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The use of radiography for measurements of the medullary cavity in the metacarpal bone of European roe deer (*Capreolus capreolus*) for assessment of individual quality – a preliminary study

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SUMMARY

The objective of the study was to test the research hypothesis that the surface area of the medullary bone is correlated with other indicators of body condition. The study also focused on identification of potential differences in and with carcass weight fat parameters and carcass weight between forest and field ecotypes of roe deer. The area of the medullary cavity was measured using DIRA 200 software. Metacarpal bone III+IV, proximal phalanges III and IV, and middle phalanges III and IV were measured as well. The study included 38 female European roe deer (*Capreolus capreolus*) aged 3-5 years. The results revealed a statistically significant negative correlation between the surface area of the medullary cavity in metacarpal bone III+IV and the kidney fat index KFI (rs = −0,483; P < 0,05) and the weight of the perirenal adipose tissue (rs = −0,362; P < 0,05). No correlation was shown between the area of the medullary cavity of metacarpal bone III+IV and the doe carcass weight (rs = 0,093; ns). The size of the medullary cavity is an anatomical parameter that is not susceptible to cyclical changes in environmental conditions. The study showed that it is independent of body weight and determines the amount of bone marrow and hence the amount of accumulated fat reserves. We believe that, alongside biometric measurements, the surface area of the medullary cavity can be a good parameter for assessment of the individual quality of roe deer and for comparison of populations.

KEY WORDS: roe deer, *Capreolus capreolus*, KFI, medullary cavity, individual quality, carcass weight

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INTRODUCTION

Rational management of wild animal populations involves coordination of their population density with the size of the food base biotope. One of the parameters reflecting an appropriate density of free-living ungulates in the feeding grounds is the fitness of individual animals, expressed by such quality parameters as body weight and size, antler quality, and body fat reserves (Bonino et al., 1998; Karpiński et al., 2008; Majzinger, 2004). Biometric methods for assessment of individual quality are successfully used in livestock animals (Alderson, 1999; Alonso et al., 2007; Salako. 2006). As biometric measurements of wild animals are difficult to perform intravitally, they are carried out post mortem (Fruziński et al., 1982). Biometric assessments are used to calculate measurement (selection) indices which reflect, depending on the measurement type, the degree of development of the musculoskeletal, respiratory, and cardiovascular systems, as well as the animals' growth rate and somatic type (Czyżowski et al., 2009; Drozd et al., 2006). Good animal fitness is evidenced by the accumulation of fat reserves, which is possible when the animal's environmental conditions are favourable in terms of climate and food accessibility. Fat deposition begins in the bone marrow. It proceeds to some internal organs (intestine and kidneys), and the final stage is deposition of subcutaneous fat. Utilization of accumulated fat reserves proceeds in reverse order, and utilization of bone marrow fat reserves indicates that the animal is in a critical state (Stephenson et al., 2002). Measurements of fat reserves and analyses of their dynamics are an important tool for assessment of the condition of Cervidae, enabling evaluation of the animals' environmental living conditions (Holand, 1992; Takatsuki, 2000).

The aim of this study was to use measurements of the area of the medullary cavity of metacarpal bone III+IV to assess the individual quality of roe deer and test the research hypothesis that the surface area of the medullary bone is correlated with other indicators of body condition and with carcass weight. The study also focused on identifying potential differences in the mean values of fat parameters and carcass weight between forest and field ecotypes of roe deer.

MATERIAL AND METHODS

The study included 38 female European roe deer *Capreolus capreolus* aged 3-5 years, which had been culled by hunters in compliance with the Principles of Ontogenetic and Population Selection of Game Animals in Poland (Annex to Resolution 57/2005 of 22 February, 2005). The specimens were from two regions in Lublin Province (Poland): a woodland habitat (10 individuals) in Żyrzyn Commune (51°30′N 22°06′E) and a field habitat (28 individuals) in Rudnik Commune (50°53′N 22°58′E).

The study involved dorsopalmar X-ray imaging of the does' right thoracic limbs removed at the carpal joint. The area of the medullary cavity was measured to within 0,1 cm^2, the kidney fat tissue was weighed (g), the kidney fat index KFI was calculated, and the carcass weight was measured (kg). Kidneys were removed from the carcasses and weighed to within 1 g. Following removal of the perirenal adipose tissue, the kidneys were weighed again. The measurement results were used to calculate the perirenal fat content (g) as the difference between the weight of the kidneys before and after fat removal. The kidney fat index (KFI) was calculated as the ratio of the weight of the kidney with fat to the kidney weight without fat (Riney, 1955). The medullary cavity area was measured using DIRA 200 software. Metacarpal bone III+IV, proximal phalanges III and IV, and middle phalanges III and IV were measured as well (Phot. 1). The area of the marrow cavity of metacarpal

bone III+IV (38 n) was used for analyses and comparisons with carcass weight and KFI. The marrow cavities of the pastern and middle phalanx were measured on 16 randomly selected individuals to determine their percentage in the area of the entire limb.

