ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN — POLONIA
VOL. XLII, 16 SECTIO C 1987

Instytut Biologii UMCS
Zakład Anatomii Porównawczej i Antropologii

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Osteometric and Gravimetric Analysis of Some Long Bones of *Mus musculus* Linnaeus, 1758, Living in the Coal-Mine

Analiza osteometryczna i wagowa niektórych kości długich *Mus musculus* Linnaeus, 1758, żyjących w kopalni węgla

Остеометрический и весовой анализ некоторых длинных костей у *Mus musculus* Linnaeus, 1758, живущих в каменноугольной шахте

The aim of the present paper is to trace linear and gravimetric changes in some long bones of the house mouse (*Mus musculus* L.) from the coal-mine. The paper is, to a certain degree, a continuation of investigations carried out in previous years (1, 9). At that time there were analysed taxonomic features of mice from coal-mines as well as changes in some internal organs, especially of those which could have a repercussion on specific character of a given habitat.

The coal-mine is a specific habitat, having different thermal, light, humidity and dustiness conditions. Half-darkness, permanently high temperature (23—25°C), a considerable humidity of the air (90), scarcely differentiated food, lack of seasonal changes in a year, are all undoubtedly the factors affecting changes in animals' activity and their metabolism.

Mice which were subject to observations have been remaining in the coal-mine for many generations. The investigations carried out earlier (9) allowed to distinguish a number of changes taking place in mice in the coal-mine in comparison with the individuals caught on the surface. At that time the following factors were observed among the coal-mine mice: smaller body and skull measurements, bigger body weight, a very good condition, lack of endoparasites, lack of distinct changes in the course of moult and a different reaction to light. In turn, in Bazan-Kubik (1), attention was paid to histomorphological changes in thyroid gland,

thymus gland, gonads, lungs and eyeball of the animals caught both in the coal-mine and of control ones.

The above-mentioned results of investigations, and specially the differences showed between both groups in measurements and body mass were thus the essential motive of undertaking the present subject.

Among the attainable publications pertaining to mice from the coal-mine, two of them are worth mentioning, namely Elton's (3) and Clegg's (2) publications which pay much attention to the history of living of this species under the ground and its conditioning. Clegg penetrated several coal-mines making interviews with miners and he made a number of basic body measurements of the caught specimens. He also quotes results of making measurements of mice from the coal-mine, obtained by Barret-Hamilton and Hinton in 1910—1921. The research proposals presented above did not, however, take into account the control materials from the direct proximity of the coal-mine, and the osteometric data.

Among the elaborations concerning measurements of long bones of small mammals there are several publications; unnumerous — on the *Insectivora* (5), and more numerous — on the rodents (4, 6, 7, 8). The subject of interest of the latter ones were mainly laboratory mice and rats (4, 7, 8); only Klevanova (6) examined 133 wild mammal species from various orders, explaining, among others, the functional meaning of anatomic modification of the bone and dependence of bone thickness on body weight and not on the systematic attachment. Hegemann and Schmidt (4), apart from describing the skeleton structure of rats and mice' legs, show measurements of long bones with regard to age and sexual dimorphism of animals. Kopeć (8) and Kopeć, Latyszewski (7), in turn, give in their works the weight and measurements of organs and of some long bones of mature mice from the laboratory. They also take into consideration sexual dimorphism and they give, among others, variability coefficients from the obtained measurements.

MATERIAL AND METHODS

The examined material came from the coal-mine in Mysłowice. Mice were caught at the level of 500 and 300 m, in various parts of the mine. For comparative reasons, there were also collected a number of mice from the surface; they were caught in the nearest vicinity of the mine. The material consisted of 40 individuals from the mine and 30 mice from the surface. All data concerning the catch, taxonomic measurements, thermal and food conditions, the development and reproduction of mice were given in the previous paper (9).

All the caught individuals, after taking measurements of their bodies, weighing

and taking off their skin were preserved in 70% methanol. The animals' age was determined on the basis of wearing of their teeth. The individuals' sex was determined on the basis of examining internal sexual organs. Then long bones of right front and back legs were skeletonized and cleaned. The bones were cleaned under binocular magnifying glass, by separating the muscles and the tendons with scalpel. The use of *Dermestidae* was also helpful in getting rid of soft parts.

