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BODY MORPHOMETRICS OF GOLDEN JACKAL IN BULGARIA

Stoyan Stoyanov

Wildlife Management Dept., University of Forestry, 10 St. Kliment Ohridski Blvd., 1797 Sofia, Bulgaria. E-mail: stoyans@abv.bg

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Abstract

The expansion of golden jackal (*Canis aureus* Linnaeus, 1758) in Europe in the last decades has triggered research interest. Many aspects of jackal's ecology, diet, population density, genetics, legal implications of range expansion and management have been studied thoroughly. However, very few studies have focused on body morphometrics. Bulgarian territory is considered the core area of golden jackal distribution in Europe with the highest population density, but morphometric studies including data about Bulgarian population were very scarce and local so far. The present study proposes the first comprehensive analysis of golden jackal morphometrics in Bulgaria, trying to clarify body shape and size related variability and differentiation. Morphometric data were analysed by applying recently developed statistical tools to respond to the following questions: (i) is there geographic variation in body size and shape among golden jackal population in Bulgaria, (ii) are there age-related differences and at what age jackals reach full growth of the body, and (iii) how pronounced is the sexual dimorphism in body shape and size among adult jackals? The body measurements of 87 golden jackals, collected all over the country were subjected to univariate and multivariate analyses. Body size and shape of golden jackal in Bulgaria show considerable individual variability, but weak intrapopulation differentiation. The differences in shape and size of the jackal body, as far as they exist, are age-related, but only 5–6 months old animals could be easily distinguished. Body growth ends at 10 months of age, but even 7–9 months old jackals are difficult to distinguish from the adults in the field. Sexual dimorphism in jackal's body is weakly pronounced, with older males a little bit larger than females. The results are consistent with recent genetic and morphological studies and give further insights on patterns in variability and population structure of golden jackal in Bulgaria.

Key words: body size, body shape, *Canis aureus*, sex dimorphism, geographic variation.

Introduction

Golden jackal (*Canis aureus* Linnaeus, 1758) is one of the most widely distributed canid species and is found in many areas of Europe, Asia and Africa (Jhala and Moehlman 2004, Arnold et al. 2012, Hoffmann et al. 2018, Moehlman and Hayssen 2018, Spassov and Acosta-Pankov 2019). Since 1980s jackals have increased in their distribution and abundance in what is arguably the most dramatic recent expansion in Europe among native predators on the continent and today it is widespread species throughout southern Asia, the Middle East and south-eastern and central Europe, where jackals inhabit a wide variety of habitats, from semi-deserts and grasslands to forested, agricultural, and semi-urban habitats (Jhala and Moehlman 2004; Šálek et al. 2014; Koepfli et al. 2015; Trouwborst et al. 2015). The jackal expansion in the last two decades was rapid and still ongoing. Jackals have expanded into Switzerland, Lichtenstein, Germany, Denmark, Poland, France, Netherlands, Baltic states, Belarus, and, in 2019, also Finland (Pyšková et al. 2016, Krofel et al. 2017, Potočnik et al. 2019). The ongoing expansion of the species in Europe has caused concerns regarding possible negative effects its presence could exert, due to excessive predation of other wildlife species or livestock, and the transmission of pathogens (Rutkowski et al. 2015; Ćirović et al. 2016). In addition, there are several uncertainties regarding jackal management and policies, often in association with the unknown origins of jackal populations (Trouwborst et al. 2015). Jackal expansion in the last decades has triggered research interest in Europe. Many aspects of golden jackal's ecology, diet, population density, genetics, legal implications of range expansion and management have been studied thoroughly in Europe. However, very few studies have focused on morphometric variability of golden jackal in Europe (Kryštufek and Tvrtković 1990, Boskovic et al. 2015). Morphometric data could be found in some books and monographs (Heptner et al. 1967, Demeter and Spassov 1993, Angelescu 2004, Jhala and Moehlman 2004, Sillero-Zubiri 2009). The most comprehensive is data set about jackal population in the Caucasus and Central Asia (Aliev 1968, Reimov and Nuratdinov 1970, Taryannikov 1974). Most of the morphometric studies focus on sexual dimorphism in jackals (Kryštufek and Tvrtković 1990, Angelescu 2004, Boskovic et al. 2015, Raichev et al. 2017).

Sexual dimorphism has been described for many carnivore species in Europe (Petrov et al. 1992, Gittleman and Valkenburgh 1997, Milenković et al. 2010). Sexual size dimorphism is common among vertebrates, males usually being the larger sex (Ralls 1977). In the end of the last century, the extreme dimorphism in Mustelidae (Moors 1980, Wiig 1986), Felidae (Wiig and Andersen 1986) and Pinnipedia (Stirling 1975), and the reversed dimorphism in predatory birds (Andersson and Norberg 1981, Pleasants 1988) attracted particular interest, and new theories were proposed, associating the sexual dimorphism with divergent selection pressures on males and females (Moors 1980, Wiig 1986, Wiig and Andersen 1986). Sexual dimorphism in Canidae, when present at all, is usually minimal, with males slightly larger than females (Jolicoeur 1959, Hell et al. 1989, Simonsen et al. 2003, Schutz et al. 2009, Sillero-Zubiri 2009). Sexual dimorphism varies in African jackal species among regions and is not as pronounced as is typical of canids (Van Valkenburgh and Wayne 1994).

Bulgarian territory is considered the core area of golden jackal distribution in Europe with the highest population density (Stoyanov 2013, Spassov and Acosta-Pankov 2019), but morphometric studies including data about Bulgarian population were very scarce and local so far (e.g. Atanassov 1953, Raichev et al. 2017). Despite numerous studies of sexual dimorphism in carnivore body size, no studies have attempted to study dimorphism in overall body shape. The present study proposes the first comprehensive analysis of golden jackal morphometrics in Bulgaria, trying to clarify body shape and size related variability and differentiation. Morphometric data were analysed by applying recently developed statistical tools to respond to the following questions:

(i) is there geographic variation in body size and shape among golden jackal population in Bulgaria, (ii) are there age-related differences and at what age jackals reach full growth of the body, and (iii) how pronounced is the sexual dimorphism in body shape and size among adult jackals? Although modern genetic methods have been applied recently in phylogeny and taxonomy, understanding patterns in morphometric variability of golden jackal still provides very valuable insights on population structure. Furthermore, it is not only crucial for understanding the phylogeny, but also for management and conservation. Moreover, integration of genetic techniques and morphometrics represent a valuable tool in the resolution of taxonomic uncertainty.

