRELATION BETWEEN SELECTED METRIC TRAITS OF THE HEAD SKELETON AND THE BONE ELEMENTS OF THE THORACIC AND PELVIC LIMBS AND SEX AND LITTER SIZE IN LONG-TAILED CHINCHILLA (*CHINCHILLA LANIGER*, MOLINA 1782)

WSPÓŁZALEŻNOŚĆ POMIĘDZY WYBRANYMI CECHAMI METRYCZNYMI SZKIELETU GŁOWY ORAZ ELEMENTAMI KOŃCZYNY PIERSIOWEJ I KOŃCZYNY MIEDNICZNEJ A PŁCIĄ I WIELKOŚCIĄ MIOTU SZYNSZYLI MAŁEJ (*CHINCHILLA LANIGER*, MOLINA 1782)

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Streszczenie. Celem badań było określenie wartości podstawowych cech osteometrycznych wybranych kości długich i kości płaskich z uwzględnieniem płci i wielkości miotu, a także ustalenie czy istnieje statystyczna współzależność między cechami czaszki a cechami wybranych kości szkieletu pozaczaszkowego. Materiałem do badań były kości ramienne, łopatki, kości udowe i miednice 136 oraz czaszki 140 szynszyli hodowlanych obojga płci, z miotów pojedynczych i wielorakich. Stwierdzono, że w szkielecie szynszyli istnieje większa współzależność między kośćcem głowy a kośćcem obręczy piersiowej i obręczy miednicznej samic niż samców oraz brak istotnego wpływu płci i wielkości miotu na cechy metryczne łopatki, kości ramiennej, miednicy i kości udowej szynszyli małej.

Key words: cranium, femur, humerus, long-tailed chinchilla, osteometry, pelvis, scapula.
Słowa kluczowe: czaszka, łopatka, kość ramienna, kość udowa, miednica, osteometria, szynszyla mała.

INTRODUCTION

The main components of the skeleton of forelimb and the hindlimb are humerus and femur. The structure of both of these bones provides a lot of information about locomotor preferences of an individual animal (Lammers and German 2002, Morgan and Álvarez 2013). As far as the femur is a massive, strongest bone of the long bones of mammalian body and, apart from supportive functions, fulfils an important motor role, the humerus, being passively burdened with the body weight in some animal species, has different shape and weight and the interaction of both of these features with environmental factors and phylogenetic context is a very interesting material, as is the head skeleton, for adaptation studies (O'Regan and Kitchener 2005). Under natural conditions, long-tailed chinchillas live on the rocky slopes in the South American mountains, establishing small colonies that inhabit mountain fissures.

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Moving around this area affects the adaptation of the two limbs and the bone elements building the girdle of the thoracic and pelvic limb of these rodents Long-tailed chinchillas are seasonally polyoestric animals which, under natural conditions, are characterised by low fertility and fecundity. It turned out that they are vulnerable to changes in light intensity, which allowed this abiotic factor to be used in the regulation of their reproductive functions in breeding (Jarosz 1973, Felska-Błaszczyk 2004). Craniological studies of these animals showed, among others, that the period of almost one hundred-year-long breeding did not produce a new skull morphotype in this species, despite different living conditions. On the other hand, it has been demonstrated on a large farm population of these animals of both sexes that the number of metric traits being significantly statistically correlated increases with age on the dorsal surface of the skull and its nuchal plane, with the number of these traits in females being greater than in males. The number of metric traits on the skull base and on the mandible being significantly correlated in subsequent periods of life has been also greater in females (Baranowski et al. 2014a, b). These observations have confirmed earlier findings that combination of the head skeleton of males and females together when comparing populations causes many important biological information to be lost (Baranowski et al. 2009). Sexual dimorphism in the cranial skeleton has been also found in other animal species (Scott 1957, Mystkowska 1966, Sladek et al. 1971, Kratochvil 1976, The and Trouth 1976, Truth et al. 1977). During ontogenesis, the head skeleton is substantially modified and undergoes considerable reconstruction, and such factors, as age and sex, are an important sources of variation during its course. Therefore, a question arises whether the post-cranial skeleton of male and female chinchillas differs with respect to morphology and osteometry and whether there are differences in the size of bone elements of the shoulder and pelvic girdles due to increased number of animals per litter in farm chinchillas.

