Indian Journal of Animal Sciences **86** (5): 568–571, May 2016/Article

Principal component analysis of body measurements based morphological structure of Madgyal sheep

DINESH KUMAR YADAV[1], REENA ARORA[2] and ANAND JAIN[3]

ICAR-National Bureau of Animal Genetic Resources, Karnal, Haryana 132 001 India

Received: 24 August 2015; Accepted: 28 September 2015

ABSTRACT

The present study describes the morphometric structure of extensively managed Madgyal sheep of Maharashtra and predicts body weight from their body biometry traits using principal component analysis (PCA). The data on body weight and 13 body measurements were recorded on 200 randomly selected sheep. Phenotypic correlation among body weight and biometric traits were positive and highly significant except some of ear length related combinations. The PCA of morphometric traits extracted two components with a total variance 67.8% explained. The first factor had high loadings for variables related to body size, whereas second factor was loaded in favour of body shape. PCA was able to define the morphological structure of Madgyal sheep and identified traits with greater variability. The principal component based regression models were more appropriate than the use of original correlated variables in predicting the body weight. The findings could be useful in designing management, selection and breeding programmes of the Madgyal sheep.

Key words: Body measurement, Madgyal sheep, Morphometric structure, Principal component analysis

Morphological structure of different livestock species is defined using body measurements which together with body weight describes more completely an individual or population (Salako 2006, Mavule *et al*. 2013, Yadav *et al.* 2013, Yadav and Arora 2014). Linear body measurements are also used to predict body weight in sheep (Yadav and Bhar 2008, Kunene *et al.* 2009, Mavule *et al*. 2013). Analysis of morphometric traits to assess the variability within the breeds can be achieved using classical principal component analysis (PCA). Several researchers used PCA to extract factors contributing towards variation amongst individual animals based on body measurements (Salako 2006, Kunene *et al.* 2009, Mavule *et al.* 2013). This paper used PCA approach that better explains the variation in body composition of Madgyal sheep (Yadav *et al.* 2014) and predicts body weights using principal component scores.

MATERIALS AND METHODS

The study was carried out in Sangli district of Maharashtra, the habitat of Madgyal sheep. Data on morphometric traits of 200 Madgyal sheep (175 female and 25 male) were recorded. The age was determined by dentition, and the animals having 2 or more permanent incisors (adult) were included in the study. Body dimensions were measured using a steel tape of 5m length of class II accuracy with records taken to the nearest centimeter (cm) holding the animal in normal standing position. The traits measured are given in Table 1. The sheep originated from different flocks and were reared under extensive management system. Statistical analysis was carried out using JMP software of SAS (2012). The morphological traits were subjected to analysis of variance to determine age and sex effects. The Kaiser Rule criterion (eigen values ≥1) was used to determine the number of factors extracted. The Varimax criterion of the orthogonal rotation was applied to enhance the interpretability of the principal components. The stepwise multiple regression procedure was used to obtain models for predicting body weight from body measurements and principal components.

RESULTS AND DISCUSSION

Descriptive statistics and significance of age and sex effects on morphological traits are presented in Table 1. Coefficients of variation (%) for all traits ranged from 4.9 to 16.3 and were similar to those obtained by Yadav and Arora (2014) in Munjal and Muzaffarnagri sheep. Relatively higher coefficients of variation were reported in Assaf sheep (Legaz *et al.* 2011) and Zulu sheep (Mavule *et al.* 2013). The rump height was slightly more than wither height suggesting that the animal is not sloppy on standing. Sex-effect was highly significant for all traits except EL. Marked sexual dimorphism was observed. Rams were 30% heavier than ewes. The average values of BW, BL, WH and HG in Madgyal rams were comparable to Munjal rams (Yadav and Arora 2014).

Pearson's coefficients of correlation among the various morphometric traits are shown in Table 2. All linear

Present address: [1,2,3]Principal Scientist (dkyadav66 @gmail.com, rejagati@yahoo.co.in, anand_nbagr@rediffmail.com).

