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The Tunisian Barbary Sheep: Correlations among Morphometric Traits in Purebred Ewes Maintained under Arid Conditions

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ABSTRACT

Background: The fat-tailed Barbary sheep are the main breed of Tunisia and their morphometry has not been deeply investigated. This study aims to estimate the degree of relationship between eight quantitative measures across eight age classes, from one to eight years.

Methods: Pearson's product-moment was calculated to evaluate the correlation among eight morphological measures, collected from 249 purebred Tunisian Barbary ewes reared under arid climate.

Result: The magnitude of pairwise phenotypic correlation among morphological traits showed a strong positive correlation (r = 0.84, P<0.001) between the shoulder and rump height at 6-7 years. The body weight was highly correlated to the height at rump during the first five years of age, whereas, it becomes more correlated to the heart girth when the ewe reaches its heavyweight at 5-6 years and older. The results of this study indicated that the rump height is the most correlated parameter to BW during the early life of this fat-tailed breed and are encouraging to fit live body weight from morphometric traits with accuracy.

Key words: Barbary breed, Ewe, Fat-tailed sheep, Morphometric traits, Phenotypic correlation.

INTRODUCTION

Barbary sheep are the main breed in Tunisia and are well-known by their rusticity to harsh environmental conditions through the ability to store fat in the tail, as reserve resources to be mobilized during the shortage feeding season, mostly characterizing the arid areas (Atti and Bocquier, 1999; Atti *et al*. 2004). Barbary's morphometry has not been extensively investigated. To our knowledge, only the study of Khaldi *et al*. (2011) covers this aim in literature in which a few quantitative measures were used to describe the morphometry of three breeds, including Barbary, in southwestern Tunisia. Referable to the high cost, compared to molecular studies, morphometric studies, at the phenotypic level, could be a serious alternative to highlight potential morphological peculiarities, developed by the breed to its environment, in the context linked to adaptation and/or production process. This task appears worth for the reason that, in many instances, researchers proved that phenotypic parameters have been similar to their genetic counterparts for morphometric (quantitative) characters (Cheverud, 1988; Sodini *et al*. 2018). The current study focuses on estimating the phenotypic relationships among eight quantitative measures, describing various morphological parts of purebred Barbary ewe reared extensively under arid conditions.

MATERIALS AND METHODS

Geographical area

This investigation was carried out in Southeastern Tunisia, precisely in Sfax governorate, having latitude and longitude coordinates, 34°44′26.02″N, 10°45′37.01″E, respectively. Two public sector farms belonging to the office of state lands: *El Salema* and *Chaal*, maintaining a purebred nucleus of the Barbary breed, were selected to collect morphometric data. The study area is included in the higher arid bioclimatic stage marked by less than 200 mm of rainfall per year.

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Data collection

From eight distant flocks, forty animals per flock were randomly sampled. Eight morphological measures (M.M) were recorded for each animal in an upright place with a metric tape (in centimeter). Each animal was weighed in Kilograms using an analog weighing scale. Official tag number was used to identify each recorded animal and was utilized to get its birth date from the sheep flock database. The age of ewe was determined as the difference between its measurement and birth date. Ewes older than nine years were not considered in the statistical treatment of data.

Eight measurements: Live body weight (BW), head

length (HL), ear length (EL), shoulder height (SH), body length (BL), heart girth (HG), height at rump (HR) and tail length (TL) were recorded early in the morning by the same person before that animal left to graze during the period ranged from February to April 2013, according to anatomical references described in FAO (2012) guidelines and as defined in Table 1. This period was conventionally marked by a well-conditioned morphological status of ewes. The feeding system was mainly based on grazing natural pastures.

Statistical treatments

R (R Core Team, 2018) software was used in the statistical treatment of data. Normality distribution assumption of MM was validated through Shapiro-Wilk test. *Hmisc* (Harrell Jr *et al*. 2018) package was used to estimate Pearson's correlation coefficients that define the relationships among pairs of quantitative traits across categorical ages. The strength of correlation was evaluated with reference to Evan's guidelines (Evans, 1996).