The prepared bones in test-tubes were weighed on torsion balance of Wt type, with range up to 250 mg, exact to 0.1 mg. The weighing was carried out three times; the average of these measurements was taken as the value mostly approximating their specific weight. The linear bone measurements were also taken three times, the average being taken for real measurements. The bones were measured by means of slide calliper with nonius, exact to 0.1 mm. The measurements were taken according to the determined principles (5), for bone length — in mostly protruded closer (proximal) and farther (distal) end of the bones, whereas for the bone width — usually in the middle section of the bone.

The results of linear and weight measurements of the bones were showed in tables and diagrams. Because of relatively scarce material, only the basic statistical calculations were used; they were consulted by dr. Henryk Wrębiakowski from the Calculation Centre of the Medical Academy in Lublin.

OWN INVESTIGATIONS

INDIVIDUAL AND AGE BONE VARIABILITY

The range of variability of the particular bones measurements shows a considerable differentiation between two groups of animals (Table 1 and 2). As it results from Table 1, the average values of the bones length slightly differ among individuals from the coal-mine and those from the surface. The individuals caught in the coal-mine have slightly longer bones than those coming from the surface. In both groups the biggest average length have: the tibia (16.40 and 16.02 mm) and the femur (13.82 and 13.67 mm). The least average length, however, has the fibula (9.26 and 8.79 mm). The similar situation is with the width of the particular bones. Except for slightly higher average values of the femur and the tibia, all the others average width measurements are slightly smaller with the mice from the surface. Differences in the average values between both groups are precisely shown in Table 2.

Individual fluctuations in the range of measurements, of both length and width of the analysed bones are, for so small mammals, inconsiderable (Table 1). The range of measurements is generally smaller with individuals from the coal-mine. The calculated indices for length-width of the bone show similar tendencies in average values. Only in two cases the indices are slightly higher in mice from the surface. This pertains to the femur and the tibia (Table 2).

Table 1. Individual variability of long bones measurements of *Mus musculus* L. from coal-mine and surface

	Bone	Length of bone mm		Width of bone mm		*M* Length × width
		min — max	*M*	min — max	*M*	
Coal-mine	Femur	12.0—16.0	13.82	0.80—1.44	1.11	15.59
	Tibia	14.8—17.9	16.40	0.60—1.00	0.83	13.50
	Fibula	8.0—10.8	9.26	0.16—0.22	0.19	1.77
	Humerus	10.0—12.0	10.97	0.68—1.00	0.79	8.41
	Radius	9.5—11.4	10.52	0.36—0.66	0.51	5.14
	Ulna	11.1—13.8	12.48	0.30—0.50	0.40	4.92
Surface	Femur	10.3—15.9	13.67	1.00—1.38	1.12	15.60
	Tibia	14.0—17.6	16.02	0.70—1.40	0.89	14.03
	Fibula	7.2—11.2	8.79	0.08—0.24	0.16	1.34
	Humerus	8.5—12.0	10.63	0.55—0.90	0.72	7.76
	Radius	6.6—11.8	10.21	0.20—0.50	0.36	3.67
	Ulna	10.5—13.5	12.11	0.20—0.50	0.37	4.51

Table 2. Average values of length and width of long bones of mice from coal-mine and surface

Bone	Length of bone			Width of bone		
	Coal-mine	Surface	K-P	Coal-mine	Surface	K-P
Femur	13.82	13.67	+0.15	1.11	1.12	−0.01
Tibia	16.40	16.02	+0.38	0.83	0.89	−0.06
Fibula	9.26	8.79	+0.47	0.19	0.15	+0.04
Humerus	10.97	10.63	+0.34	0.79	0.72	+0.07
Radius	10.52	10.21	+0.31	0.51	0.36	+0.15
Ulna	12.48	12.11	+0.37	0.40	0.37	+0.03

The differentiation of measurements of long bones of both groups of mice, with consideration to the animals' age does not show significant fluctuations. Both young and mature individuals (Table 3) have slightly bigger bones than there are in mice from the coal mine (Figs. 1 and 2).

