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Morphometric Traits of the Heart in Standard and Mutational Colour Variants of American Mink (*Neovison vison*)

Características Morfométricas del Corazón en las Variantes de Color Estándar y Mutacional del Visón Americano (*Neovison vison*)

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SUMMARY: The aim of this study was to estimate the values of morphological traits of myocardium in American minks. The study was conducted on 342 male mink hearts and 416 female mink hearts. Mink coat coloration resulting from mutation or cross-breeding of mutational variants with each other and sex were assumed as a source of variation. Carcass, lung and heart weights, heart height, width, depth and circumference, as well as left and right ventricular wall weights and thickness at two locations were determined. The values of 10 indices characterising the relative size of the heart were estimated. The results showed no normal distribution of the heart traits examined. The greatest average heart weight was characteristic of male mutational colour variant minks (17.40 ± 2.34 g). These hearts were heavier by more than 8 % than those of male standard colour variant minks. The hearts of male mutational colour variant minks were characterised by the greatest left and right ventricle weights ($P \leq 0.01$) compared to those of male standard colour variant minks, in which in turn the greatest left and right ventricle wall thickness was larger than that in standard colour variant minks. It was found that a greater difference calculated between mean left ventricle wall thickness and mean right ventricle wall thickness in standard colour variant minks may provide more evidence of its adaptation to a greater effort, referring thus to their evolutionary history than to the occurrence of signs of multistage myocardial hypertrophy.

KEY WORDS: Domestication of animals; American mink; Heart biometry; Myocardial structure.

INTRODUCTION

Research on the structure of the heart in different groups of animals includes, among others, the relationships between heart size and body size (Prothero, 1979; Heusner, 1991; Koritiaki *et al*., 2013), body performance and the effect of effort or its cessation on the morphological traits of the heart and cardiac contractility (Steel *et al*., 1976; Nielsen & Vibe-Petersen, 1980; Pape *et al*., 1984; Gunn, 1989), or the association of heart morphological parameters with various environmental factors (Viscor & Fuster, 1987; Simpson *et al*., 2007). In studies on the heart morphology, it is important to establish the relationship between the weight of this organ and the body weight, which may be induced by the level of growth and sex hormones being secreted or diet (Bailey *et al*., 2004; Simpson *et al*.). Analysis of differences in heart vasculature or heart size in animals that are phylogenetically close to each other (Besoluk & Tipirdamaz, 2001) also leads to interesting observations. Obtaining information about the heart of wild animals makes it possible to estimate the values of its parameters during ontogeny (Cavallini, 1997; Kowalczyk *et al*., 2014) or a change in its morphometry as a result of domestication (Wysocki *et al*., 2010). Keeping animals under the conditions of breeding environment with limited movement and intensive nutrition can cause, among others, changes in ventricular wall thickness and vascular sclerosis leading to heart rhythm abnormalities (Mayer *et al*., 2011) or heart failure, including sudden heart death (Hyun & Filippich, 2006). On the one hand, right ventricular heart failure, most often induced by respiratory tract diseases, pulmonary artery stenosis or pulmonary hypertension, induced in turn by left ventricular heart failure (Dunn *et al*., 1973; Kisloff & Schaffer, 1976), can be a cause of ascites, hydrothorax, hydropericardium, congestive oedema of parenchymal organs, resulting in the impairment of their function (Birgens *et al*., 1978; Field & Meyer, 1978; Lambert, 1991). On the other hand, more intensive breeding with the increasingly frequent use of mutations may lead to far-reaching changes in general health

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status of animals. In American minks kept under human control and undergoing selective pressure, there have been a change in the morphological type (Kruska, 2005; Baranowski *et al*., 2014), as well as a number of coat coloration mutations, as a typical consequence of their domestication (Castle & Moore, 1946). This requires paying attention to the possibility of side effects of one-sided selection and raising awareness to the effect of mutations on the cardiac status. In humans, 8 genes responsible for the development of arrhythmogenic right ventricular cardiomyopathy (ARVC) and more than 140 mutations in the genes being responsible for its development have been identified (Fatkin & Graham, 2002), therefore it cannot be excluded that more intensive breeding may lead to the development of heart diseases in some genetic lines of American minks.