The aim of this study was to determine the values of basic osteometric traits of such bones as scapula, humerus, pelvis and femur in long-tailed chinchillas allowing for sex and litter size as sources of variation and to find out whether there is a statistical correlation between the cranial traits and those of selected bones of the shoulder and pelvic girdles.

MATERIAL AND METHODS

The study was conducted on long-tailed chinchilla skeletons obtained randomly from the carcasses of farm animals. The animals had been kept in cages housed in animal buildings ensuring fixed environmental conditions with respect to feeding, temperature, humidity and photoperiod and under controlled reproduction. The material consisted in total of 136 skulls and 140 post-cranial skeletons. The average age of males was 357 days ±41, while that of females 319 days ±46. Detailed data referring to the number of examined specimens, allowing for sex and litter size at birth, are presented in Tables 1 and 2. Using an electronic calliper (Orion 31170 150, wit accuracy to 0.01 mm) and applying previously adopted methodology (Baranowski et al. 2008, Stacharski et al. 2010), the following seven distances were measured on the dorsal plane and the base of skull: greatest skull length (A-P); neurocranium length (A-N); viscerocarnium length (N-P); length of the skull base (B-P); length of the neurocranium base (B-Pm); length of the diastema of the vsicerocranium base (P-Pm); palatal length (P-Po); greatest breadth of the neurocranium (Eu-Eu); greatest breadth of the cranium (Zyg-Zyg).

Table 1. The number of measurements made on the left (s) and the right (d) side of the post-cranial skeleton elements in long-tailed chinchilla allowing for sex and litter size at birth (1 – single, 2 – twins, >2 – multiple litters, more than two animals per litter)

Tabela 1. Liczba dokonanych pomiarów lewej (s) i prawej (d) strony elementów szkieletu pozaczaszkowego w zależności od płci i wielkości miotu urodzenia (1 – jedynaki, 2 – bliźnięta, >2 – mioty wielorakie, ponad dwa osobniki w miocie) szynszyli małej

Trait Cecha		Body side Strona ciała	Male – Samce N litter size N osobników w miocie				Female – Samice N litter size N osobników w miocie			
			1	2	>2	Σ	1	2	>2	Σ
	Scapula Łopatka									
Height along the spine Wysokość grzbietu łopatki	HS	s	17	29	39	**85**	8	16	10	**34**
		d	17	28	40	**85**	8	17	13	**38**
Smallest length of the *Collum scapulae* Szerokość wydrążenia stawowego	SLC	s	17	29	41	**87**	8	16	10	**34**
		d	17	28	40	**85**	8	17	13	**38**
Greatest length of the *Processus articularis* Największa długość wyrostka stawowego	GLP	s	17	29	40	**86**	8	16	10	**34**
		d	17	28	40	**85**	8	17	13	**38**
Greatest dorsal length Wysokość grzbietu łopatki	LD	s	17	29	40	**86**	8	16	10	**34**
		d	17	28	40	**85**	8	17	13	**38**
	Humerus Kość ramienna									
Greatest length of humerus Największa wysokość	GL	s	19	27	42	**88**	9	20	13	**42**
		d	19	27	42	**88**	8	20	13	**41**
Greatest breadth of the proximal end Największa szerokość nasady proksymalnej	Bp	s	19	27	42	**88**	9	20	13	**42**
		d	19	27	42	**88**	8	20	13	**41**
greatest breadth of the distal end Największa szerokość nasady dalszej	Bd	s	19	27	42	**88**	9	20	13	**42**
		d	19	27	43	**89**	8	20	13	**41**
Smallest breadth of *diaphysis* Najmniejsza szerokość trzonu	SD	s	19	27	44	**90**	9	20	13	**42**
		d	19	27	43	**89**	8	20	13	**41**
	Coxae Kość miedniczna									
Greatest length of one half Największa długość	GL	s	19	24	42	**85**	9	19	12	**49**
		d	19	25	43	**87**	9	20	12	**41**
Smallest breadth of the shaft of *ilium* Najmniejsza szerokość trzonu	SB	s	19	25	42	**86**	9	19	12	**40**
		d	19	25	43	**87**	9	20	12	**41**
	Femur Kość udowa									
Greatest length of femur Największa długość kości udowej	GL	s	19	27	41	**87**	9	20	13	**42**
		d	19	28	41	**88**	9	20	13	**42**
Greatest length from caput femoris Największa długość od głowy kości udowej	GLC	s	19	27	41	**87**	9	20	13	**42**
		d	19	28	41	**88**	9	20	13	**42**
Greatest breadth of the proximal end Największa szerokość nasady proksymalnej	Bp	s	19	28	44	**91**	9	20	13	**42**
		d	19	28	43	**90**	9	20	13	**42**
Greatest breadth of the distal end Największa szerokość nasady dystalnej	Bd	s	19	27	42	**88**	9	20	13	**42**
		d	19	28	42	**89**	9	20	13	**42**
Smallest breadth of *diaphysis* Najmniejsza szerokość trzonu	SD	s	19	28	43	**90**	9	20	13	**42**
		d	19	28	42	**89**	9	20	13	**42**