RESULTS AND DISCUSSION

Phenotypic correlation-ordinarily calculated by the product-moment statistics, was defined as an estimate of the correlation between records of two traits of the same animal (Searle, 1961); its sign has a substantial interest in understanding the evolution of the considered trait (Lynch, 1999). Herein, contrary to studies in which phenotypic correlations have been estimated globally (for all ages), this investigation presents the product-moment correlation for each age class, separately, to explore the trend evolution of this parameter across age. Initially, means and standard deviations of M.M through age groups are ranged in Table 2. Highest morphometric means for HL (26.14 cm ±1.15), EL (15.22 cm ±1.28), SH (66 cm ±2.22), HG (89.25 cm ±1.69) and HR (67.62 cm ±2.80) were observed at 4-5 years. Besides, the highest BW (44.75 kg ±7.51) and BL (74.04 cm ±3.67) means were shown, later, at 5-6 years, while the highest TL (38.50 cm ±2.09) mean was observed at an early age (1-2 years). These results indicate that the full conformation is achieved generally at 4-5 years, excepting BW and BL which are the lately maturing traits (5-6 years). On the contrary, TL seems to be an early maturing trait (1-2 years). Estimates Pearson's correlation coefficients (Table 3) revealed 69 significant correlations. The amount of significance showed at 5-6 years, with 16 correlations. Coefficients ranged from (-0.40) to 0.84 and none of the negative correlations were significant. The highest ($P<0.001$) correlation $r = 0.84$ estimated between HR and SH at 6-7 years and its significance was maintained through the advance of age. The lowest ($P<0.05$) correlation was between TL and HG ($r = 0.32$) at 7-8 years. The correlations SH-HR ($r=0.80$, $P<0.001$; $r=0.84$, $P<0.001$) were remarkably higher in the age groups of 5-6 and 6-7 years, respectively. The same correlation ($r=0.84$) has been estimated in Kupreska Pramenka sheep (Važić *et al*. 2017). Jafari and Hashemi (2014) reported a higher correlation ($r=0.90$) value by bi-variate analyses in Iranian fat-tailed Makuie sheep between HR and SH. In Moghani sheep, using restricted maximum likelihood method, Bakhshalizadeh *et al*. (2016) determined a correlation $r = 0.88$ between HR-SH with an immense genetic correlation ($r = 0.99$). Thus, this high relationship indicates that SH and HR traits may be closely linked; consequently, a selection that affects one height even leads to some change in the other.

A slight higher correlation was observed between SH-BL ($r = 0.56$, $P<0.05$), compared to HR-BL ($r = 0.51$, $P<0.05$), at 1-2 years. This finding was in accordance with the reports of Važić *et al*. (2017) in Bosnian Kupreska Pramenka sheep who reported a value $r = 0.65$ between SH-BL, and $r = 0.46$ between HR-BL. Similarly, correlation estimates in Moghani sheep, by bi-variate analysis, were 0.08 and 0.04 between the couples: SH-BL and HR-BL, respectively (Ghavi Hossein-Zadeh and Ghahremani, 2017). In contrast, the correlation HR-BL ($r = 0.53$) was slightly superior to SH-BL ($r = 0.51$) in Makuie sheep (Jafari and Hashemi, 2014). In this study, BL was moderately correlated to HR ($r = 0.57$, $r=0.59$) than SH ($r = 0.47$, $r = 0.44$) at 5-6 and 6-7 years, respectively.

The magnitude of correlation in young (1-2 years) was amply higher than other age classes, suggesting that M.M are more connected at this age. This result argues with those of Zulu sheep (Mavule *et al*. 2013) and could probably be induced by a change in gene expression between these age transition stages (Douet *et al*. 2014).