The aim of this study was to determine whether coat coloration of American minks, resulting from the effects of 31 pairs of dominant and recessive genes, with coat coloration other than standard one, which is the result of mutation in 1 locus or cross-breeding of mutational colour variants with each other, differs in the morphological traits of myocardium.

MATERIAL AND METHOD

All animals, from which the hearts were collected, came from the same farm (53°40'N, 15°08'E) and were housed in identical standard breeding cages (72 × 30 x 42 cm) with wooden boxes, placed in outdoor pavilions. These buildings are located in north-south direction. The animals were kept in accordance with the European Convention for the Protection of Vertebrate Animals and complied with the conditions of the Act of 29 June 2007 in force in Poland. The animals were in good condition over the entire period to their technological slaughter at the age of 7 months which was performed during two skinning seasons: 1) 21-27 November 2012, and 2) 5-8 November 2013. The minks were fed with fresh balanced feed being administered 3 times a day directly per cage. The feed included beef, pork, poultry, fish and other by-products originating from the food industry. The feed contained about 3850 kcal/kg metabolic energy in dry mass, of which 45 % were from protein, 31 % from fat and 24 % from carbohydrates. Animal watering system was automatic. Veterinary supervision of the farm was exercised by a District Veterinary Officer. The rib cage of randomly selected 342 male and 416 female minks of four colour variants (standard – Black, n = 202, and Mahogany, n = 164; mutational – Silver Blue, n = 197, and Regal White, n = 195), the carcass weight (CW) of which was determined in grams (g) after taking off the skin, was opened. The lungs and the heart – from which large blood vessels were cut off at a height of about 1 cm from its base, were removed from it and weighed, after rinsing the blood off under running water, removing the pericardium and drying. Then, the image of the heart was captured with a Canon EOS-1000D digital camera with a Macro EFS60 mm f/2.8 lens. The hearts were measured with an electronic calliper (ORION INOX Digital Vernier Callipers 31170-150, 150 x 0.01 mm / 6 x 0.0005") employing the methodology used in mammalian and avian heart morphology (Stahl, 1965; Holt *et al*., 1968; Viscor & Fuster; Drabek, 1989).

The following parameters were determined:

H – heart weight (measurement made with an electronic balance);
L – heart height (measured from the apex of the heart to its base);
W – heart width (measured at the coronary groove together with fat in a horizontal plane);
D – heart depth (measured as the largest sagittal diameter of the heart);
C – heart circumference (measured with a measuring tape at the coronary groove);
Lg – lung weight (measurement made with an electronic balance).

After completing the measurements, each heart was subjected to preparation in the following way: atria were separated – left (atrium sinistrum) and right (atrium dextrum) – by an incision running above the coronary groove. Then, the anterior wall of the right ventricle was separated by making an incision running through the anterior wall of the right ventricle along the intraventricular groove, close by the trabeculae carneae, towards the apex of the heart. Next, an incision was made along the interventricular septum (septum interventriculare) from the base of the heart to its apex. This made it possible to open the left ventricle without damaging papillary muscles (mm. papillaris). On the thus prepared ventricle, another incision was made running along the wall of the left ventricle, exactly between papillary muscles, which allowed determining the thickness (in mm) of the left ventricular wall (TLV1). This thickness was measured each time in the same place at the attachment of the tendinous chords (chordae tendineae) to the papillary muscle of the left heart and the left ventricular wall. Another incision was made on the left half of the left ventricular wall, exactly half the width of the papillary muscle along its axis in order to determine the thickness of the left ventricular wall (TLV2). The same incision and measurement were made on the ventricular wall of the right heart (TRV1 and TRV2). In the next stage, photographs of individual heart elements were taken against the reproduction table scale. The reference value was callipers. In addition, the following parameters were determined:
LV – left ventricular wall weight;
RV – right ventricular wall weight.
Using MultiScan software, the following was measured:
TLV1 – left ventricular wall thickness 1

TLV2 – left ventricular wall thickness 2
TRV1 – right ventricular wall thickness 1
TRV2 – right ventricular wall thickness 2.
The results obtained were the basis for estimating the values of the indices that characterise relative heart parameters:
I1 – heart height x 100/heart width, L/W
I2 – heart volume, SVOL = L x W x D;
I3 – percentage of left ventricular wall weight in heart weight, LV/H;
I4 – percentage of right ventricular wall weight in heart weight, RV/H
I5 – percentage of heart weight in 1000 g of carcass weight, 1000H/B
I6 – right ventricular wall weight to left ventricular wall weight ratio, RV/LV
I7 – heart width to heart height ratio, W/L
I8 – heart weight to lung weight ratio, H/Lg
I9 – right ventricular wall weight to lung weight ratio, RV/Lg
I10 – difference between mean left ventricular wall thickness 1 and 2 (TLV1+TLV2/2) and mean right ventricular wall thickness 1 and 2 (TRV1+TRV2/2).