Explanations: s – sinistra, d – dextra.
Objaśnienia: s – sinistra. d – dextra.

Table 2. The number of measurements made for surface area of the left and right femur allowing for sex and litter size at birth*
Tabela 2. Liczba pomiarów elementów powierzchni lewej i prawej kości udowej w zależności od płci i wielkości miotu urodzenia*

Traits Cechy	Designation Oznaczenie	Body side Strona ciała	Male Samce N litter size N osobników w miocie				Female Samice N litter size N osobników w miocie			
			1	2	>2	Σ	1	2	>2	Σ
Total surface area Powierzchnia całkowita kości udowej	P.C.	s	19	27	41	**87**	9	20	13	**42**
		d	19	28	41	**88**	9	20	13	**42**
Surface area of diaphysis Powierzchnia trzonu kości udowej	P.T.	s	19	27	41	**87**	9	20	13	**42**
		d	19	28	41	**88**	9	20	13	**42**
Proximal end of the left and right femur Powierzchnia nasady proksymalnej kości udowej	P. px.	s	17	34	35	**86**	12	25	15	**52**
		d	18	35	36	**89**	13	24	15	**52**
Surface area of distal end Powierzchnia nasady dystalnej kości udowej	P. dt.	s	17	34	32	**83**	13	27	15	**55**
		d	18	32	36	**57**	13	26	14	**53**

Explanations: * – designation of the number of males and females in litter as in Table 1.
Objaśnienia: * – oznaczenie liczby samców i samic w miocie jak w tabeli 1.

On selected left and right largest bone elements of the girdle of the thoracic limb and the girdle of the pelvic limb being left after animal skinning, the following measurements were made:

– scapula: height along the spine (HS); smallest length of the collum scapulae (SLC); greatest length of the processus articularis (GLP); greatest dorsal length (LD);
– humerus: greatest length (GL); greatest breadth of the proximal end (Bp); greatest breadth of the distal end (Bd); smallest breadth of diaphysis (SD);
– pelvis: greatest length of one half (GL); smallest breadth of the shaft of ilium (SB);
– femur: greatest length of femur (GL); greatest length from the caput femoris (GLC); greatest breadth of the proximal end (Bp); greatest breadth of the distal end (Bd); smallest breadth of diaphysis (SD).