Material and Methods

The body measurements of 87 jackals, 45 males and 42 females, collected in the period 1998–2007, originating from 20 sites in Bulgaria, were analysed. The main part of the sample was collected in three main regions with the highest jackal's population density: Yambol, Veliko Tarnovo and Burgas. The age of jackals was determined in consideration of upper incisive teeth wear (Lombaard 1971) and for some individuals also by counting the annual cementum layers in canines (Klevezal and Kleinenberg 1967). Both methods are reliable enough for the purposes of the study and provide accurate results, with precision up to one year for the first one (Harris et al. 1992, Raichev 2002). The animals were assigned to three age groups: juveniles, subadults and adults. Juvenile specimens were defined as individuals with fully developed second dentition, but less than 10 months of age, subadults as individuals more than 10 months, when they reach sexual maturity, but less than two years of age, and adults as two years and older. Studies on the reproduction of golden jackal in Bulgaria have shown that jackals give birth from 10 April till 5 May in Southern Bulgaria, and from 25 April till 20 May in Northern Bulgaria (Vassilev and Genov 2002). Timing of births coincides with abundance of food supply and depends on weather conditions. However, it can be assumed that pups are born in the second half of April and early May. Knowing the age in years and the exact shooting date of each jackal in our sample, we determined the age of the animal with precision up to one month. Estimating the exact age in months allowed following the growth in first stages of ontogenetic development. According to growth stages, jackals in their first year were divided further to three age groups: 5–6 months old (6 individuals), 7–9 months old (7 individuals), and 10 months and older (2 individuals). Joint group of subadult and adult jackals included 72 animals, 42 males and 30 females.

For each individual 18 body measurements were taken (see Table 1) by using a metal measuring tape to the nearest 1 mm, following adopted standard techniques for carnivores (Heptner et al. 1967, Foresman 2012). Body weight was measured on lab scales with precision up to 50 g.

Statistical methods

All measurements were tested for normality by QQ plots and Shapiro-Wilk test. Homogeneity in variance was examined by Fligner–Killeen test. Differences in body size between age groups were tested by one-way analysis of variance (ANOVA) and visualized by applying Tukey's Honestly Significant Difference test (Tukey's

HSD). The dependence of body mass on season and month of the year was examined by one-way ANOVA. Kruskal-Wallis test was applied for testing the differences in body measurements that deviated from normal distribution. Statistical significance of the difference in means between males and females for each body measurement was examined by Wilcoxon–Mann–Whitney test.

Multivariate analyses were employed in order to explore the most significant variation in body size and shape. Shape in general tends to provide more reliable information than size on the morphology of organisms (Jolicoeur and Mosimann 1960). Size is often considered as a nuisance because it is strongly dependent on ecological factors (McCoy et al. 2006), but separation of size and shape in multivariate studies of morphological data is problematic (Claude 2008). This problem was addressed by using principal component analysis (PCA). Baur and Leuenberger (2011) have developed new methods allowing interpretation of principal components in terms of ratios and clear separation of size and shape. The authors defined an isometric size axis, called 'isosize', as the geometric mean of the original measurements and thus comprising only differences in scaling. For the exact definition of 'isosize', see Baur and Leuenberger (2011). Allometry free shape variables could be obtained by projecting the measurements orthogonal to isosize. A PCA calculated on the covariance matrix of these shape variables then accounts solely for differences in proportions. Baur and Leuenberger (2011) suggested to plot the isosize against each significant shape component in order to assess the amount of allometry in the data. Hence, for clear separation of shape and size, the PCA was applied on the standardized (dividing each measurement by geometric mean) and log-transformed ratios of the original measurements (Claude 2008, Baur and Leuenberger 2011).

Geometric interpretation of PCA was made by using graphical tools developed by Baur and Leuenberger (2011). The 'PCA ratio spectrum' was applied for the interpretation of principal components in shape space. The amount of allometry in the data was assessed by the 'allometry ratio spectrum'. For detailed mathematical description and statistical framework of the applied methods see Claude (2008) and Baur and Leuenberger (2011).

All statistical and graphical analyses were performed with R, version 3.6.1 (R Core Team 2019). Slightly modified versions of the R-scripts provided by Baur and Leuenberger (2011) and Claude (2008) were employed for calculations. PCA was performed by using the MASS software package (Venables and Ripley 2002).

Ethics statement

The body measurements used in the analyses were taken from individuals that died in vehicle collisions, due to natural causes or as a result of legal hunting. No animal was killed for the purpose of this study.

Results

Shapiro-Wilk tests and QQ plots showed that half of all measurements did not deviate significantly from normal distribution: weight, tail length, trunk length, withers height, sacral height, neck girth, chest girth, and belly girth. This allowed applying one-way ANOVA for exploring age-related differences in body size. Kruskal-Wallis test was applied for testing the differences in body measurements that deviated from normal distribution. However, for most of the following statistical methods the assumption of normally distributed data is not strongly suggested. The results from Tuckey's HSD test showed that jackals up to one year old differ from the older animals only in few body measurements: weight, withers height, sacral height, neck girth, chest girth, and hind paw width (Fig. 1). Estimating the exact age in months allowed following the growth of body in first stages of ontogenetic development. The most pronounced are differences in body weight (Fig. 2). Males have bigger size, but with large overlap, both between sexes, and between juvenile, subadult and