The values of measurements for the weight of the heart and its elements, and that of lungs were determined to the nearest 0.01 g, while those for length, width and height to the nearest 0.01 mm. The measurement results were analysed statistically with Statistica v.13PL software. The normality of trait distributions was analysed. Due to the absence of normal distribution, analysis of variance with the Mann-Whitney U test and the Kruskal-Wallis test was used to estimate the value of differences between groups (sex, colour variant). Furthermore, the value of Spearman's correlation coefficients was estimated. Differences between two correlation coefficients were evaluated using the panel "other significance tests", taking into account the group sizes.

RESULTS

The hearts were collected during two consecutive seasons of mink skin harvesting. Table I presents the results of the Mann-Whitney U test estimated to determine the effect of the year of sampling on carcass weight and heart weight, taking into account mink colour variant and sex. No effect of the year of sampling was found, which allowed for the cumulative estimation of the values of the heart traits examined in respective colour variants from two consecutive years. Table II presents mink carcass weight of both sexes. The greatest weight was characteristic of the carcasses of male mutational colour variant minks (x = 1865.44 ± 309.82 g) and they were heavier by 6.75 % ($P \leq 0.01$) compared to those of male standard colour variant minks (1747 ± 201.67 g). Sexual dimorphism in carcass weight was also found ($P \leq 0.05$).

The average values of heart morphological traits for male and female minks are presented in Table III. Comparison of the values of these traits in both sexes showed sexual dimorphism in all examined traits ($P \leq 0.01$). In addition, differences were found ($P \leq 0.05$ and $P \leq 0.01$) between mink colour variants in the heart traits examined. The greatest mean heart weight was characteristic of male mutational colour variant minks (17.40 ± 2.34 g). These hearts were heavier by more than 8 % than those of male standard colour variant minks. The hearts of male mutational colour variant minks were also characterised by the greatest left ventricular wall and right ventricular wall weights ($P \leq 0.01$) compared to the hearts of male standard colour variant minks, the greatest thickness of the left and right ventricular walls of which was larger than that of mutational

Table I. The values of Mann-Whitney U test calculated for the year of sampling by carcass weight and heart weight in standard and mutational colour variant minks chosen for the study

Weight	Male minks		Female minks	
	Standard	Mutational	Standard	Mutational
carcass	0.330	0.380	0.407	0.148
heart	0.423	0.370	0.146	0.174

Table II. Carcass weight [g] of male and female standard and mutational colour variant minks chosen for the study

Measure	Male mink colour variant (n =		Female mink colour variant (n =	
	Standard	Mutational	Standard	Mutational
n	180	164	187	229
x	1747.49*[A]	1865.44*[A]	1045.46*[a]	1018.70*[a]
sd	201.67	309.82	135.43	150.89
min.	1070.00	1180.00	776.00	645.00
max.	2301.00	2760.00	1450.00	1572.00

Explanations: for each colour and variety, mean values marked in rows with the same letters differ significantly: a b – $P \leq 0.05$; A B –-$P \leq 0.01$. Mean values marked in rows with * differ significantly at $P \leq 0.05$.

colour variant minks. In turn, the hearts of female standard colour variants minks were characterised by larger left ventricular wall weight and larger (P≤0.01) thickness of this ventricular wall compared to mutational colour variant minks. The hearts of male mutational colour variant minks exceeded significantly (P≤0.01) those of male standard colour variant minks in heart weight, height and depth. This pattern was also confirmed (P≤0.05) in the group of female minks. By contrast, the thickness of the left ventricular wall and that of the right ventricular wall in the hearts of male and female standard colour variant minks exceeded (P≤0.01) the values of these traits in the hearts of mutational colour variant minks.

Table IV presents the ratio of selected absolute values of mink body traits in standard and mutational colour variants expressed as a percentage. Standard colour variant minks were smaller than mutational ones, and the weight of their heart made this difference clearly evident. In this table, the value of the parameter estimated for a difference in the thickness of the left and right ventricular walls is of particular interest. The value of this parameter is dominant in standard colour variant minks.