Moreover, measurements of the surface area of diaphysis (PT), proximal end (Ppx) and distal end (Pdt) were made, as well as the total surface area (PC) of the left and right femur. To make the above measurements, each bone was placed under a digital camera (Canon EOS-1000D), being installed on a calibrated frame, equipped with Macro EFS 60 mm f/2.8 lens and photographed. The photographs were always taken in such a way that the photographed plane was situated perpendicularly to the camera lens and image sensor. Digital recording data were entered into a computer with MultiScan measuring software with ScanBase image-text database (Licence No. 172/12/12/12/34) by which the detailed measurements of each trait were made. The obtained data from all made measurements were entered into statistical computer software (Statistica v.10.PL) and the following parameters were calculated for them: mean value, standard deviation, minimum and maximum values, and coefficient of variation. The indices of the examined bones were calculated and additionally, for femora, the values of the following indices:

1. Total femoral massiveness index (WMO) = total surface area of the projection (PC) x 100 / greatest length of femur (GL).
2. Femoral epiphyseal-diaphyseal index (WNT) = surface area of proximal end (Ppx) and distal end (Pdt) x 100 / surface area of diaphysis (PT).
3. Femoral proximal epiphyseal index (WNB) = surface area of proximal end (Ppx) x 100 / total surface are of femur (PC).
4. Femoral distal epiphyseal index (WND) = surface area of distal end (Pdt) x 100 / total surface are of femur (PC).

The results were processed statistically allowing for two sources of variation, i.e. sex and litter size. Due to no normal distribution of the traits, differences between groups were estimated using a non-parametric Mann-Whitney U test for two independent samples. To estimate the correlation of sex and litter size, a two-factor analysis of variance was conducted for the traits using the Tukey test. The correlation of metric traits was estimated using the Spearman's rank correlation In estimating the differences and the values of correlation coefficients, two levels of significane were accepted: $P \leq 0.05$ and $P \leq 0.01$. The sex x litter size interaction was non-significant, therefore it was omitted when discussing the study results.

RESULTS AND DISCUSSION

Table 3 presents mean values for the carcass weight of animals, the skeletons of which were used in the study, as well as the weight of their craniums and mandibles and the values of basic metric traits of their skulls.

Table 3. The values of carcass weight and head skeleton weight (g) and metric traits (mm) of long-tailed chinchilla skulls of both sexes (n = 136)
Tabela 3. Wartości masy tuszy i szkieletu głowy (g) oraz cech metrycznych (mm) czaszek szynszyli małej obojga płci (n = 136)

Traits Cechy	x	Sd	Min.	Max.	V [%]
Carcass weight * Masa tuszy*	396.11	44.44	282.55	572.45	11.22
Weight of skull** Masa czaszki**	5.75	0.48	4.16	7.52	8.36
Weight of mandible** Masa żuchwy**	1.96	0.24	1.32	3.10	12.42
A-P	60.64	1.60	56.34	66.60	2.63
A-N	44.00	4.59	36.17	52.98	10.43
N-P	17.95	3.35	12.26	23.86	18.65
B-P	53.08	1.61	50.42	61.79	3.03
B-Pm	38.81	1.43	35.60	43.65	3.68
P-Pm	14.64	0.97	12.45	17.80	6.58
P-Po	27.34	0.91	25.28	29.67	3.35
Eu-Eu	24.30	1.33	22.03	35.01	5.48
Zyg-Zyg	32.16	0.88	30.08	36.25	2.73

Explanations: * – carcass weight after skinning; ** – weight of dry element.
Objaśnienia: * – masa tuszy po oskórowaniu; ** – masa elementu suchego.

Table 4. Distribution of the length measurements for selected metric traits of long-tailed chinchilla skulls and long bones
Tabela 4. Rozkład wymiarów długości wybranych cech czaszki i kości długich szynszyli małej