The weight values of the particular long bones oscillate quite considerably (Table 4). In both groups, from the coal-mine and from the surface, the highest average weight values have the femur (25.47 and 25.48 mg) and the tibia with fibula (21.06 and 22.24 mg). The least weight in both groups has the radius (4.47 and 4.53 mg), apart from the separated fibula. There are inconsiderable differences in the weight of the particular bones in both groups of mice. The coal-mine mice in all cases (except for the humerus) have slightly smaller average values of bones weight in comparison with the individuals from the surface (Table 5). It results from that table that the least differences, as far as the average weight values of both mice groups are concerned, are shown by the femur (0.01 mg) and the radius (0.06 mg), whereas the greatest differences — by the tibia together with the fibula (1.08 mg).

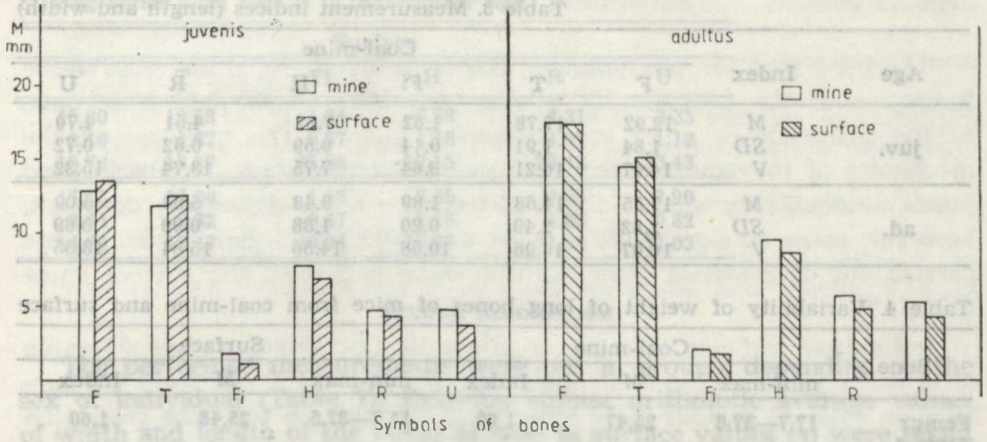

Fig. 1. Level of average values of bones length of mice from coal-mine and surface with regard to age

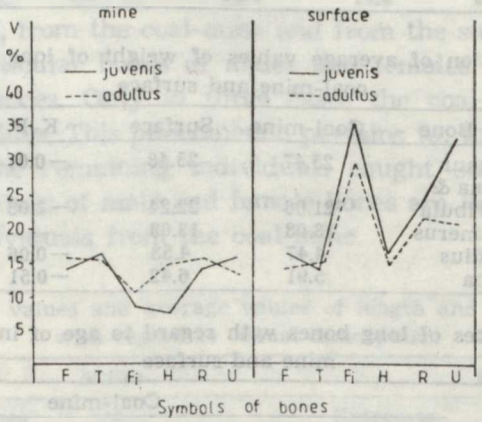

Fig. 2. Variablity coefficients (V) from particular long bones with regard to age of both populations

The differentiation of the bone weight, depending on age, is presented in Table 6. The average weight values of the particular bones differ among young and mature individuals. The level of these differences, however, shows similar tendencies in the animals from both the coal-mine and from the surface. High variability coefficients have also been found in both groups. In some cases they reach over 30%. The lowest coefficient of variability was found in young individuals, in both groups, in the weight of tibia and fibula, whereas the highest coefficient — in the femur, in young individuals from the surface and mature ones from the coal-mine (Table 6).