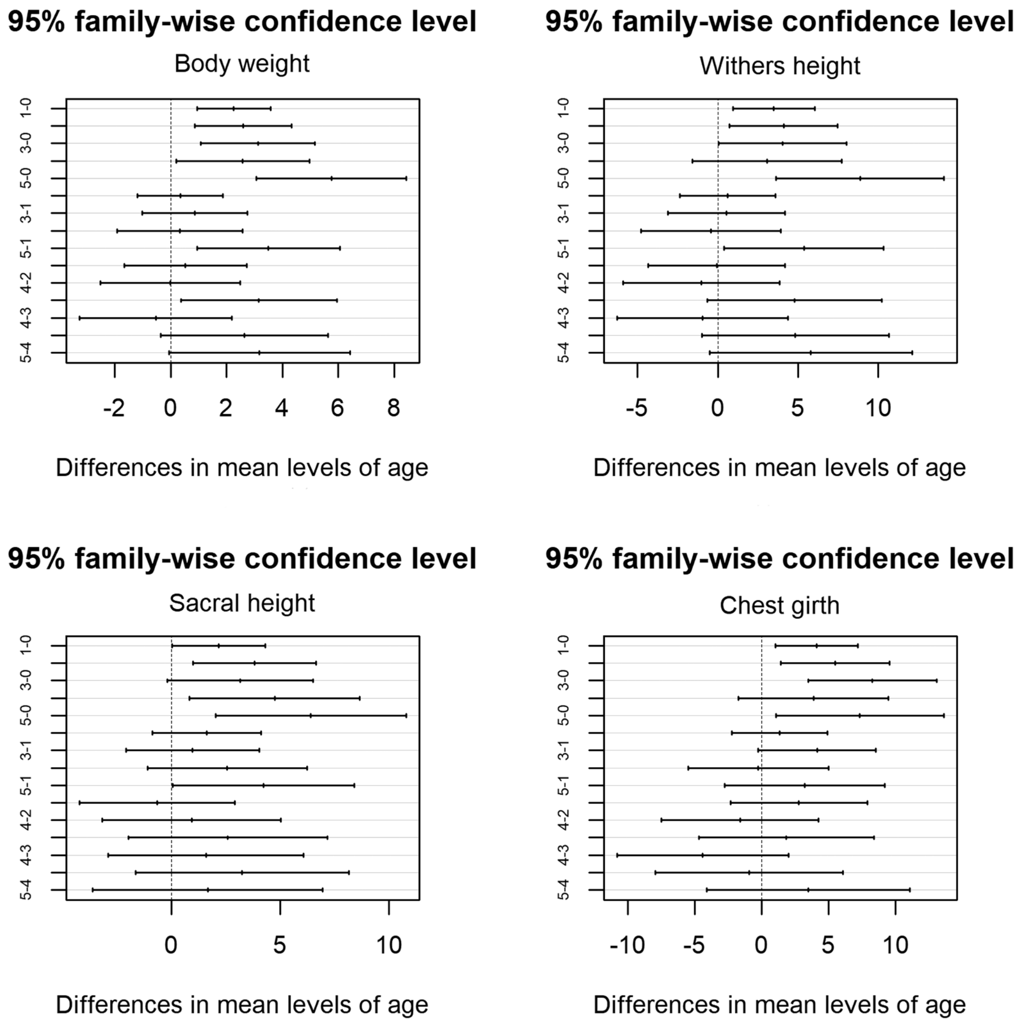

Fig. 1. Differences by age in some basic body measurements.

Note: Results from Tukey's Honestly Significant Difference test.

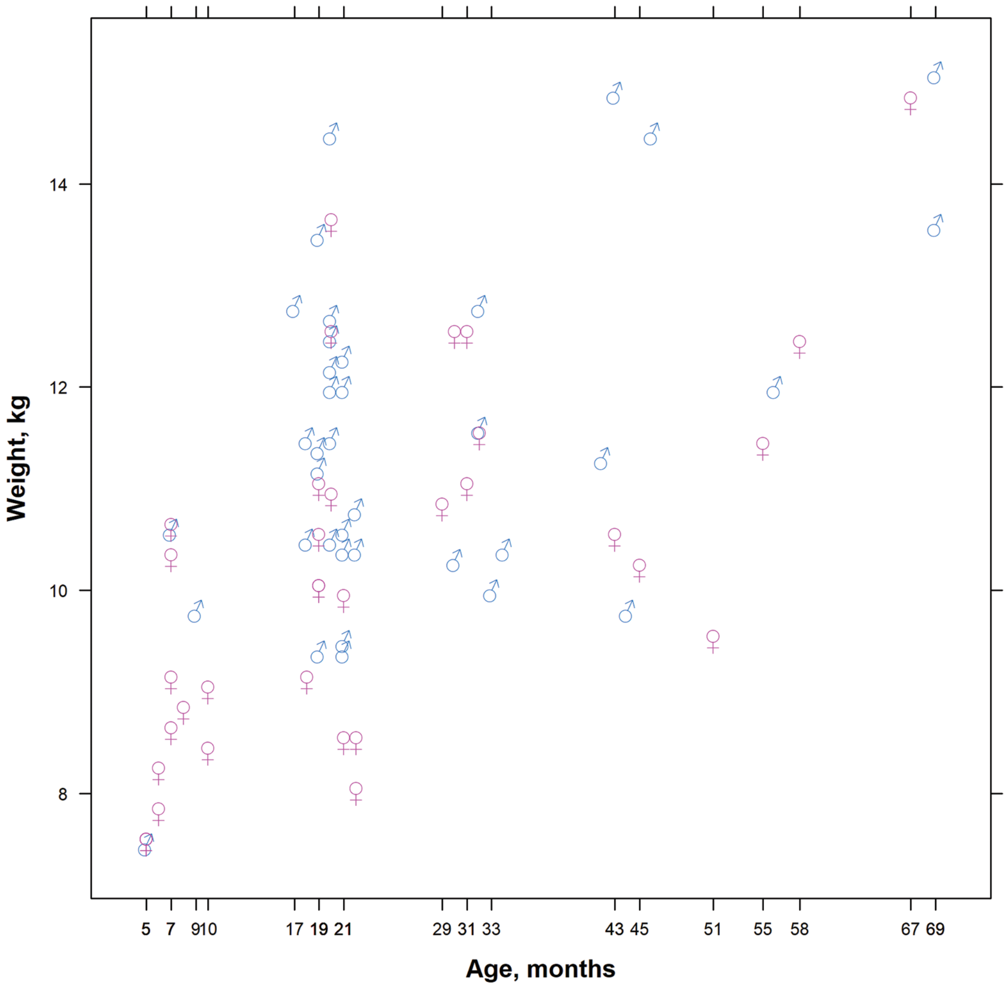

Fig. 2. Body weight of jackals by age and sex.

adult jackals. Despite the small number of individuals in the sample who are below 10 months of age, some of these animals almost reach the adult body mass. The same applies to other body measurements. In October and November, when they are 5–6 months old, the young jackals still differ in size. In winter, at 7–9 months, they are already almost reaching the size of adults and are difficult to distinguish (Fig. 3). We can assume that at the age of 10 months, at the end of winter, the juvenile jackals grow fully and reach adult body size. In some measurements, such as body length, tail length, neck girth, and leg length, even animals at 5–6 months of age do not show significant differences from adult jackals. However, summary statistics of body measurements were calculated for joint group of subadult and adult jackals, i.e. animals older than 10 months.