Table IV. Comparison of the relative parameters of carcass weight and heart traits in standard and mutational colour variant minks

Parameter	Parameter value Standard / Mutational x 100
CW	96.838
H	93.193
L	97.464
W	99.135
C	99.271
LV	99.649
RV	98.191
LV+ RV	99.319
TLV1+TLV2/2 – TRV1+TRV2/2	103.416

The average values for the lung weight of the minks examined are presented in Table V. Male minks were characterised by a larger weight of this organ compared to female ones (P≤0.01; P≤0.05). Consolidation of the weight of this organ in standard colour variants was greater than in mutational colour variants (V %s = 14.81 v. V %m = 18.54). In the group of female minks, this consolidation was similar (V %s = 17.70 v. V %m = 18.22). Calculation of the values of the lung weight resulted from the need to estimate the values of some indices characterising the relationships of heart traits, carcass weight and right ventricular wall thickness to lung weight (Table VI). The values of indices did not confirm absolute differences between male colour variant minks only in relation to the right ventricular wall weight-to-left left ventricular wall weight ratio (index I6) and differences between mean left ventricular wall and right ventricular wall thickness values (index I10). In the group of female minks, the heart volume was similar, and the accepted source of variation – colour variant – proved to be significant (P≤0.01) only in relation to male minks. The values of indices I8 and I9 present a relationship between heart weight and lung weight of an individual and between right ventricular wall weight and lung weight. In the case of these two indices, colour variant – both in male and female minks – was a significant source of variation. The values of the indices expressing the percentage of the left ventricular wall weight in heart weight (index I3) and the percentage of the right ventricular wall weight in heart weight (index I4) draw particular attention. The value of the two indices is higher (P≤0.01) in both sexes in the group of standard colour variant minks compared to that of mutational colour variant minks.

Table III. The values of selected heart traits in male and female standard and mutational colour variant minks.

Trait	Measure	Male minks		Female minks	
		Standard	Mutational	Standard	Mutationa
	n	180	164	187	229
H	x	15.95**^{A}	17.40**^{A}	10.06**^{a}	10.50**^{a}
	sd	2.24	2.34	1.69	1.75
L	x	38.35**^{A}	40.14**^{A}	33.06**	33.13**
	sd	3.47	2.99	2.72	2.24
W	x	30.02**	30.56**	25.43**	25.37**
	sd	2.73	3.19	2.97	2.09
D	x	20.97**^{A}	21.57**^{A}	18.39**^{a}	18.83**^{a}
	sd	2.27	2.52	2.40	1.77
C	x	82.18**	82.77**	71.15**	71.69**
	sd	5.29	5.26	5.34	5.45
LV	x	10.57**^{a}	11.11**^{a}	6.37**^{A}	5.89**^{A}
	sd	1.93	2.16	1.30	1.03
TLV1	x	7.15**	7.04**	6.28**^{A}	5.76**^{A}
	sd	0.78	0.86	0.72	0.73
TLV2	x	7.82**^{A}	7.56**^{A}	6.70**^{A}	6.23**^{A}
	sd	0.88	0.92	0.75	0.69
RV	x	3.49**^{a}	3.65**^{a}	2.04**	1.98**
	sd	0.81	0.81	0.51	0.46
TRV1	x	2.66**^{A}	2.50**^{A}	2.38**^{A}	2.16**^{A}
	sd	0.45	0.50	0.35	0.38
TRV2	x	2.72**^{A}	2.49**^{A}	2.39**^{A}	2.22**^{A}
	sd	0.43	0.54	0.35	0.37

Table V. Lung (Lg) weight [g] in male and female standard and mutational colour variant minks.

Measure	Male minks		Female minks	
	Standard	Mutational	Standard	Mutational
n	180	164	187	229
x	42.10**	42.22*	29.10**	29.36*
sd	5.59	7.17	4.56	4.91
min	26.08	21.52	19.23	15.93
max	56.95	69.10	40.82	43.04

Explanations: mean values marked with * differ significantly at P≤0.05; those marked with ** differ significantly at P≤0.01.

Table VI. The values of heart indices in male and female standard and mutational colour variant minks.