Table 1. Mean, standard error, coefficient of variation and sexual dimorphism of the morphological traits in Madgyal sheep

Trait	Statistics		Effects		Sex differences		Sexual dimorphism
	Mean±SE	CV	Age	Sex	M(25)	F(175)	
BW	47.8±0.55	16.3	***	***	59.8±1.82	46.1±0.45	1.30
BL	77.5±0.28	5.1	ns	***	83.5±0.92	76.7±0.22	1.09
WH	78.8±0.28	5.0	ns	***	84.8±0.78	77.9±0.24	1.09
RH	81.2±0.28	4.9	ns	***	87.5±0.80	80.3±0.23	1.09
HG	82.8±0.32	5.5	***	***	87.7±1.11	82.1±0.30	1.07
EL	20.1±0.08	5.7	ns	ns	20.2±0.29	20.1±0.08	1.00
TL	19.9±0.11	7.9	ns	***	21.7±0.34	19.7±0.10	1.10
TD	36.8±0.15	5.7	***	***	39.7±0.46	36.4±0.13	1.09
RW	17.5±0.07	6.1	**	***	18.4±0.24	17.4±0.08	1.06
RL	21.5±0.09	5.8	ns	***	23.4±0.23	21.2±0.08	1.10
ShC	10.2±0.06	8.6	ns	***	11.6±0.16	10.0±0.05	1.16
TC	9.1±0.08	12.4	ns	***	10.0±0.22	9.0±0.08	1.11
HL	22.7±0.09	5.5	ns	***	24.5±0.27	22.4±0.08	1.09
HW	9.9±0.07	9.9	*	***	11.8±0.18	9.7±0.05	1.22

BW, body weight; BL, body length; WH, withers height; RH, rump height; HG, heart girth; EL, ear length; TL, tail length; TD, thorax depth; RW, rump width; RL, rump length; ShC, shin circumference; TC, tail circumference; HL, head length; HD, head width; BW measured in kilogram and rest of the traits in centimeters; M, male; F, Female; values within parentheses indicate number of observations; ***P<0.0001; ** P<0.001; *P<0.01.

Table 2. Correlation coefficients among morphometric traits of Madgyal sheep

Trait	BW	BL	WH	RH	HG	EL	TL	TD	RW	RL	ShC	TC	HL	HW
BW	1.00	0.80	0.76	0.77	0.90	0.27	0.39	0.86	0.67	0.78	0.62	0.40	0.70	0.68
BL		1.00	0.88	0.87	0.71	0.37	0.52	0.75	0.60	0.78	0.65	0.38	0.75	0.59
WH			1.00	0.97	0.70	0.39	0.47	0.76	0.57	0.78	0.68	0.35	0.75	0.59
RH				1.00	0.69	0.37	0.47	0.77	0.57	0.79	0.71	0.38	0.75	0.62
HG					1.00	0.29	0.28	0.85	0.65	0.71	0.49	0.37	0.64	0.59
EL						1.00	0.33	0.29	0.30	0.29	0.21	0.07	0.39	0.20
TL							1.00	0.35	0.24	0.38	0.47	0.24	0.40	0.40
TD								1.00	0.68	0.75	0.58	0.38	0.63	0.65
RW									1.00	0.66	0.43	0.32	0.52	0.45
RL										1.00	0.67	0.36	0.67	0.64
ShC											1.00	0.41	0.59	0.62
TC												1.00	0.34	0.34
HL													1.00	0.62
HW														1.00

body measurements were positively and significantly (P<0.05/0.01) inter-correlated except for correlation between EL and TC. However, ear length and tail length related combinations had lower correlation coefficients. The study showed high correlations of BW with HG, WH, TD, BL, RL, HL and ShC. The correlation coefficient values found in this study are higher than those reported by Mavule *et al.* (2013).The positive correlation between BW and morphological traits indicate that an increase in anyone body measurement would result in a corresponding increase in live body weight. EL and TL depicted lower correlation coefficients with other body traits. Therefore, selecting those traits in breeding program will not lead to significant improvement of BW and other measurement that are of economic interest. Positive correlations of morphometric traits suggest that traits may be under the same genetic influences. The association between traits found in the study may be useful as selection criterion depending upon the production objectives, selection goals and even the socio-cultural demands or conditions of the farmers (Birteeb *et al.* 2012).