Statistical analysis of the results was carried out using the Statistica 10.0 PL package. The paper presents mean values of the analysed parameters as well as their range and standard deviation. To determine the correlations between the size of the medullary cavity and KFI, kidney fat weight, and carcass weight, the Spearman correlation coefficient between the parameters was calculated. The means of the parameters for forest and field roe deer were compared. The normality of the distribution of the variables was tested using the Shapiro-Wilk test. Since the distributions of the parameters significantly deviated from normality, the non-parametric Mann–Whitney U test for two independent samples was employed. The distributions were described using measures of location of the means, i.e. the median and quartiles.

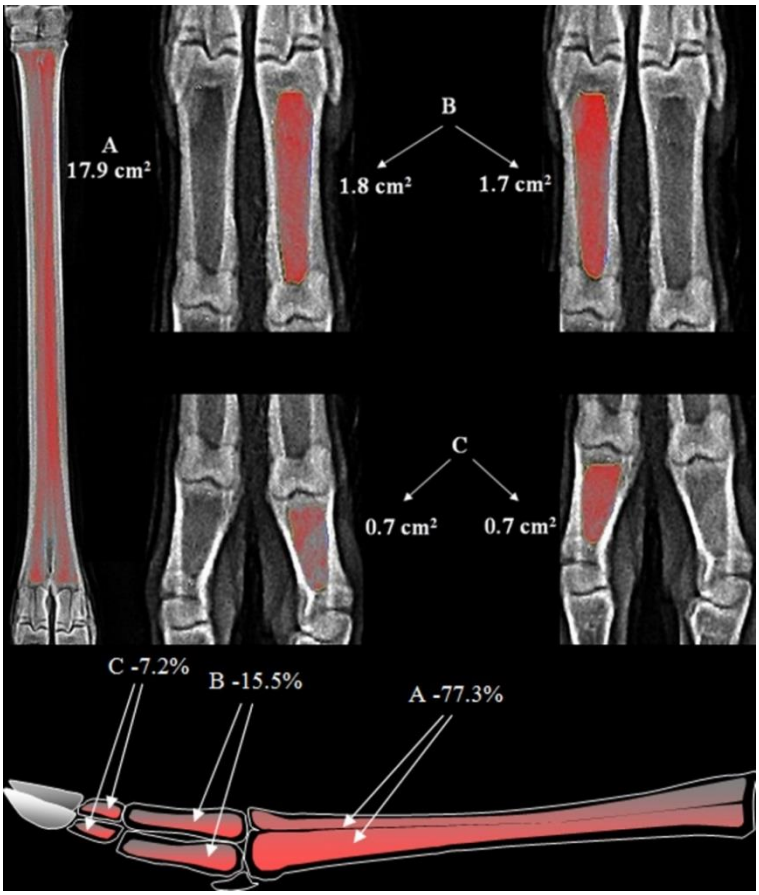
RESULTS

The mean surface area of the medullary cavity in the metacarpal bones accounted for over 73% of the total area of all bones in the metacarpus (Table 1 and Phot. 1), which directly corresponds to the distribution of the accumulation of bone marrow reserves. A statistically significant negative correlation was shown between the surface area of the medullary cavity in metacarpal bone III+IV and the kidney fat index KFI ($rs = -0{,}483$; $P < 0{,}05$) and the weight of the perirenal adipose tissue ($rs = -0{,}362$; $P < 0{,}05$). No correlation was shown between the area of the medullary cavity of metacarpal bone III+IV and the carcass weight ($rs = 0{,}093$; ns). Additionally, positive but statistically insignificant correlations were found between the carcass weight and the kidney fat index KFI ($rs = 0{,}220$; ns) and the perirenal fat weight ($rs = 0{,}270$; ns).

Table 1

Mean carcass weight (kg), perirenal fat weight (g), and KFI

Parameter	$\bar{x}$	n	Range	SD
Carcass weight (kg)	15,37	38	11,0-20,0	2,68
Kidney fat weight (g)	38,16	38	8,0-78,0	21,65
KFI	1,49	38	1,12-1,98	0,28
Metacarpal III+IV area (cm^2)	15,04	38	12,9-17,7	1,55
Proximal phalanx III area (cm^2)	1,56	16	1,3-1,8	0,21
Proximal phalanx IV area (cm^2)	1,45	16	1,2-1,7	0,19
Middle phalanx III area (cm^2)	0,73	16	0,6-1,0	0,12
Middle phalanx IV area (cm^2)	0,68	16	0,5-1,0	0,14



Phot. 1. Example of measurement of the surface area of the medullary cavity of metacarpal bone III+IV (A), proximal phalanges III and IV (B), and middle phalanges III and IV (C) – dorsopalmar projection

Analysis of the roe deer parameters in relation to their habitat revealed significantly higher values of the kidney fat index (KFI) and higher values for perirenal fat weight ($Z = -2.453$; $P = 0,014$) in the animals from field areas (Mann–Whitney U test; $Z = -2,188$; $P = 0,29$) compared with the forest roe deer. The analyses did not show significant differences in the carcass weight and the area of the medullary cavity of metacarpal bones between animals from the two habitat types (Table 2).