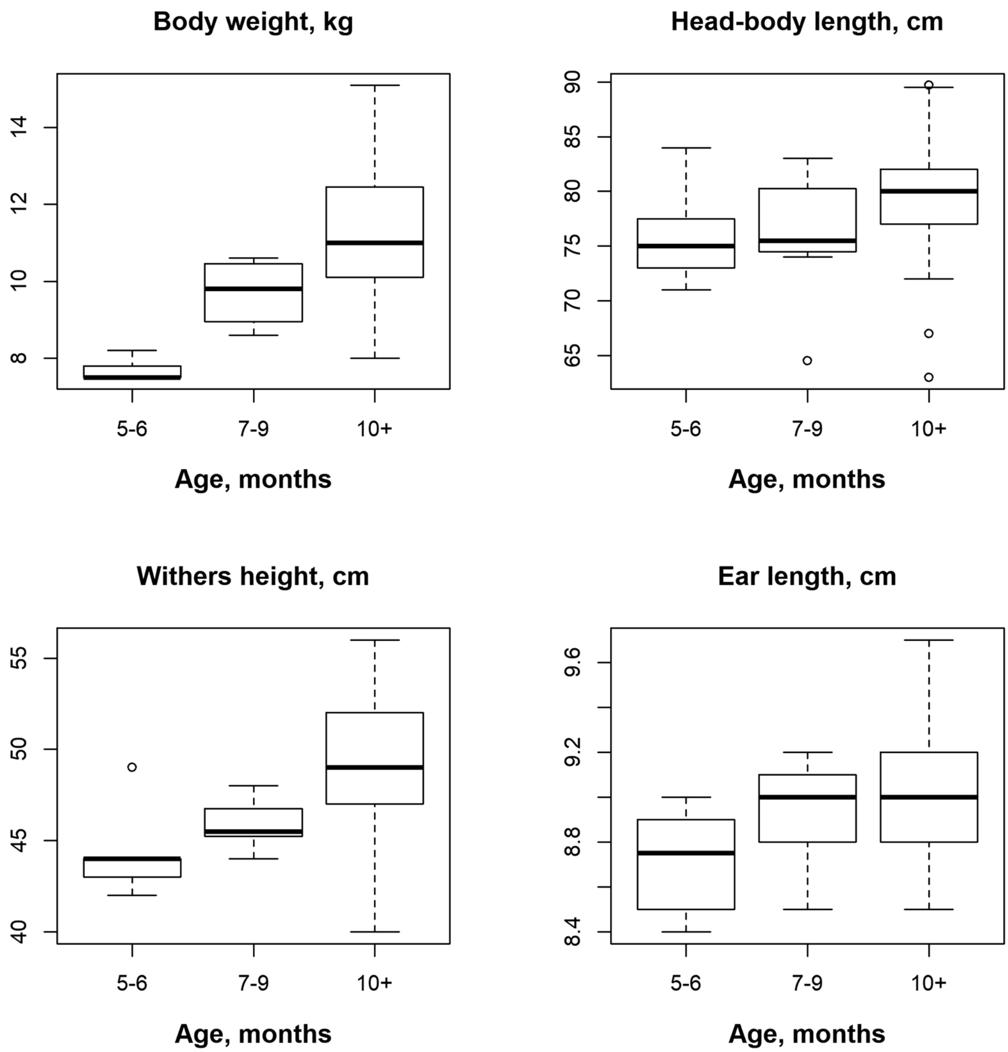

Fig. 3. Comparison of some basic body measurements between jackals in their first year and older animals.

Sexual dimorphism in body size was examined by Wilcoxon–Mann–Whitney test (Table 1). In half of all body measurements differences in means between males and females are statistically significant. However, there is a large overlap in all measurements, and the sexes could not be separated by body size. As a rule, males are bigger with mean body mass about 8 % higher than females.

Table 1. Descriptive statistics of body measurements and statistical significance of the differences examined by Wilcoxon–Mann–Whitney test.

Measurements	Abbreviation	Males (n=42)				Females (n=30)				p
		min	max	$\bar{x}$	s	min	max	$\bar{x}$	s	
Weight, kg	Wt	9.4	15.1	11.8	1.5	8.0	14.8	10.9	1.5	0.031*
Head-body length, cm	HBL	73.0	90.7	81.5	4.1	63.0	85.0	77.4	4.8	0.0004***
Tail length, cm	TL	20.0	30.0	24.8	2.1	19.0	30.0	23.8	2.2	0.040*
Trunk length, cm	TrL	46.0	61.0	51.5	3.1	46.0	58.0	50.3	2.6	0.042*
Withers height, cm	WH	41.0	55.0	49.8	3.0	40.0	56.0	48.4	3.1	0.023*
Sacral height, cm	SH	46.0	56.0	51.2	2.6	46.0	56.0	50.0	2.4	0.022*
Neck girth, cm	NG	21.8	30.0	25.7	2.1	22.0	29.0	25.3	1.4	0.490
Chest girth, cm	CG	35.5	54.0	43.3	3.3	36.0	49.0	43.5	3.5	0.689
Belly girth, cm	BG	26.0	46.0	34.5	4.8	26.5	43.5	35.0	3.8	0.623
Hand length, cm	HL	9.5	14.0	12.4	0.9	11.0	13.5	12.3	0.5	0.197
Forearm length, cm	FAL	15.0	19.0	17.2	0.9	14.7	18.0	16.6	0.7	0.004**
Foot length, cm	FL	14.0	17.5	15.9	0.8	13.9	17.0	15.6	0.8	0.137
Leg length, cm	LL	16.0	22.0	18.6	1.6	15.7	20.5	18.1	1.1	0.192
Ear length, cm	EL	8.5	9.7	9.1	0.3	8.5	9.4	8.9	0.2	0.100
Front paw length, cm	FPL	5.0	6.8	5.8	0.4	4.8	6.5	5.6	0.4	0.038*
Front paw width, cm	FPW	3.4	4.5	3.9	0.2	3.3	4.6	3.8	0.3	0.271
Hind paw length, cm	HPL	4.5	6.2	5.4	0.4	4.3	6.3	5.2	0.4	0.015*
Hind paw width, cm	HPW	3.0	4.0	3.5	0.2	3.2	4.0	3.5	0.2	0.179

Note: Level of statistical significance: * – p<0.05, ** p<0.01, *** – p<0.001. $\bar{x}$ – mean, s – standard deviation.

The PCA was applied including specimens from all age groups. The first principal component in shape space accounted for 34.23 % of the variance. Projecting the data along isosize and first principal component in shape space did not reveal any specific patterns in distribution or clustering of the individuals (Fig. 4). Only the cluster of 5–6 months old jackals is well separated from older animals as it is shown by the ellipses enclosing 95 % of the confidence interval for each age group. Juvenile jackals above 6 months of age have the same body shape and size as subadults and two years old animals. The sex dimorphism in body shape and size is not pronounced and there is a large overlap between males and females. Differences are mainly in size, but not in shape. Some males above three years old are bigger, but this does not depend on their exact age.