Index	Measure	Male minks		Female minks	
		Standard	Mutational	Standard	Mutational
	n	180	164	187	229
I1	x	1.28*A	1.32A	1.30*	1.31
	sd	0.11	0.11	0.11	0.10
I2	x	24.51**A	26.78**A	15.80**	15.92**
	sd	6.74	6.67	5.78	2.90
I3	x	66.73**A	64.14**A	63.96**A	56.59**A
	sd	10.21	10.52	12.24	8.60
I4	x	21.92**	21.10**	20.52**A	19.04**A
	sd	3.96	4.10	4.97	3.98
I5	x	9.18**a	9.48**a	9.66**A	10.42**A
	sd	1.27	1.46	1.39	1.64
I6	x	33.02	33.17	32.23a	33.99a
	sd	4.40	5.28	5.58	7.19
I7	x	78.57*A	76.24A	76.95*	76.76
	sd	6.91	6.85	6.67	6.23
I8	x	0.38**A	0.42**A	0.35**a	0.37**a
	sd	0.06	0.09	0.06	0.07
I9	x	0.08**A	0.09**A	0.07**	0.07**
	sd	0.01	0.02	0.02	0.02
I10	x	4.79	4.80**	4.10	3.80**
	sd	0.66	0.77	0.57	0.56

Explanations: see Table II.

DISCUSSION

All animals, the hearts of which were used in the study, were subjected to the same euthanasia procedure with carbon monoxide. No data have been found in literature sources on the assessment of the effect of this gas on organs, as it has been done in the case of hydrogen cyanide and electric current (Daniel, 1959; Wood *et al*., 1965). However, in the conclusion of these papers their authors agreed that the heart – compared to the liver, kidneys or spleen – is the least likely to lose weight post mortem and is the most important parameter of the assessment of the organ-to-body weight relationship. Also the brain is considered as an equally suitable organ for this type of comparisons (Kruska & Schreiber, 1999) but its field application is of little use (Daniel). Only non-eviscerated carcass weight, without skin, was taken into account in the study, which makes it difficult to compare the values of heart indices evaluated with literature data in which body weight of different animal species is usually available (Cavallini; Barszcz *et al*., 2012; Senos *et al*., 2013; Pérez *et al*., 2018). It is believed that body weight, as a parameter being taken into account when evaluating the organ / body weight relationship, is too strongly dependent on environmental factors (Kowalczyk *et al*.), which masks possible genetic predispositions of the relationship of these traits (Kruska & Schreiber). However, in this study we are dealing with constant conditions of the breeding environment, so the effect of diet is not significant, and the organ (heart) / body weight relationship is identical for all examined animals. The value of the relative heart weight ratio is different in particular taxonomic groups and, for instance, in birds is in the range of 0.73-1.45 (Straub *et al*., 2002), in cats 0.40-0.80, in dogs 0.65-0.78 (Nickel *et al*., 1976), but in this species there is 8.10 g and 7.92 g of heart weight per one kilogram of body weight in male and female dogs, respectively. Dog breed and sex are not without effect on the value of heart weight-to-body weight ratio (Miller *et al*., 1965). In horses, heart weight is estimated at about 4 kg, which is 0.7 % of body weight. An exception was the heart of a racing stallion, Eclipse, which weighed 6.5 kg (Poplewski, 1948). The relative weight of the heart in this species is in the range of 0.4-1 %, which depends on the horse condition, use and breed (Sisson & Grossman, 1975).

Interspecific and intraspecific differences in heart weight depend on the effort which an animal performs but also on the type of environment in which it lives. A particular example can be penguins of one of the species capable of diving to great depths. Their hearts is characterised by larger right ventricular weight to total heart weight compared to other diving birds but with significantly greater body weight. In this case, it is believed (Drabek & Tremblay, 2000) that a higher percentage of the right ventricle weight in heart weight may significantly affect the increase in lung tissue perfusion during their stay on the water surface and the shortening of this stay. The aquatic or semi-aquatic (living in aquatic and terrestrial environment) Mustelidae species have invariably smaller hearts than terrestrial animals. Also the lungs of these animals are smaller than, for instance, in martens or otters, the activity and mobility of which is exceptional (Daniel).