Table 3. Measurement indices (length and width)

Age	Index	Coal-mine					
		F	T	Fi	H	R	U
juv.	*M*	12.92	17.78	1.62	7.61	4.51	4.70
	SD	1.84	1.91	0.14	0.59	0.62	0.72
	V	14.47	16.21	8.64	7.75	13.74	15.32
ad.	*M*	17.55	14.68	1.89	9.48	5.68	5.09
	SD	2.82	2.49	0.20	1.38	0.90	0.69
	V	16.07	16.96	10.58	14.56	15.84	13.55

Table 4. Variability of weight of long bones of mice from coal-mine and surface

Bone	Coal-mine			Surface		
	min-max	*M*	Index	min-max	*M*	Index
Femur	17.7—37.8	25.47	1.60	11.2—37.5	25.48	1.60
Tibia & Fibula	16.4—31.5	21.06	1.38	11.8—33.5	22.24	1.44
Humerus	7.1—18.4	13.08	1.57	5.2—19.9	13.08	1.65
Radius	2.3—6.2	4.47	0.87	2.7—6.5	4.53	1.27
Ulna	4.1—8.5	5.91	1.24	4.1—8.8	6.42	1.47

Table 5. Differentiation of average values of weight of long bones of mice from coal-mine and surface

Bone	Coal-mine	Surface	K-P
Femur	25.47	25.48	−0.01
Tibia & Fibula	21.06	22.24	−1.08
Humerus	13.08	13.08	—
Radius	4.47	4.53	−0.06
Ulna	5.91	6.42	−0.51

Table 6. Weight indices of long bones with regard to age of individuals from coal-mine and surface

Age	Index	Coal-mine				
		F	T & Fi	H	R	U
juv.	Extremes	17.7—37.8	16.4—22.8	7.1—13.7	2.3—4.9	4.1—6.4
	M	20.4	18.9	10.5	3.8	5.1
	SD	3.3	2.7	2.3	1.4	0.9
	V	16.1	14.5	21.9	37.7	17.4
ad.	Extremes	21.5—37,8	17.5—31.5	11.5—18.4	3.6—6.2	4.6—8.5
	M	29.0	22.5	14.9	5.0	6.5
	SD	8.9	4.2	2.7	1.04	1.6
	V	30.8	18.5	18.4	20.8	25.0
Age	Index	Surface				
juv.	Extremes	11.2—31.4	11.8—24.8	5.2—13.4	2.7—5.6	4.1—7.3
	M	19.0	18.9	10.3	3.7	5.3
	SD	5.8	3.2	2.7	0.8	1.0
	V	30.8	17.0	26.7	22.9	19.0
ad.	Extremes	21.5—37,5	20.5—33.5	7.6—19.9	3.3—6.5	5.5—8.8
	M	29.8	24.9	14.9	5.1	7.3
	SD	4.8	5.1	3.3	0.9	1.1
	V	16.4	20.5	22.1	18.8	15.1

of long bones with regard to individuals' age

Surface					
F	T	Fi	H	R	U
13.30	12.58	1.04	6.88	4.31	3.35
2.10	1.67	0.37	1.18	1.01	1.12
15.79	13.27	35.58	17.15	23.43	33.43
17.13	15.00	1.57	8.35	4.69	2.90
2.44	2.32	0.47	1.16	1.03	0.82
14.24	15.47	29.94	13.80	21.96	21.03

SEXUAL DIMORPHISM

The performed measurements were put in groups, depending on the sex of individual (Table 7). Extreme values, arithmetic average values of width and length of the bones as well as surface values (π) were taken into consideration. The data obtained in the table point to slightly higher average values and surface values of the bones for both sexes of mice from the coal-mine.

In both groups, from the coal-mine and from the surface, the average values of the particular bones of males and females, do not show any significant differences. Only in three cases the coal-mine males have slightly higher values. This phenomenon pertains to: the femur, humerus and radius. In the remaining individuals caught on the surface, the average weight values of male and female bones are lower in comparison with those of individuals from the coal-mine.