Table 2

Values of the parameters analysed for forest and field roe deer (median, Q25-Q75, n)

Trait	Measure	Forest roe deer	Field roe deer	P-value
Carcass weight (kg)	Median	15,5	16,0	0,389
	(Q25-Q75)	(12,0-18,0)	(16,0-17,0)	
	n	28	10	
KFI	Median	1,38	1,70	0,029*
	(Q25-Q75)	(1,22-1,68)	(1,36-1,87)	
	n	28	10	
Perirenal fat (g)	Median	28,0	56,0	0,014*
	(Q25-Q75)	(16,0-47,0)	(33,0-78,0)	
	n	28	10	
Surface area of medullary cavity (cm^2)	Median	15,1	13,7	0,112
	(Q25-Q75)	(13,6-17,0)	(13,6-14,4)	
	n	28	10	

*significant at $P \leq 0,05$

DISCUSSION

All animals were obtained in autumn (November), the period when the body weight of does is highest (Janiszewski and Kolasa, 2007). Since body weight correlated positively with the analysed indicators of fat reserves, it can be assumed that the highest amounts of fat were deposited during this period. This is confirmed by results reported by other authors (Okarma, 1991; Ratcliffe, 1980), who found that the highest fat content was deposited in the bone marrow before the winter.

The size of the medullary cavity is an ontogenetic trait specific to an individual in the same way as body size, chest measurements and shape, bone weight, or other biometric parameters. The larger the surface of the medullary cavity, the greater the amount of bone marrow contained in it, and thus the higher the fat storage capacity. The study showed an inverse correlation between the medullary cavity of the long bones and the value of the fat index (KFI) and perirenal fat weight. This may indicate that the potential accumulation of greater amounts of fat in the bone marrow is associated with lower accumulation of fat reserves around the organs. This is supported by a study by Watkins et al. (1991), which showed a negative correlation between the content of medullary fat and the amount of fat deposited around the organs and as subcutaneous tissue in Cervidae. A study of fat reserves in Cervidae (Torbit, 1988) found that KFI was more strongly correlated with total fat reserves in the body than was medullary fat; therefore, KFI is a better predictor of changes in total fat reserves than bone marrow fat. Many researchers believe that kidney weight is a better indicator of fat reserves in Cervidae than is KFI (Serrano et al., 2008; Yokoyama et al., 2001). In research by Stephenson et al. (2002), perirenal fat weight and KFI were found to be moderate indicators of the total adipose tissue content in the body. The authors suggested that changes in body weight are not an ideal indicator of the dynamics of fat reserves in adult females but a good indicator of changes in fat-free body weight. Takatsuki (2000) proposed that the kidney fat index KFI is a good indicator of nutritional status, but does not reflect poor fitness in individuals; hence, the fitness of Cervidae should

be assessed using KFI and indicators of medullary fat content. Hewison et al. (1996) suggest that carcass weight is a more reliable indicator of fitness status in roe deer than changes in fat reserves, which are more closely linked to seasonal changes in the annual cycle. Holand (1992) suggest that KFI is not adequate in the case of animals with low body fat content. Only a combination of fat parameters can be a reliable indicator of the individual condition of roe deer. Other researchers indicate that fat reserves in roe deer are low in comparison with other animals; therefore, body weight is a better indicator of the ontogenetic status in this species (Andersen et al., 2000; Toigo et al., 2006). Other researchers (Janiszewski and Kolasa, 2007; Karpiński, 2013; Petelis and Brazaitis, 2003) have shown that there are two ecotype forms, field and forest roe deer, associated with their habitat. They demonstrated that the carcass weight of field roe deer is higher than that of the forest ecotype. Jepsen and Topping (2004) described behavioural differences between typical forest roe deer and those living in field habitats, where the animals form larger herds. In the present study, differences in the area of the medullary cavity of metacarpal bone III+IV were found between does from field and forest areas; however, these differences were not statistically significant, unlike in the case of the KFI index and perirenal fat weight. It is likely that with a larger sample size, the differences might be statistically significant.

SUMMARY

The size of the medullary cavity is an anatomical parameter that is not susceptible to cyclical changes in environmental conditions. As shown in this study, it is independent of body weight and determines the amount of bone marrow and hence the amount of accumulated fat reserves. We believe that, in addition to biometric measurements, the surface area of the medullary cavity can be a good parameter for assessment of the individual quality of roe deer and for comparison of populations; therefore, this type of research should be continued.

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