The first two principal components in shape space accounted for 50.93 % of the variance (Fig. 5). Projecting the data along first and second principal components reveals only differences in body shape. The group of 5–6 months old jackals could be distinguished clearly by shape from subadult and adult males but overlap with females. There are no differences in body shape between males and females. Projecting individuals along isosize and first principal component (Fig. 6) and along the first two principal components in shape space (Fig. 7) did not reveal any clustering depending on the collection site as well. Jackals from Northern and Southern

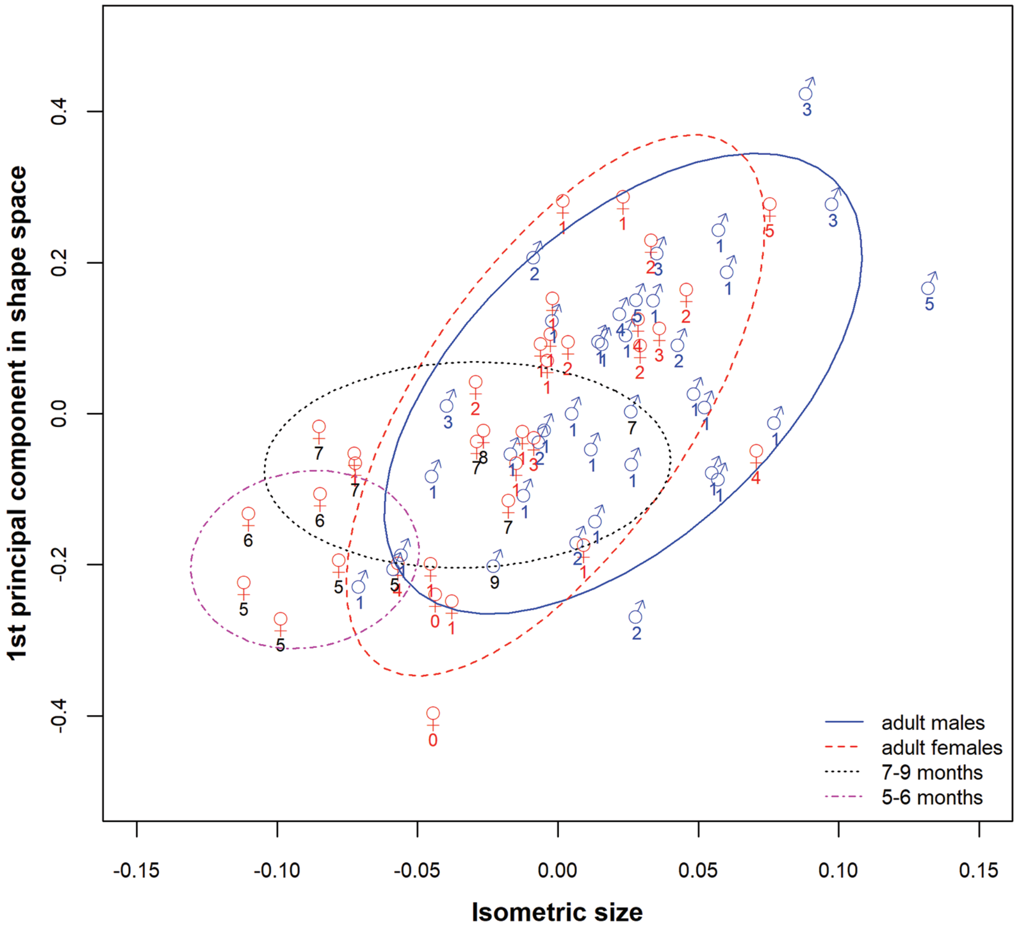

Fig. 4. Projection of individuals along isometric size and first principal component in shape space.

Note: Ellipses enclose 95 % confidence interval for each group. Sex and age of each individual are shown. Numbers in blue and red represent age in years for males and females respectively. Numbers in black correspond to age in months for juvenile individuals.

Bulgaria could not be clearly separated by their body size and shape.

The 'PCA ratio spectrum' allows the interpretation of principal components in shape space (Fig. 8). Considering factor loadings, ratios between body weight (Wt), belly girth (BG), chest girth (CG), leg length (LL), on the one side, and remaining body measurements, on the other side, explained a large proportion of the variance of the first and second shape principal components. The same ratios, however, showed the most distinctive allometric behaviour as could be seen from the 'allometry ratio spectrum' (Fig. 9). Presence of allometry could be assessed as well, while projecting the first shape principal component orthogonal to the isometric size (Fig. 4). Judging from the graph, there is only a very moderate cor-

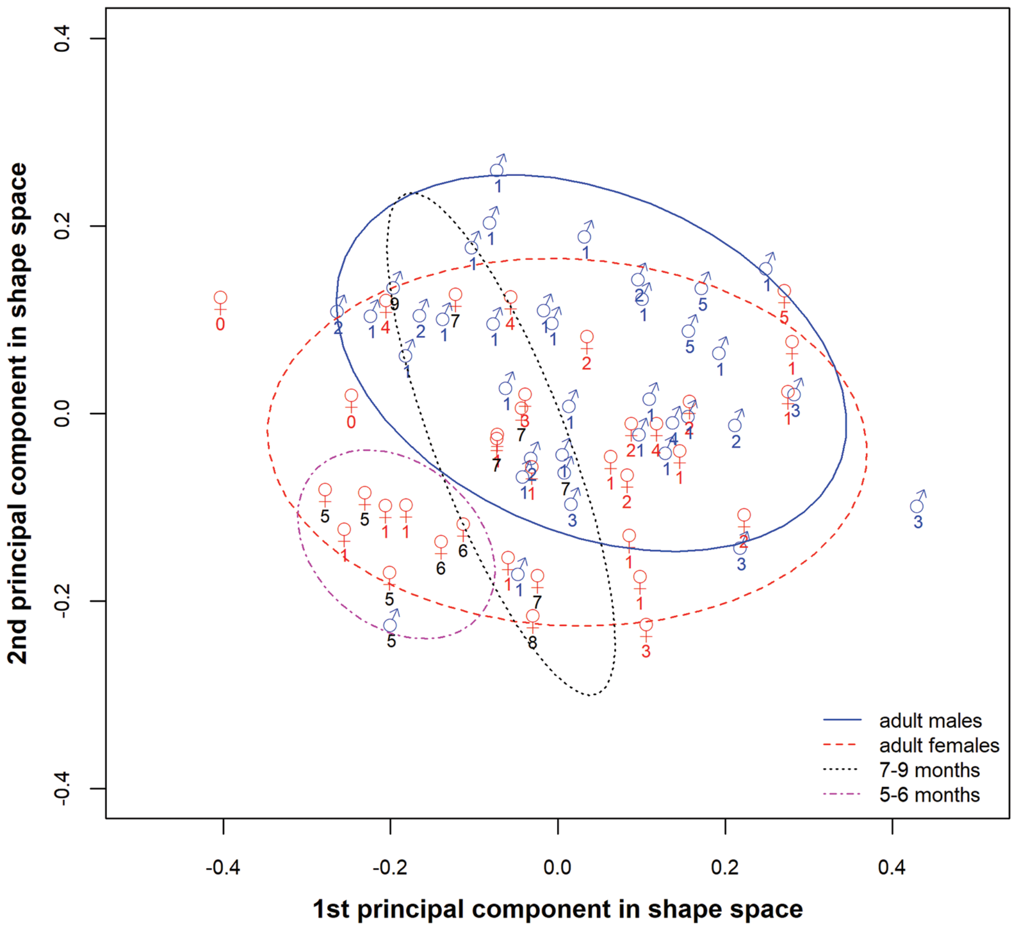

Fig. 5. Projection of individuals along first two principal components in shape space.
Note: Ellipses enclose 95 % confidence interval for each group. Sex and age of each individual are shown. Numbers in blue and red represent age in years for males and females respectively. Numbers in black correspond to age in months for juvenile individuals.

relation between shape and size. Hence, allometric variation was of marginal importance concerning our data set.