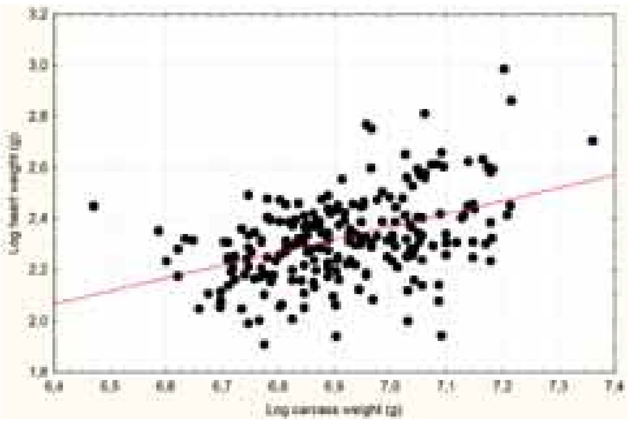

Fig. 1. The relationship between heart weight (g wet weight , log transformed) and carcass weight (g wet weight, log transformed) for femals minks of the mutation variety. Regression lines represent standardized major axis regressions ± 95% confidence intervals. (females minks mutation var.carcass x heart.)

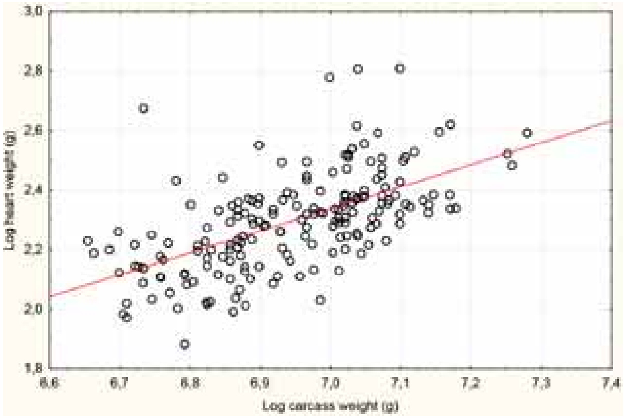

Fig. 2. The relation The relationship between heart weight (g wet weight , log transformed) and carcass weight (g wet weight, log transformed) for femals minks of the mutation variety. Regression lines represent standardized major axis regressions ± 95% confidence intervals. (females minks standard var.carcass x heart).

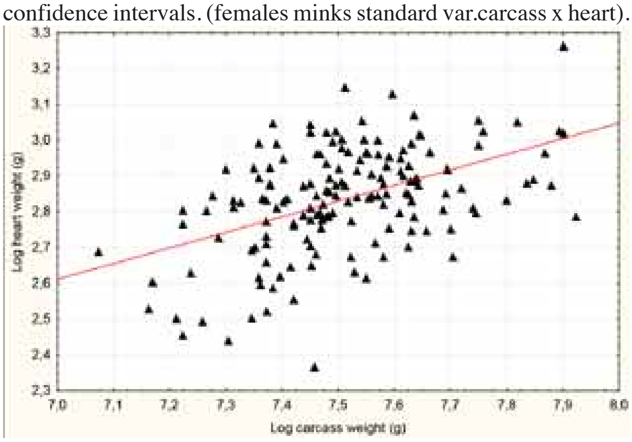

Fig. 3. The relation The relationship between heart weight (g wet weight , log transformed) and carcass weight (g wet weight, log transformed) for femals minks of the mutation variety. Regression lines represent standardized major axis regressions ± 95% confidence intervals. (males minks mutation var.carcass x heart).

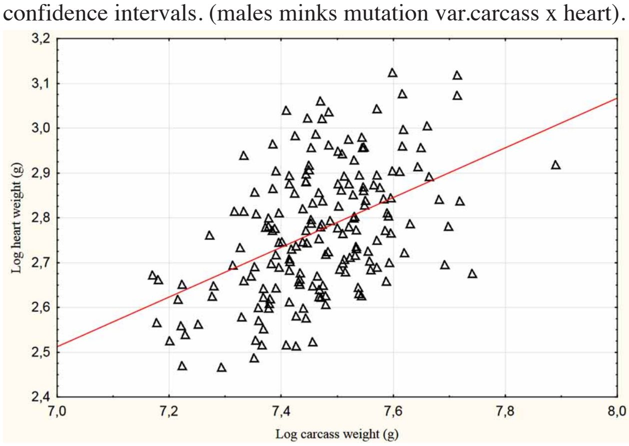

Fig. 4. The relation The relationship between heart weight (g wet weight , log transformed) and carcass weight (g wet weight, log transformed) for femals minks of the mutation variety. Regression lines represent standardized major axis regressions ± 95% confidence intervals. (males minks standard var. carcass x heart).