Trait Cecha	18.68–22.68	22.69–26.69	26.70–30.70	30.71–34.71	34.72–38.72	38.73–42.73	42.74–46.74	46.75–50.75	50.76–54.76	54.77–58.77	58.78–62.78	62.79–66.79	Σ n	x
A-P										16	109	11	136	66.64
B-P								5	117	13	11		136	53.08
B-Pm					66	67	3						136	38.32
P-Po		34	102										136	27.34
Scapula Łopatka HS (s)		31	71	17									119	28.36
Scapula Łopatka HS (d)	1	26	78	17	1								123	28.49
Humerus Kość ramienna Gl (s)			2	89	38	1							130	34.00
Humerus Kość ramienna Gl (d)			2	89	37	1							129	33.95
Coxae Kość miedniczna Gl (s)							1	8	38	63	15		125	55.75
Coxae Kość miedniczna Gl (d)								2	35	73	16	2	128	59.35
Femur Kość udowa Gl (s)								7	70	47	4	1	129	54.37
Femur Kość udowa Gl (d)								6	70	51	2	1	130	54.43

These values are given with their standard deviations, ranges and coefficients of variation. They do not differ significantly from the results obtained on other long-tailed chinchilla populations (Crossley and Miguéles 2001). The statistical analysis allowing for sex as a source of variation showed no statistical differences in the carcass weight of males and females (398.03 g ±38.81 and 379 g ±53.09, respectively). These results indicate no reversed sexual dimorphism in farm animals, as opposed to that being observed in animals living in the wild (Walker 1975, Spotorno et al. 2004). The weight of craniums (5.73 g ±0.47 and 5.86 g ± 0.48, respectively) and mandibles (1.97 g ±0.27 and 2.04 g ±0.26, respectively) of the male and female chinchillas chosen to the study did not differ statistically significantly. Sex and litter size were not sources of variation for the metric traits of the chosen skulls either, therefore the values of metric traits for the whole studied population are presented in Table 3. Table 4 presents the distribution of ranges within which the mean values of selected metric traits of the head skeleton and the left and right scapulae, humeri, pelvises and femora of long-tailed chinchillas of both sexes are observed, together with the their numbers in respective classes, The greatest skull length, being measured along the dorsal plane, is within 56.34–66.60 mm, on average 60.64 mm, with the greatest number of specimens (n = 109) being within 58.78–62.78 mm. The mean value the metric trait characterising the greatest breadth of the skull (Zyg-Zyg) was 32.16 mm ±0.88, with the limit values of this trait being within 30.08–36.25 mm.

Tables 5 and 6 present the mean values of the metric traits for the left and right scapulae, humeri, pelvises and femora as well as the values of surface areas of the projections of femoral elements.

Table 5. The values of metric traits for the bone elements of the shoulder girdle skeleton of long-tailed chinchilla allowing for sex and litter size
Tabela 5. Wartości cech szkieletu elementów obręczy piersiowej szynszyli małej w zależności od płci i wielkości miotu

Trait Cecha	Body side Strona ciała	The number of males in the litter Liczba samców w miocie				The number of females in the litter Liczba samic w miocie			
		1	2	>2	sd	1	2	>2	sd
					Scapula Łopatka				
HS	s	26.95	27.75	27.37	1.40–2.15	27.33	27.73	28.87	1.35–3.12
	d	26.98	27.76	27.37	1.41–2.21	27.32	28.10	28.70	1.40–3.16
SLC	s	3.48	3.82	3.64	0.33–0.77	3.72	3.59	3.96	0.55–0.71
	d	3.42	3.59	3.54	0.31–0.67	3.82	3.63	3.89	0.44–0.60
GLP	s	4.43	4.96	4.55[a]	0.54–1.05	4.72	5.28	6.56[a]	1.19–2.99
	d	4.37	4.93	4.56[a]	0.54–1.05	4.85	5.37	6.54[a]	1.16–3.00
LD	s	12.54	12.75	12.79	0.65–1.40	12.07	12.64	12.81	1.10–1.96
	d	12.32	12.55	12.70	0.58–1.32	12.01	12.75	12.77	1.17–1.88
					Humerus Kość ramienna				
GL	s	33.66	33.49	33.69	1.22–1.68	33.28	33.99	34.95	1.02–1.58
	d	33.58	33.49	33.69	1.23–1.78	33.25	34.00	34.93	1.03–1.59
Bp	s	6.84	6.94	6.83	0.23–0.37	6.68	6.93	6.70	0.52–1.09
	d	6.87	6.96	6.87	0.21–0.36	6.79	6.99	6.71	0.43–1.05
Bd	s	5.49	5.68	5.19[a]	0.48–0.76	6.09	6.00	5.47[a]	0.76–1.40
	d	5.49	5.60	5.23[a]	0.49–0.75	6.16	5.99	5.47[a]	0.76–1.28
SD	s	2.47	2.62	2.51	0.13–0.32	2.83	2.58	2.67	0.29–0.65
	d	2.47	2.62	2.51	0.13–0.30	2.81	2.58	2.68	0.28–0.63