Correlation of metric traits to BW

Several metric traits were correlated ($P<0.05$; $P<0.01$; $P<0.001$) to BW of ewes, indicating that different body parts could be implicated in predicting the live BW. All significant correlations were positive, which may be helpful in improving BW through indirect selection. Five significant correlations were observed in both age groups of 5-6 and 6-7 years. At 1-2 years of age, some of the parameters such as HL, SH, BL and HR (Table 3) showed substantial correlations with BW. The highest correlation $r = 0.83$ ($P<0.001$) was noticed among BW and HR in 1-2 years age group. HR trait showed strong associations with BW from the age of 1-2 to 4-5 years, suggesting that BW may be predicted with more accuracy at 1-2 years. In older ewes (5 and above years), HG showed strong positive correlations with BW, supporting broadly the wide use of this measure as the most reliable single estimator of BW. The earlier reports of fat-tailed sheep (Topai and Macit, 2004; Kunene *et al*. 2009; Shirzeyli *et al*. 2013; ÇiLek and Petkova, 2016; Maylinda and Busono, 2019; Özen *et al*. 2019; Worku, 2019) are in agreement with this finding. The amount of correlation ($r = 0.62$, $P<0.01$) between BW and HG was observed at the age of 5-6 years when Barbary ewes reach their peak body weight. Ghavi Hossein-Zadeh and Ghahremani (2017) found that the highest correlation of yearling weight was associated with HG ($r=0.35$) in Moghani sheep. The correlation value between HG and BW,

Table 1: Definition of anatomical reference points of morphological measures (M.M) and their related abbreviations (Abr).

M.M	Abr	Description
Body weight	BW	Live body weight determined as the difference between weights indicated in the scale and the weight of the bag.
Head length	HL	Distance between the proximal end of the head and the inferior incisor end.
Ear length	EL	Distance from the base to the endpoint of the ear, when it is horizontally maintained.
Shoulder height	SH	The vertical distance between tape on the shoulder and the soil.
Body length	BL	Diagonal distance from the point of anterior shoulder to pin bone.
Heart girth	HG	Circumference of thorax behind the front legs.
Height at rump	HR	The vertical distance between tape on the rump and the soil.
Tail length	TL	Distance from the base of the tail to the endpoint.

Table 2: Mean ± standard deviation of morphological measures (M.M) across age groups in purebred Barbary ewes.

M.M (cm)	Age group (Years)							
	[1-2]	[2-3]	[3-4]	[4-5]	[5-6]	[6-7]	[7-8]	[8-9]
BW	40.30± 5.66	40.78± 7.23	40.55± 4.46	44.43± 6.49	44.75± 7.51	43.51± 6.76	41.56± 6.31	40.11± 5.42
HL	24.09± 1.30	25.09± 0.84	25.31± 1.01	26.14± 1.15	25.75± 1.44	25.82± 1.20	25.54± 0.80	25.70± 0.97
EL	14.29± 0.97	14.56± 1.08	14.58± 0.85	15.22± 1.28	14.36± 0.86	14.82± 0.90	14.55± 0.95	14.70± 1.15
SH	62.80± 2.76	64.21± 2.51	64.71± 2.10	66.00± 2.22	65.09± 2.46	65.40± 3.07	63.61± 1.63	64.96± 2.28
BL	69.35± 4.62	69.76± 3.31	71.47± 2.69	72.56± 4.13	74.04± 3.67	71.97± 3.70	70.83± 3.55	70.65± 4.16
HG	86.70± 6.87	85.40± 4.73	86.17± 5.34	89.25± 1.69	86.08± 5.17	85.90± 5.09	85.38± 5.14	84.46± 5.03
HR	65.98± 3.03	66.55± 2.13	66.87± 2.23	67.62± 2.80	66.91± 2.81	66.93± 2.95	66.02± 2.09	67.25± 2.49
TL	38.50± 2.09	37.65± 4.63	35.82± 3.69	37.81± 3.10	34.66± 2.49	35.23± 4.25	34.56± 4.27	35.00± 4.83
N	20	47	34	16	24	43	39	26

BW- Body Weight; HL- Head Length; EL- Ear Length; SH- Shoulder Height; HG- Heart Girth; BL- Body Length; HR- Height at Rump; TL- Tail Length; N- Number of observations in each age group.