Eigen values and share of total variance along with factor loadings and communalities of the measured traits are summarized in Table 3. Following Keiser criterion (eigen value>1), 2 factors were extracted which accounted 67.8 % of total variance. The percentages of variation explained by PCA in this study is higher than those reported by Mavule *et al.* (2013) in adult Zulu sheep and are lower than those reported by Birteeb *et al.* (2014) in Djallonke sheep. The results indicated that more conformational variation was left unexplained. Mavule *et al.* (2013) reasoned wider age ranges of the animals included in the study. BW, HG, TD

Table 3. Varimax rotated factor loadings, eigen values, percentage of total variance and communalities of morphometric traits of Madgyal sheep

Trait	PC1	PC2	Communality
BW	0.85	0.44	0.92
BL	0.54	0.76	0.87
WH	0.52	0.77	0.87
HG	0.91	0.28	0.91
EL	0.17	0.36	0.16
TL	0.15	0.55	0.33
TD	0.80	0.43	0.82
RW	0.63	0.34	0.51
RL	0.61	0.61	0.74
ShC	0.38	0.64	0.55
TC	0.33	0.27	0.18
HL	0.50	0.63	0.65
HW	0.54	0.45	0.50
Eigen values	7.74	1.07	
% of total variance	59.5	8.25	

Table 4. Step-wise multiple regression among morphometric traits of Madgyal sheep

X_i	a	b_i	R^2	RMSE
(i) Morphometric traits as predictors				
CG	–80.07	1.54	0.808	3.43
CG	–98.08	1.14	0.865	2.89
BL		0.66		
CG	–94.46	1.05	0.878	2.75
BL		0.56		
HW		1.18		
CG	–95.27	0.89	0.883	2.70
BL		0.48		
HW		0.97		
TD		0.59		
CG	–95.02	0.92	0.886	2.67
BL		0.42		
HW		0.75		
TD		0.53		
ShC		0.72		
(ii) Principal components as predictors				
PC1	47.81	7.35	0.802	3.48
PC1	47.81	7.01	0.944	1.86
PC2		3.22		

X_i, i^{th} predictor; a, intercept; b_i, i^{th} regression coefficient.

and RW were heavily loaded on first component (PC1) while the second component (PC2) had its loadings for BL, WH, RL, ShC and HL. The morphometric traits loaded on PC1 and PC2 were good descriptors of body size and shape, respectively. Other researchers (Salako 2006, Mavule *et al.* 2013) have also reported similar findings describing first factor as a representation of the general body size. While principal components are orthogonal, the traits loaded on one component are not related to traits loaded on another component. So selection to improve body shape, an important target for meat production (Salako 2006) implies little variation in body size. Hence, breeders could improve body shape in order to better meat production traits and maintain an animals' body size suitable for walking longer distances and survival in harsh environmental conditions (Mavule *et al.* 2013).

The inter-correlated original morphometric traits and their independent principal component scores were used to predict body weight (Table 4). The accuracy of the prediction model increased to 88.6% when four more variables were added to HG. Use of PC1 and PC2 together accounted for 94.4% of the variation in body weight. Body weight increase in sheep production is one of the essential goals of improvement programmes, which requires adequate knowledge of correlated traits that can be considered when selection is to be applied (Mavule *et al.* 2013). Several authors in similar studies have concluded that heart girth can be used as a sole predictor of body weight due to high associate regression coefficients obtained (Kunene *et al.* 2009). This, however, has limitations of presence of multicollinearity amongst linear traits, rendering weight prediction unreliable. The use of PCA factor scores which are orthogonal and not correlated eliminating the problem of collinearity. The current study demonstrated that the use of principal components (PC1, PC2) was more appropriate than the use of original correlated variables in predicting body weight.

Madgyal sheep is large in body size. From the normalized varimax rotation, two principal components extracted from body measurements represent the general body size and shape. Body weight, heart girth, whither height, shin circumference, head length, head width, rump width and rump length contributed remarkably towards total morphostructural variance. On the contrary, peripheral traits such as ear length, tail length and tail circumference have been shown to be poorly related with other body measurements and contribute less towards total variance of body conformation. The results suggest that PCA could be used in breeding programmes to select animals based on a group of variables rather than on isolated traits. Presence of multicollinearity between the traits can lead to unstable regression coefficients. Hence, the use of principal components could be more appropriate than the use of original correlated variables in predicting body weight. The findings will foster future studies to understand role of different traits in selection programs.

ACKNOWLEDGEMENT

The authors are thankful to Director, ICAR-National Bureau of Animal Genetic Resources, Karnal for providing the facilities. Financial assistance provided by Indian

Council of Agricultural Research, Krishi Bhawan, New Delhi is gratefully acknowledged. Technical assistance provided by Sh. Subhash Chander, Technical Officer is duly acknowledged. Punyashloke Ahilyadevi Maharashtra Mendhiva Sheli Vikas Mahamandal Ltd., Pune, Maharashtra and sheep owners are thankfully acknowledged for help and cooperation during the field visits.

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