Explanations: mean values in rows marked with the same lowercase letters differ significantly at: a – P ≤ 0.05; A – P ≤ 0.01.
Objaśnienia: średnie w wierszach oznaczone tymi samymi małymi literami różnią się istotnie a – P ≤ 0,05; A – P ≤ 0,01.

Table 6. The values of metric traits for the bone elements of the pelvic girdle skeleton of long-tailed chinchilla allowing for sex and litter size

Tabela 6. Wartości cech szkieletu elementów obręczy miednicznej szynszyli małej w zależności od płci i wielkości miotu

Trait Cecha	Body Strona	The number of males in the litter Liczba samców w miocie				The number of females in the litter Liczba samic w miocie			
		1	2	>2	SD	1	2	>2	SD
		x	x	x		x	x	x	
Coxae Kość miedniczna									
GL	s	55.23	55.81	55.68	1.92–2.22	54.99	55.60	57.44	2.11–3.71
	d	55.12	55.85	55.65	1.87–2.18	55.69	56.56	57.28	1.56–3.62
SB	S	3.30	3.39	3.37	0.29–0.43	3.21	3.44	3.47	0.29–0.49
	d	3.32	3.31	3.38	0.22–0.37	3.28	3.44	3.48	0.28–0.39
Femur Kość udowa									
GL	s	53.87	53.75	53.76	1.45–2.29	53.39	54.66	54.65	1.80–3.77
	d	53.86	53.69	53.79	1.41–2.29	53.40	54.71	65.66	1.73–3.80
GLC	s	50.89	50.82	52.76	1.53–2.37	51.21	51.51	51.75	1.14-3.34
	d	50.88	50.83	50.76	1.53–2.38	51.26	51.49	51.76	1.18–3.33
Bp	s	11.30	11.51	11.43	0.47–0.59	10.94	11.69	11.26	0.52–0.82
	d	11.30	11.50	11.32	0.58–0.59	10.93	11.71	11.28	0.49–0.80
Bd	s	8.96	8.97	8.77	0.35–0.37	8.70	8.98	9.00	0.23–0.38
	d	8.86	8.98	8.77	0.34–0.45	8.74	8.99	8.97	0.26–0.36
SD	s	4.87	4.76	4.75	0.29–0.51	4.56	4.77	4.98	0.23–0.60
	d	4.88	4.77	4.75	0.30–0.50	4.57	4.78	4.96	0.23–0.60
Designation of surface areas of femur* Pola powierzchni rzutu elementów kości udowej*									
P.C.	s	300.47	316.34^{a}	309.86	30.44–49.68	300.26	297.33^{a}	291.30	33.46–48.25
	d	300.13	314.56^{a}	313.15	33.29–43.18	301.93	290.94^{a}	294.07	38.26–48.23
P.T.	s	179.63	191.95^{A}	186.36	19.96–32.78	182.42	171.40^{A}	170.99	22.13–29.66
	d	176.11	182.93^{A}	178.41	20.22–33.04	181.39	166.25^{A}	171.73	22.25–29.47
P. px	s	58.12	56.48	55.38	5.87–8.47	55.15	57.21	56.91	5.28–10.33
	d	57.24	56.46	56.32	5.98–7.78	55.35	56.96	57.36	5.03–8.14
P. dt	s	56.06	55.55	55.55	4.60–7.19	54.42	56.46	56.91	5.72–10.33
	d	55.37	55.76	55.56	5.17–6.85	54.09	55.50	57.46	5.60–-9.90
WMO	s	5.52	5.80	5.76	0.55–0.88	5.32	5.45	5.25	0.67–0.78
	d	5.66	5.71	5.81	0.60–0.84	5.44	5.31	5.30	0.64–0.92
WNT	s	65.72	58.43	59.78	7.70–11.14	60.98	67.21	65.55	9.47–11.11
	d	65.89	57.59	63.42	9.51–12.65	61.74	68.79	65.15	8.89–1192
WNB	s	19.73	17.79	18.01	2.34–3.20	18.71	19.73	19.62	2.35–3.27
	d	19.47	17.83	18.37	2.46–2.83	19.05	19.89	19.92	1.80–3.36
WND	s	19.21	17.96	17.99	2.10–2.83	18.52	19.29	19.27	2.52–2.67
	d	18.78	17.97	18.17	2.21–2.63	18.41	19.29	19.05	2.08–3.45