Body weight highly determines the morphometric differences between jackals, as far as they exist. Furthermore, this measurement showed the most distinctive allometric behaviour. Many factors could influence the weight of jackals, even the time of measurement. However, no dependence of body weight on the season and even on the month of the year was found in both sexes (F=0.963, df=5, 34, p=0.454 for males and F=1.652, df=5, 20, p=0.192 for females).

Discussion

The results suggest that the differences in body size and shape of jackals, as far as they exist, are age-related. However,

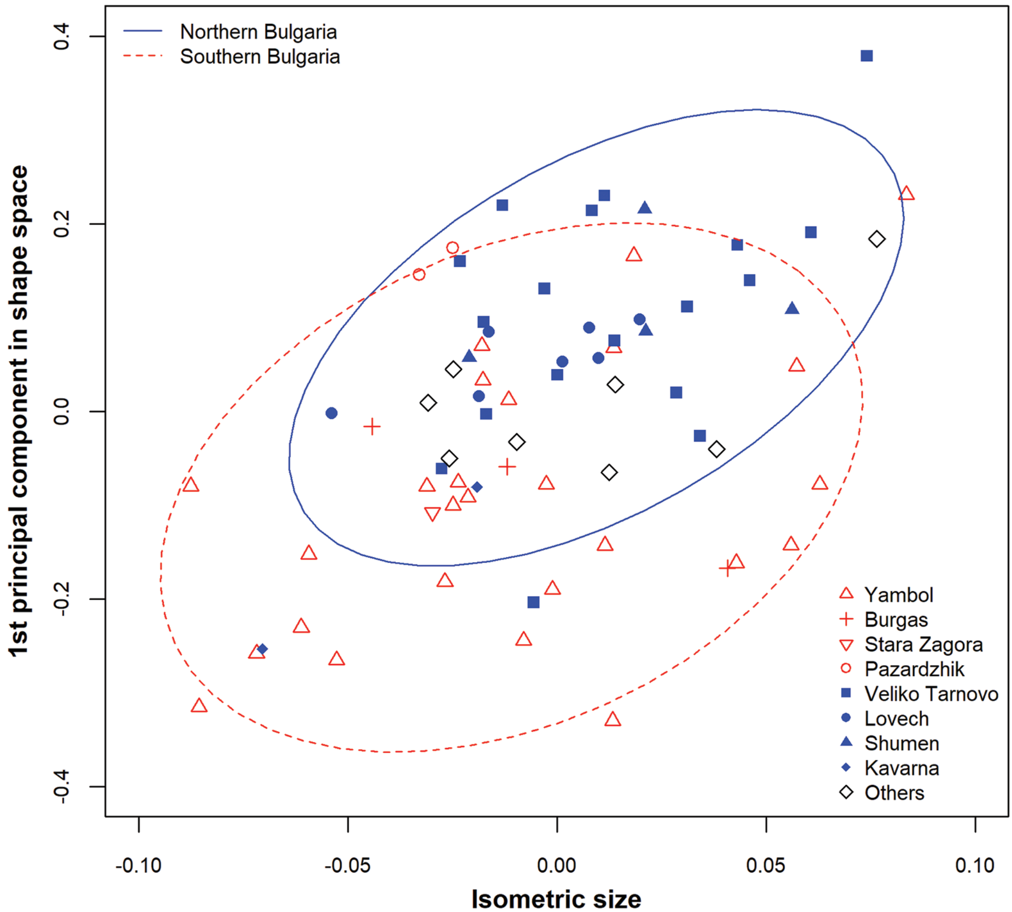

Fig. 6. Projection of individuals along isometric size and first principal component in shape space, according to collection site.

Note: Ellipses enclose 95 % confidence interval for each group, Northern Bulgaria and Southern Bulgaria correspondingly.

there is no clear differentiation between subadult and adult animals. Only 5–6 months old juvenile individuals could be separated by shape and size of the body. In winter, at 7–9 months, they are already almost reaching the size of the adults and are difficult to distinguish. At the end of winter, at the age of 10 months the juvenile jackals grow fully and reach adult body size. Univariate analyses showed that in all body traits juveniles, i.e. jackals below10 months of age, differ from the older jackals. The results of other studies for the growth rate of jackals are similar. The jackals grow rapidly during the first 5–6 months of their lives, after which the growth rate slows down, and after 10 months of age they almost reach the size of the adults (Taryannikov 1974). Studies in Uzbekistan show that by the end of October, at 6–7 months of age, the young jackals are almost indistinguishable from the adults in overall body size, but their weight is almost two times less