Table 7. Surface (π) values and average values of length and width of mice bones with regard to sexual dimorphism

	Bone	Males			Females		
		Extremes length × width	*M* length × width	π	Extremes length × width	*M* length × width	π
Coal-mine	Femur	10.0—21.8	15.87	49.83	9.7—20.3	15.42	51.97
	Tibia	11.3—17.9	14.60	45.86	8.9—17.5	12.72	40.01
	Fibula	1.7— 1.9	1.77	5.56	1.4— 2.4	1.78	5.60
	Humerus	6.8—10.6	8.87	27.88	7.0—12.0	8.64	27.13
	Radius	3.6— 7.1	5.08	15.95	3.8— 6.6	5.18	16.27
	Ulna	4.6— 6.0	5.31	16.67	3.3— 6.7	4.71	14.81
Surface	Femur	10.3—20.7	15.88	49.88	10.9—21.0	15.41	48.38
	Tibia	9.8—18.8	14.83	46.56	11.4—16.7	13.51	42.43
	Fibula	0.7— 2.2	1.49	4.70	0.8— 2.0	1.24	3.89
	Humerus	4.6—10.4	7.87	24.72	5.3— 9.5	7.69	24.16
	Radius	2.6— 5.2	3.72	11.37	2.1— 5.1	3.72	11.69
	Ulna	21.1— 6.2	4.19	13.18	3.3— 6.0	4.78	15.02

RECAPITULATION OF RESULTS

The bony skeleton of mammals, due to its structure, is the most stable formation of the organism. It is also very little elastic and little open to the influence of outer environmental factors. The pressure of the mechanics of movement, acting through intensive work of muscles and joints, undoubtedly shapes the skeleton to a high degree; it does not, however, cause so significant changes as in the soft organs. Observations carried out on material from the coal-mine and from the surface show this (1, 9).

Individual and age changes in bones do not show any considerable differences in both groups of mice from the coal-mine and from the surface. In spite of smaller body size in the individuals from the coal-mine (9), the average value of the particular long bones do not show any significant differences in comparison with long bones of individuals from the surface. Only variability coefficients (*V*) are distincly lower in case of bone sizes of coal-mine mice (Fig. 2).

Similarly, the weight of the particular bones in both groups does not differ, in spite of the fact that the body weight of the coal-mine mice was bigger than that of the control group (9). The indices given for the analysed bones of both groups point to a slight increase of the average values of bone mass in mice from the surface. Variability coefficients, pertaining to the weight of the particular bones which show high lability (reaching up to ca. 40%) both in young and mature individuals, prove a considerable individual and age variability of the investigated feature in both analysed populations.

Analysing the weight and linear measurements of the bones of mice from the coal-mine and from the surface and with regard to sexual dimorphism, a random nature of changes occurring in both groups was found. There is a slight tendency towards the increase of the average values of some long bones in males coming from the coal-mine.

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STRESZCZENIE

Przeprowadzono analizę pomiarów liniowych i wagowych niektórych kości długich *Mus musculus* L., żyjących w kopalni węgla i na powierzchni. Mimo różnic w długości i ciężarze ciała między obu grupami, nie stwierdzono istotnych zmian w wymiarach kości. Zarówno indywidualne, jak i wiekowe wartości średnich długości i szerokości kości długich wykazywały umiarkowane zróżnicowanie między obu grupami. Podobnie w ciężarze poszczególnych kości, mimo że średni ciężar ciała myszy z kopalni był wyższy, nie stwierdzono istotnych zróżnicowań między badanymi grupami. Wartości współczynnika zmienności poszczególnych kości długich w aspekcie indywidualnym i wiekowym wykazywały znaczną labilność analizowanych cech, zarówno u myszy z kopalni, jak i z powierzchni. Nieznaczne tendencje zwyżkowe w wartościach średnich liniowych i wagowych niektórych kości długich stwierdzono u samców myszy z kopalni.

РЕЗЮМЕ

Проведен анализ линейных и весовых измерений некоторых длинных костей у *Mus musculus* L., взятых из угольной шахты и с поверхности. Несмотря на разницы в длине и весе тела у особей обеих групп, существенных изменений в размерах костей не установлено. И индивидуальные, и возрастные величины средней длины и ширины длинных костей у особей обеих групп дифференцированы умеренно. Кроме того, вес отдельных костей в этих группах не отличается существенной дифференциацией, хотя средний вес тела мыши из шахты был больше. Величины коэффициента изменчивости отдельных длинных костей как в аспекте индивидуальном, так и возрастном указывают на значительную лабильность анализированных признаков у одних и других мышей. Незначительные тенденции к повышению средних линейных и весовых величин для некоторых длинных костей выявили у самцов из угольных шахт.