observed in this study, is higher than those of Harnali (r=0.59, Kumar *et al*. 2017) and Rampur-Buchair sheep (r=0.42, r=0.47, Sankhyan *et al*. 2017) and slightly lower than the earlier series of studies in various sheep breeds: In Belgian Bleu du Maine (r=0.69), Texel (r=0.67), Suffolk (r 0.74, Janssens and Vandepitte, 2004), Crioula Lanada ewes (r=0.72, Silva *et al*. 2013), Purky (r=0.96, Khan *et al*. 2016) and young Dorper rams (r=0.79, r=0.80, Fourie *et al*. 2002). These strong correlations validate the widespread use of HG, as the best measure, to predict live body weight. This investigation, however, highlights that HG-BW correlation is dependent on the degree of ponderal maturity of ewe; HG is evaluated as the best-correlated measure to BW when ewe achieves the heavyweight status at 5-6 years. Jafari and Hashemi (2014) found the same correlation approximately between HR-BW (r=0.46) and HG-BW (r=0.47) in Makuie sheep, which validates partly our finding and supports the presence of more than one (at least) single reliable estimator of BW that could be different from HG.

In this study, the tail length is given much attention as it has some adaptive properties of the fat-tailed sheep. The relationship BW-TL, notably, was higher at 5-6 years and was categorized as moderate (r=0.46, P<0.05). In contrast, Hamouda and Atti (2011) reported very weak correlations between BW-TL in Barbary lambs. These correlations could be linked indirectly to the tail fat proportion from the overall weight, because tail fat was found highly correlated to carcass fat (r=0.93) and total body fat (r=0.91) in Barbary lambs (Atti and Ben Hamouda, 2004). Correspondingly, Kiyanzad (2004) estimated a strong correlation r=0.69 and r= 0.75, between the weight of tail fat and live BW, in Moghani and Makuie sheep, respectively. In Menz and Horro fat-tailed sheep, TL had the lowest contribution, compared to tail volume and circumference, in varying dissected tail and rump fat (DTRF) for both breeds (25.4% for Menz and 32.1% for Horro); the correlation TL-DTRF then was determined as r = 0.45 (Ermias and Rege, 2003). Together, these results open the reflections about, disposing of a long tail, favored Barbary ewes to be heavier in BW term.

Except oldest ewes (8-9 years), HL was correlated (P<0.05; P<0.01; P<0.001) to BW, with weak to moderate coefficients ranging from r = 0.35 to r = 0.57. The highest value (r = 0.57) observed at an early age stage (1-2 years), whereas the lowest (r = 0.35) was at 6-7 years. This finding is in accordance with earlier findings of Silva *et al*. (2013) and Legaz *et al*. (2011) where moderate (r = 0.44) and weak (r = 0.34) correlations have been observed among HL and BW in adult Crioula lanada ewes and Assaf ewes, respectively. Conversely, Mavule *et al*. (2013) found a weak correlation (r = 0.33) in adult Zulu, but a very strong (r = 0.85) in young, which is huger than present study values. The differences in correlation strength, showed between morphometric studies, could be associated with differences in developmental characteristics and genetic backgrounds of breeds, leading to different head sizes and consequently, diverse contributions to the live BW.

Table 3: Pairwise Pearson's correlation coefficients among morphological measures (M.M) across age in purebred Barbary ewes.