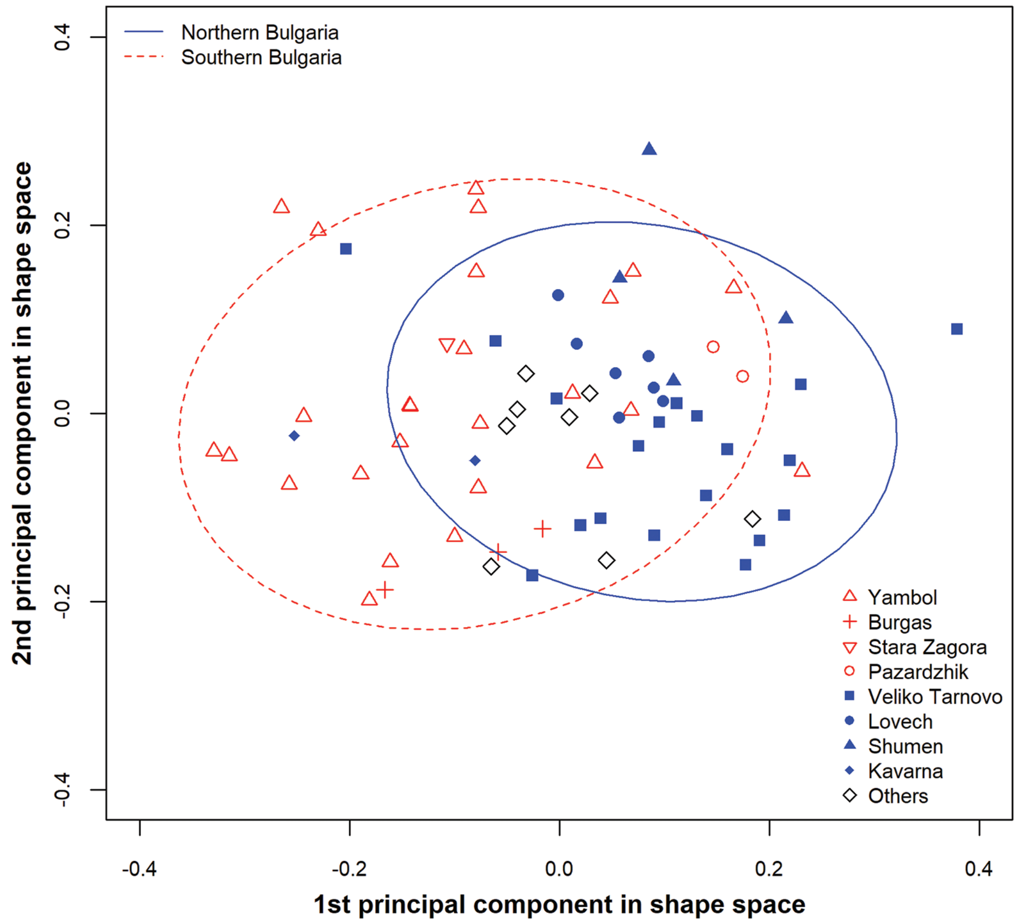

Fig. 7. Projection of individuals along first two principal components in shape space, according to collection site.

Note: Ellipses enclose 95 % confidence interval for each group, Northern Bulgaria and Southern Bulgaria correspondingly.

(Taryannikov 1976). Hence, jackals can be divided into two age groups in terms of body size, juveniles (up to 10 months) and adults (older than 10 months). Dividing the whole sample to three age groups was based on population demography of golden jackal and differences in the reproductive value of subadult and adult individuals (Stoyanov 2013). Golden jackals reach sexual maturity at the age of 10–11 months (Taryannikov 1976), but they rarely reproduce at this age. In Tanzania 70 % of known surviving pups were observed helping with the next year's litter and thus didn't rear their own offspring (Moehlman 1987). According to the same author, retaining helpers potentially increases the parents' reproductive success, that is, it increases the parents' chances of passing on their genes to future generations. Our results showed that the jackals in reproductive age reach full body size. All infe-

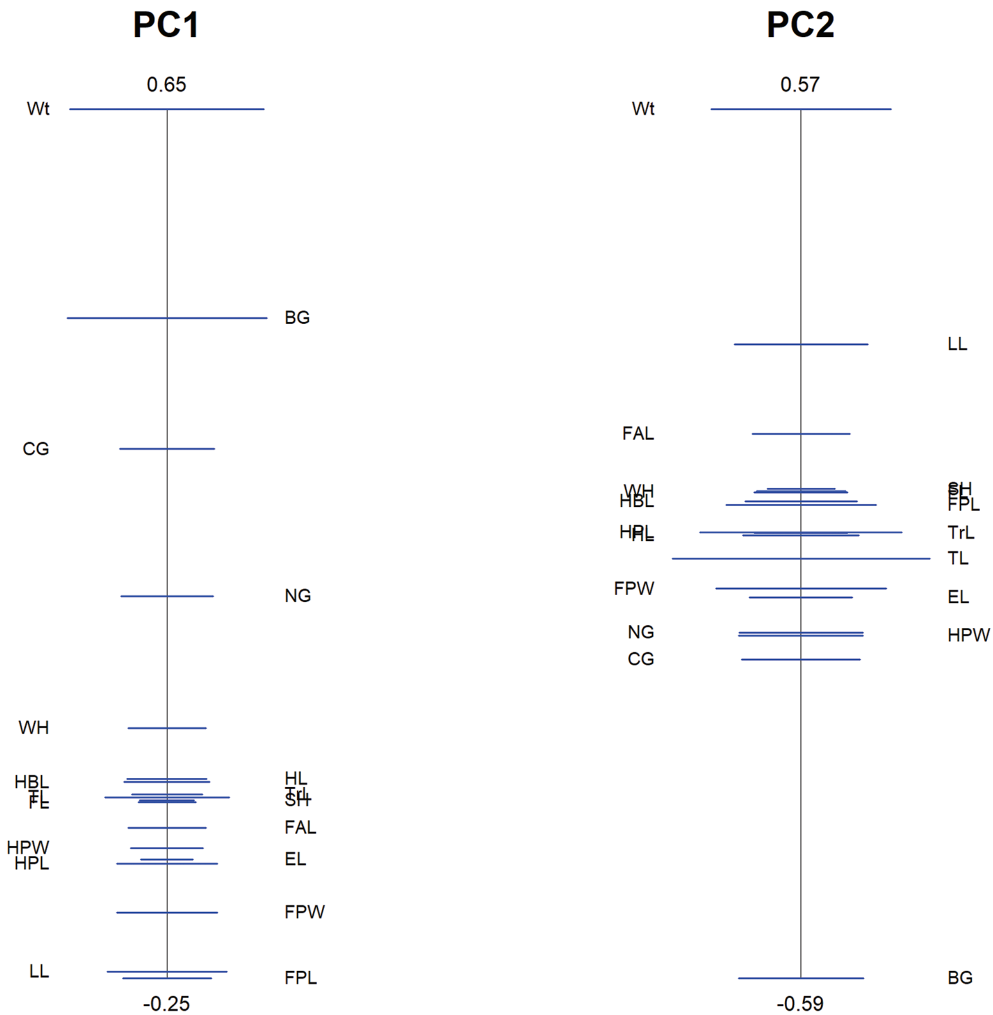

Fig. 8. PCA ratio spectrum for the first and second principal component in shape space. Note: Bars represent 68 % confidence intervals based on 500 bootstrap replicates.

rences about growth of the body, based on such studies, however, should be treated cautiously. The data did not allow following the ontogenetic development of jackals because we compared different individuals. Usually more viable and healthy individuals reach senescence, while weaker and smaller animals die earlier and do not reach more than 2–3 years of age. Studies on population demography of golden jackal in Bulgaria showed that about 10 % of jackals from one cohort could reach up to 5 years and over, and jackals above 3 years comprise only 6 % of the population (Stoyanov 2013). Thus, post mortal comparison of body measurements leads to biased data. The best way to address this problem is to measure animals kept in

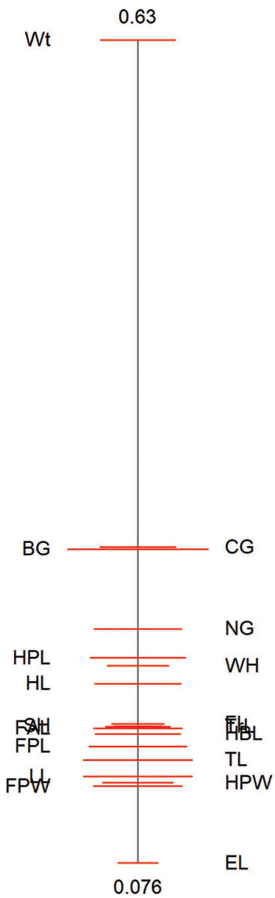

Fig. 9. Allometry ratio spectrum.