Table VII. The values of Spearman's correlation coefficients for carcass weight (CW) and selected heart traits in male standard and mutational colour variant minks.

	Mink colour variant	CW	H	Lg	I2	Mutational LV	RV	TLV1	TRV2	TLV2	TRV2
Standard	CW		0.439**	0.505**a	0.478**	0.366**	0.292*	0.055	-0.080	0.147	-0.140
	H	0.478**		0.204*	0.487**	0.513**	0.513**	0.034	0.116	0.062	0.085
	Lg	0.330**a	0.359**		0.245**	0.125	0.114	0.089	0.057	0.122	0.005
	I2	0.380**	0.511**	0.256**		0.270**	0.193**	0.085	-0.085	0.038	-0.092
	LV	0.387**	0.546**	0.169*	0.085		0.679**	0.274**	0.297*	0.256**	0.255**
	RV	0.321**	0.597**	0.323**	0.597**	0.742**		0.232**	0.327**	0.242**	0.219**
	TLV1	0.130	0.197**	0.172*	0.029	0.262*	0.160*		0.347**	0.563**	0.249**
	TRV2	0.073	0.093	0.229*	-0.087	0.307**	0.229*	0.355**		0.342**	0.669**
	TLV2	0.053	0.083	0.153	-0.117	0.164	0.153	0.622**	0.392**		0.232**
	TRV2	0.211**	0.090	0.145	0.013	0.160	0.145	0.259**	0.626**	0.322**	

Explanations: the values of correlation coefficients rxy marked with asterisk differ significantly (* – P≤0.05; ** – P≤0.01); those marked with the same letters differ significantly (a – P≤0.05; A - P≤0.01).

Table VIII. The values of Spearman's correlation coefficients for carcass weight (CW) and selected heart traits in female standard and mutational female colour variant minks.

	Mink colour variant	CW	H	Lg	I2	Mutational LV	RV	TLV1	TRV2	TLV2	TRV2
Standard	CW		0.611**	0.420**	0.434**	0.378*	0.189*	0.084	-0.021	0.158	0.004
	H	0.638**		0.343**	0.673**	0.560**	0.492**	0.090	-0.049	0.136	-0.082
	Lg	0.447**	0.437**		0.382**	0.158	-0.091	-0.087	-0.159	0.134	-0.125
	I2	0.517**	0.741**	0.376**		0.411**	0.334**	-0.041	-0.085	0.059	-0.072
	LV	0.351**	0.460**	0.165*	0.130		0.488**	0.260**	0.178*a	0.247**	0.119
	RV	0.328**	0.396**	0.054	0.068	0.709**		0.239**	0.250**	0.192**	0.186*
	TLV1	0.084	0.033	0.020	-0.043	0.351*	0.207**		0.373**	0.550**	0.325**
	TRV2	0.019	0.096	0.088	-0.054	0.360**a	0.193**	0.397**		0.329**a	0.707**
	TLV2	0.150	0.132	0.062	-0.028	0.451**	0.302**	0.675**	0.482**a		0.334**
	TRV2	0.070	0.074	0.012	-0.102	0.362**	0.228**	0.371*	0.679**	0.401**	

Explanations: see Table VII.

Figures 1 to 4 present the correlation of the values of heart weight and carcass weight logarithms in minks of both colour variants: standard and mutational, while the values of Spearman's correlation coefficients estimated for carcass weight and heart traits in minks of both sexes and colour variants are presented in Tables VII and VIII. These data show that there is no effect of mutation on the relationship of these parameters, while the calculated correlation coefficients show a weak or moderate correlation in both sexes and colour variants. In large mammals, heart weight shows a strong correlation with its basic dimensions. For example in European bison, the correlation between heart height and its absolute weight is significant (P≤0.01) and is r = 0.805 for male bisons and r = 0.976 for female bisons. Similarly, heart circumference in this species is strongly dependent on its weight, and the correlation coefficients are r = 0.802 and r = 0.901 (P≤0.01), respectively, whereas the relative value of heart weight strongly and inversely correlates with body weight (Wegrzyn & Kupczynska, 1986).