Explanations: mean values in rows marked with the same lowercase letters differ significantly at: a – P ≤ 0.05; A – P ≤ 0.01. * – designation of surface areas as in Table 3.

Objaśnienia: średnie w wierszach oznaczone tymi samymi małymi literami różnią się istotnie a – P ≤ 0,05; A – P ≤ 0,01. * – oznaczenie skrótów nazw pól powierzchni jak w tabeli 3.

Table 7. The mean values of correlation coefficients for the cranial traits and the metric traits of selected post-cranial elements of male and female long-tailed chinchillas
Tabela 7. Wartości średnie współczynników korelacji cech czaszki i cech wybranych elementów szkieletu pozaczaszkowego samców i samic szynszyli małej

Male Samce Female Samice	Carcass Wright Masa tuszy	Weight of skull Masa czaszki	Weight of mandible Masa żuchwy	A-P	A-N	B-P	B-Pm	P-Po	Eu-Eu	Zyg-Zyg	Scapula Łopatka HS	Humerus Kość ramienna GL	Coxae Kość miedniczna GL	Femur Kość udowa GL
Carcass weight Masa tuszy											–0.13	–0.03[a]	–0.03	–0.21[b]
Weight of skull Masa czaszki											0.28*	0.34*	0.30*	0.32*
Weight of mandible Masa żuchwy											0.02[a]	0.18	0.03[b]	0.12[c]
A-P											0.36**	0.53**	0.35**	0.55**
A-N											0.44**	0.29**	0.20	0.34**
B-P											0.26	0.44**	0.43**	0.40**
B-Pm											0.16	0.42**	0.29*	0.28*
P-Po											0.10	0.27*[a]	0.32**	0.30*[b]
Eu-Eu											0.06[a]	0.02	0.04	0.03
Zyg-Zyg											0.34**	0.09[a]	0.17	0.16[b]
Scapula Łopatka HS	0.09	0.52**	0.33[a]	0.48**	0.63**	0.35	0.49*	0.39*	–0.38*[a]	0.17				
Humerus Kość ramienna GL	0.43*[a]	0.53**	0.40	0.69**	0.50*	0.46*	0.55**	0.58**[a]	0.05	0.43*[a]				
Coxae Kość miedniczna GL	0.28	0.61**	0.49*[b]	0.48**	0.34	0.59**	0.50*	0.61**	0.05	0.38*				
Femur Kość udowa GL	0.42*[b]	0.54**	0.47*[c]	0.75**	0.35	0.56**	0.53**	0.60**[b]	0.03	0.54**[b]				

Explanations: correlation coefficient values marked with asterisk are statistically significant at: * – P ≤ 0.05; ** – P ≤ 0.01; correlation coefficient values for the same traits in males and females marked with the same lowercase letters differ significantly at: a, b, c – P ≤ 0.05; underlined values denote the highest correlation coefficients.
Objaśnienia: wartości współczynników korelacji oznaczone gwiazdkami są istotne statystycznie: * – P ≤ 0,05; ** – P ≤ 0,01.; wartości współczynników korelacji tych samych cech samców i samic oznaczone tymi samymi literami różnią się istotnie: a, b, c – P ≤ 0,05; podkreślono wartości najwyższe współczynników korelacji.