Note: Bars represent 68 % confidence intervals based on 500 bootstrap replicates.

captivity or by applying capture-mark-recapture approach. However, animals kept in captivity show different growth rate due to limited space and artificial feeding.

Sexual dimorphism in body size and shape is not clearly expressed, despite the statistical significance of differences in mean values between males and females in half of all measurements. The high level of statistical significance, as demonstrated by Wilcoxon–Mann–Whitney test, was due to the large sample size, and could be misleading. However, there is large overlap between males and females in all traits, and they could be hardly differentiated only by body size. Furthermore, principal component analysis did not reveal any differentiation in body size and shape between males and females. The males are bigger with mean body mass about 8 % higher than females. The same results were confirmed by other studies as well (Atanassov 1953, Heptner et al. 1967, Aliev 1968, Reimov and Nuratdinov 1970, Taryannikov 1974, Jhala and Moehlman 2004, Sillero-Zubiri 2009, Raichev et al. 2017). In India male jackals have 12 % higher body mass than females (Jhala and Moehlman 2004, Sillero-Zubiri 2009). However, in the latter study the sample size was too small for making general conclusions.

Sexual dimorphism in Canidae, when present at all, is usually minimal, with males slightly larger than females (Sillero-Zubiri 2009), although studies on wolves from the Balkans show significant sexual dimorphism in adult individuals (Trbojević and Ćirović 2016). Such sexual dimorphism of golden jackal, with males a little bit larger than females, could be explained with monogamous reproductive system and the presence of male parental care (Kleiman 1977, Bekoff et al. 1981, Moore 1981, Moehlman 1987). Dimorphism is negatively correlated with age at independence or dispersal and age at first breeding (Bekoff et al. 1981). Furthermore, delayed dispersal and delayed breeding also are associated with monogamy (Kleiman 1977). Golden jackals form pair-bonds that are characterized by friendly behaviour and last the 6 to 8 years of their usual lifespans, there is little sexual dimorphism, either physically or behaviourally, and they share equally in most activities, such as marking and defending their territory, foraging and resting (Moehlman 1987). Small to moderate sexual dimorphism in size may also be related to the fact that there does not appear to be intense competition for mates among male canids (Bekoff et al. 1981). Such degree of sexual dimorphism in Canidae was confirmed by other studies as well (Jolicoeur 1959, Hell et al. 1989, Simonsen et al. 2003, Schutz et al. 2009).

Bulgarian jackals measured in our study do not differ from jackals in Romania, the Caucasus, Central Asia, Tajikistan and Uzbekistan compared to data published by other studies (Heptner et al. 1967, Aliev 1968, Taryannikov 1974, Angelescu 2004). Comparison of some basic body measurements from different parts of the range (Heptner et al. 1967, Jhala and Moehlman 2004) shows that the jackals in Europe, including our Bulgarian sample, and Central Asia are larger than the African and Indian jackals. Recent genetic analyses revealed that *Canis aureus* from North Africa should be considered as separate species (Koepfli et al. 2015). Moreover, Indian jackals (*Canis aureus indicus* Hodgson, 1833) belong to different subspecies (Moehlman and Hayssen 2018), and such differences in size are expected.

The body mass of jackals in Bulgaria did not depend on season and habitat. Males are on average 8 % heavier than females but with large overlap between sexes. Although some male animals weigh above 15 kg, body weight of an adult jackal is usually between 10 and 14 kg (Fig. 2). Most of juveniles and subadults weigh below 10 kg. Recent study in Sredna Gora Mountain and Thracian Plain reported similar results (Raichev et al. 2017). The body mass of jackals is usually overestimated by hunters. However, the body weight depends on habitat quality and in areas with improved nutrition jackals in good condition could have increased their weight. In Bulgaria in the last decades jackals have flourished due to low sanitation and wide availability of easily accessible carcasses and other food resources in garbage dumps around villages. In Israel in the last 50 years an increase in body weight and length was found due to improved nutrition owing to a substantial increase in the amount of garbage and agricultural crops available (Yom-Tov 2003).

There could be hardly seen any differences in body shape between jackals from different regions of Bulgaria. The amount of geographical variation in Bulgarian population is comparable with sex and age differences. Although the sample size included in the analyses was not small, the projected data form a homogenous cluster, but with large individual variability. There are no morphologic differences in body size and shape between Northern and Southern Bulgaria. The lack of intrapopulation differentiation could be expected for such mobile, opportunistic and highly adaptable mesocarnivore as golden jackal. The jackals can easily expand their range and colonize new habitats. The recent colonization of the Baltic States is most likely a case of long-distance dispersal. It is not uncommon for golden jackals to disperse over several hundred kilometers in human-dominated landscapes (Rutkowski et al. 2015). This could explain the speed of jackal expansion in Europe that has been observed in the last decades (Trouwborst et al. 2015). Golden jackal has appeared in high mountains above 1000 m a.s.l. and Stara planina Mountain couldn't be considered a physical barrier. The results are consistent with recent genetic and morphological studies as well (Raichev et al. 2017, Rezić et al. 2017). Genetic studies focused on jackals in Bulgaria, Serbia, Croatia and Italy suggested a low level of genetic diversity and weakly pronounced genetic structure, with only the coastal population from Dalmatia clearly differentiated from other Balkan samples (Zachos et al. 2009, Fabbri et al. 2014, Rutkowski et al. 2015).

Conclusion

Body size and shape of golden jackal in Bulgaria show considerable individual variability, but weak intrapopulation differentiation. The differences in shape and size of the jackal body, as far as they exist, are age-related, but only 5–6 months old animals could be easily distinguished. Body growth ends at 10 months of age, but even 7–9 months old jackals are difficult to distinguish from adults in the field. However, their body weight is smaller. Subadult and adult jackals largely overlap in body size and shape. Sexual dimorphism in jackal's body is weakly pronounced, with older males a little bit larger than females. The results are consistent with recent genetic and morphological studies suggesting little morphological variation, low level of genetic diversity and weakly pronounced genetic structure in European population of golden jackal.

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