The conducted study shows a clearly significant (P≤0.01) relationship between heart weight and height and heart circumference in male standard colour variant minks (not presented in tables): rHxL = 0.363 and rHxC = 0.589, respectively; whereas in male mutational colour variant minks: rHxL = 0.502 and rHxC = 0.610, respectively. In the female minks of examined colour variants these relationships were significant (P≤0.01) and meaningful. They took the following values: rHxL = 0.612 and rHxC = 0.726 for standard colour variant minks, and rHxL = 0.576 and rHxC = 0.643 for mutational colour variants minks, respectively.

Comparison of the parameters of relative carcass weight and heart traits in minks (Table IV) shows that the examined heart traits of standard colour variant minks are smaller than those of mutational colour variant ones, except for the differences between mean left ventricular wall thickness and mean right ventricular wall thickness. This may provide more evidence of the adaptation of this ventricle's wall in male and female standard colour variant minks to a greater effort, thus referring to their evolutionary history and bringing the values of these traits closer to the characteristic values for other species of the Mustelidae family, which are martens and otters (Daniel) that live free, rather than to the occurrence of signs of multistage myocardial hypertrophy, as demonstrated in pigs (Chiu *et al*., 1999; Huang *et al*., 1999) and described in humans, cats and dogs (Liu *et al*., 1993).

In summary, the findings presented in this paper do not give grounds for considering the effect of mutation or cross-breeding of mutational colour variants with each other on the morphological traits of the heart of minks of both sexes to be significant. Nevertheless, it should be borne in mind that identification of the genes correlated with hypertrophic cardiomyopathy (HCM) in humans and its occurrence in farmed species may, in some genetic models resulting from inbreeding or mutations, cause loss of animal performance and lead to increased mortality due to morphological changes in the myocardium, disorganisation of myocardial tissue myocytes, and myocardial fibrosis. At the same time, the presented empirical measurement data for the traits of morphological heart elements presented in this study can be a contribution to a better understanding of the mink heart structure, as well as to further research on this organ or its relationship with other organs. These findings can be helpful as reference values when examining the heart structure in other Mustelidae species, both farmed and free-living ones. These mammals are useful indicator organisms. They are widespread stock animals that can be kept and examined in captivity, and, moreover, are found in various ecosystems, showing a high level of trophic status, bioaccumulation potential, sensitivity to pollution, and can be caught alive in sufficient numbers and have well-known biology.

BARANOWSKI, P. & ZUK, K. Características morfométricas del corazón en las variantes de color estándar y mutacional del visón americano (*Neovison vison*). *Int. J. Morphol., 37(2)*:757-765, 2019.

RESUMEN: El objetivo de este estudio fue estimar los valores de los rasgos morfológicos del miocardio en el visón americano. El estudio se realizó en 342 corazones de visón macho y 416 corazones de visón hembra. La coloración de la capa de visón resultante de la mutación o el cruce de variantes mutacionales entre sí, y el sexo se asumieron como una fuente de variación. Se determinaron los pesos de la canal, los pulmones y el corazón, la altura del corazón, el ancho, la profundidad y la circunferencia, así como los pesos y el grosor de las paredes de los ventrículos izquierdo y derecho en dos ubicaciones. Se estimaron los valores de 10 índices que caracterizan el tamaño relativo del corazón. Los resultados no mostraron una distribución normal de los rasgos de los corazones examinados. El mayor peso promedio del corazón fue característico de los visones de variante de color mutacional macho (17,40 ± 2,34 g). Estos corazones eran más pesados en más de un 8 % que los de los visones con variante de color estándar machos. Los corazones de los visones de variante de color mutacional macho se caracterizaron por los mayores pesos de los ventrículos izquierdo y derecho (P≤0,01) en comparación con los de los visones de color estándar machos, en los que a su vez el mayor grosor de las paredes de los ventrículos izquierdo y derecho fue mayor que el de las variantes de colores estándar. Se observó que una mayor diferencia entre los grosores medio de las paredes de los ventrículos izquierdo y derecho en las variantes de color estándar, puede proporcionar más pruebas de su adaptación a un mayor esfuerzo, refiriéndose así a su historial evolutivo, pese a la aparición de signos de hipertrofia miocárdica multietapa.

PALABRAS CLAVE: Domesticación de animales; Visón americano; Biometría del corazón; Estructura del miocardio.

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