Statistical analysis showed that litter size was not a source of variation for the morphological traits of bones of the thoracic limb girdle of males and females, nor sex and litter size fir the bone elements of the pelvic limb girdle. On the other hand, it was found that females of the group with more than two animals per litter have significantly longer articular process of the scapula ($P \leq 0.05$) and the largest breadth of the distal end of humerus. No significant effect of sex or litter size on the metric traits of pelvis and femur were found. On the other hand, the calculation of the values of projections of femoral surface areas showed that the total surface are of femur and the diaphyseal surface area of this bone in animals from twin litters depends on sex. The males of long-tailed chinchilla had significantly larger values of these traits ($P \leq 0.05$ and $P \leq 0.01$, respectively) than females. The calculated values of the total femoral massiveness index, femoral epiphyseal-diaphyseal index, femoral proximal epiphyseal index and femoral distal epiphyseal index did not differ statistically significantly.

One of the study objectives is to answer the question whether a statistical correlation exists between the metric traits of the skull and those of the bones of both girdles. Therefore, the analysis of correlation coefficients being estimated for the metric traits of cranium length and breadth and those of shoulder and pelvic girdle bone length in males and females and of the relationship of carcass weight, cranium weight and mandible weight with the metric traits of the studied bones was performed (Table 7). No correlation was found for the carcass weight, cranium weight and mandible weight and the length of scapula, humerus, pelvis and femur in the group of males. On the other hand, the correlation of carcass weight and skull weight and the metric traits of these bones in females was medium and statistically significant ($P \leq 0.05$; $P \leq 0.01$). A strong, positive correlation ($r_{xy} = 0.75$; $P \leq 0.01$) was observed in the relationship of the metric trait for the greatest skull length (A-P) with the greatest length of femur (GL) in the group of female long-tailed chinchillas. Statistical analysis also showed differences ($P \leq 0.05$) between the values of correlation coefficients in the group of males and females.

The detailed description of long-tailed chinchilla skeleton is presented and referred to the anatomy of respective bone groups of other small rodents (Çevik-Demirkan et al. 2007) but without the characteristics of size proportions between the skull bones and the long bones of the thoracic and pelvic limbs. Such characteristics have been presented for the skeleton of sheep (Haak 1965) and goat (Schramm 1967), roe-deer (Frankerberger 1963, Godynicki 1970), horse (Chrószcz et al. 2014), small cursorial mammals (Seckel and Janis 2008), and cattle (Skibniewski et al. 2007). Some of these reports confirm huge intraspecific polymorphism and contributes to allometric studies (Alpak et al. 2004).

In the osteometric studies, also the goals are being set which intend to estimate the correlations taking place between the skull length, particularly the lengths inside the brain case, and the withers height of animals (Chrószcz et al. 2007).

CONCLUSIONS

In the skeleton of female long-tailed chinchillas, there is a greater correlation between the head skeleton and the skeleton of the shoulder and pelvic girdles than in males.

Sex and litter size at birth are not important sources of variation for the size of such bones as scapula, humerus, pelvis and femur of long-tailed chinchilla.

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Abstract. This study aimed at determining the values of basic osteometric traits of the long and flat bones allowing for sex and litter size as well as finding out whether a statistical correlation exists between the cranial traits and those of selected post-cranial bones in long-tailed chinchilla. The study material consisted of 140 humeri, scapulae, femora and pelvises and 136 crania of farm long-tailed chinchillas of both sexes from single and multiple litters. A greater correlation was found in the chinchilla skeleton between the head skeleton and the skeleton of the shoulder and pelvic girdles in females than in males, whereas no significant effect of sex and litter size on the metric traits of long-tailed chinchilla scapula, humerus, pelvis and femur.