Age Group (years)	M.M (cm)	BW	HL	EL	SH	BL	HG	HR
[1-2]	BW							
	HL	0.57**						
	EL	-0.08	0.12					
	SH	0.68***	0.64**	0.09				
	BL	0.67**	0.49*	0.01	0.56*			
	HG	0.38	-0.12	-0.17	0.16	0.14		
	HR	0.83***	0.54*	-0.19	0.70***	0.51*	0.33	
	TL	-0.36	-0.29	-0.08	-0.28	-0.23	-0.40	-0.27
[2-3]	BW							
	HL	0.50***						
	EL	-0.12	0.07					
	SH	0.15	0.25	0.01				
	BL	0.36*	0.23	0.01	0.34*			
	HG	0.27	0.06	0.09	0.22	0.44**		
	HR	0.40**	0.28	0.00	0.58***	0.26	0.44**	
	TL	0.28	0.29	-0.08	0.19	0.28	0.15	0.20
[3-4]	BW							
	HL	0.43*						
	EL	-0.26	0.16					
	SH	-0.04	0.17	0.29				
	BL	0.31	0.22	0.09	-0.05			
	HG	0.31	-0.04	-0.04	0.31	0.24		
	HR	0.05	0.29	0.51**	0.36*	0.18	0.07	
	TL	-0.07	0.06	0.08	-0.23	0.01	-0.08	0.10
[4-5]	BW							
	HL	0.50*						
	EL	0.06	0					
	SH	0.26	0.23	0.12				
	BL	0.51*	0.18	0.51*	0.15			
	HG	0.20	-0.17	0.16	0.20	-0.03		
	HR	0.61*	0.48	0.49	0.70**	0.45	0.19	
	TL	-0.02	0.19	-0.18	-0.16	0.23	-0.35	-0.03
[5-6]	BW							
	HL	0.51*						
	EL	0.09	0.51*					
	SH	0.37	0.41*	0.45*				
	BL	0.51*	0.63**	0.55**	0.47*			
	HG	0.62**	0.40	0.04	0.22	0.29		
	HR	0.56**	0.60**	0.48*	0.80***	0.57**	0.40	
	TL	0.46*	0.08	-0.14	0.14	0.22	0.43*	0.29
[6-7]	BW							
	HL	0.35*						
	EL	-0.11	0.18					
	SH	0.30	0.46**	0.20				
	BL	0.40**	0.44**	-0.04	0.44**			
	HG	0.46**	-0.08	0.15	0.04	0.14		
	HR	0.41**	0.46**	0.20	0.84***	0.59***	0.08	
	TL	0.43**	0.03	-0.06	0.02	0.36*	0.19	0.10
[7-8]	BW							
	HL	0.37*						

Table 3: Continue...

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	EL	-0.30	0.28					
	SH	0.09	0.10	0.17				
	BL	0.55***	0.25	-0.02	0.28			
	HG	0.61***	-0.04	-0.29	-0.01	0.26		
	HR	0.39*	0.34*	0.18	0.52***	0.35*	0.13	
	TL	0.21	0.05	-0.26	-0.28	0.07	0.32*	-0.19
[8-9]	BW							
	HL	0.38						
	EL	-0.17	0.21					
	SH	-0.10	-0.02	0.48*				
	BL	0.28	0.25	0.13	0.10			
	HG	0.54**	0.50**	0.36	0.31	0.40*		
	HR	0.05	0.24	0.62***	0.69***	0.06	0.41*	
	TL	0.09	-0.07	0.38	0.39	-0.01	0.14	0.53**

*Significant at P<0.05; ** Significant at P<0.01; *** Significant at P<0.001; BW- Body Weight; HL- Head Length; EL- Ear Length; SH- Shoulder Height; HG- Heart Girth; BL- Body Length; HR- Height at Rump; TL- Tail Length.

Note: The guidelines proposed by Evans, (1996) were used to evaluate the strength of correlation coefficient: 1) very weak: 0–0.19; 2) weak: 0.20-0.39; 3) moderate: 0.4-0.59; 4) strong: 0.6-0.79; 5) very strong: 0.8-1.

CONCLUSION

The height measures: SH and HR, are strongly correlated in Barbary ewes. The BL is slightly more correlated to HR compared to SH. The correlation between metric traits and BW indicated a strong correlation with HR trait during the first five years of age. Older than five years, the BW will be mostly correlated to HG. The TL of this fat-tailed breed is moderately related to the heavyweight status of ewes. To conclude, our results clarify some peculiarities allied to the morpho-genetic architecture across age and are useful to set up a suitable genetic improvement plan for this valuable breed.

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