



## Principal component analysis of biometric traits to explain body conformation in Kajali sheep of Punjab, India

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### ABSTRACT

Different body biometric traits were analysed in Kajali ewes (395) of Punjab (India) using varimax rotated principal components (PCA) with Kaiser Normalization to explain their body conformation and were subsequently used to predict adult body weight. These traits revealed that Kajali sheep were large in size and suitable for mutton production. The positive and highly significant phenotypic correlations among most of the traits indicates high predictability among these traits. PCA extracted major three components which explained 68.66% of total variation of body biometry. First component described the body size and explained about 36% of total variation. It was represented by high component loadings for chest girth, paunch girth and body weight. The second component described the tail length, height and ear length and explained about 21% variation. The communalities ranges between 0.33 (face length) to 0.87 (chest girth). The lower communality of face length and ear length indicates that these traits are less effective to explain the body conformation. The study suggested that PCA could be used in breeding programme for phenotypic selection of Kajali ewes and PCA is more appropriate compared to multiple regression analysis in predicting adult body weight. In predicting body weight using multiple regression analysis, chest girth alone accounted for 55% of total variation in body weight whereas, use of first principal component as a single predictor explained 79% of total variance and the best prediction equation ( $R^2 = 0.83$ ) was obtained after inclusion of second and third component in the model.

**Key words:** Kajali sheep, Morphometry, Multivariate analysis, PCA

Principal component analysis (PCA) has been used as tool to evaluate the body size and shapes which could be of evolutionary significance as well as permit an understanding of the complex growth process going on among the body dimensions of an animal (Salako 2006, Sadak *et al.* 2006). In lambs, PCA of different linear body measurements has been successfully used with a view to describe body shapes because of more demand and preference for mutton. Moreover, morphological classification using PCA will not only impact and improve the management of animals but also support selection for multiple economic traits and also in identification and conservation of diversity (Brown *et al.* 1973, Yunusa *et al.* 2013). The purpose of PCA is to develop a minimum number of composite variables that account for the maximum portion of the variance present in the original set of variables. It assumes that the unique variance represents a small portion of the total variation. Mavule *et al.* (2013) and Okpeku *et al.* (2011) used extracted principal components in sheep and goat, respectively, and

concluded that resultant factor score coefficients could be used to predict body weight. Kajali is a mutton type sheep, distributed in Sangrur, Barnala, Ludhiana, Moga and adjoining districts (Anonymous 2015) of Punjab (India). Scanty reports are available on this lesser known sheep population. Body conformation is an important parameter in phenotypic classification of any breed or population. Therefore, it is imperative to describe the body conformation by recording minimum number of biometric traits which reduces labour, time and cost. Keeping this in view, the present investigation was undertaken to study the different body biometry traits, understand their relationships and further to develop unobservable components to define which of these measures best represent body conformation in Kajali sheep.

### MATERIALS AND METHODS

Data consisted of nine different body traits which can explain the body conformation in sheep were measured on Kajali sheep population in its native breeding tract. Traits included in the study were body length (BL), height at wither (H), chest girth (CG), paunch girth (PG), ear length (EL), face length (FL), face width (FW), tail length (TL) and adult body weight (BW). To overcome the effect of age, only adult sheep (2 teeth stage and above) were included in the

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study. Body biometric data on 395 ewes was collected from Sangrur, Barnala, Ludhiana, Moga, Bhatinda and Ferozpur districts of Punjab, India. The body measurements were recorded by using tape measure and body weight were taken using spring weighing balance.

**Statistical analysis:** To study the effect of district on all recorded body measurements, data were analysed using first model of Harvey (Harvey 1987). Physical characterization of adult ewes and phenotypic correlations between different body biometric traits were estimated using partial correlations. PCA, a multivariate approach, is used when the recorded traits are highly correlated. Varimax rotation was used for rotation of principal components through the transformation of the components to approximate a simple structure. Kaiser-Meyer-Olkin (KMO) test of sampling adequacy and Bartlett's test of sphericity were computed to establish the validity of data set, at 1% level of significance. All the analysis was carried out using the SPSS (2001) statistical package. The stepwise multiple regression procedure was used to establish best fit models for predicting adult body weight in Kajali ewes using combinations of different body biometry traits (1) and principal components (2).

$$BW = a + b_1x_1 + \dots + b_nx_n \quad (1)$$

$$BW = a + b_1PC_1 + \dots + b_nPC_n \quad (2)$$

Where, BW is the body weight; a, is regression intercept;  $b_1, \dots, b_n$  are the  $i^{\text{th}}$  partial regression coefficients of the  $i^{\text{th}}$

linear body measurements;  $x_1, \dots, x_n$  are the observed value of  $i^{\text{th}}$  traits and PC is principal component.

## RESULTS AND DISCUSSION

**Biometric traits:** The descriptive statistics for all the biometric traits along with standard deviation (SD), coefficient of variation (CV) are given in Table 1. The means of body biometry showed that Kajali ewes were larger in body size. The coefficient of variation (CV) for different morphometric traits ranges between 4.6 (height at wither) to 16.3 (body weight). Majority of the biometric traits showed higher consistency except for face width, tail length and body weight which were comparatively more variable. The body biometry of Kajali is comparable with finding of Yadav *et al.* (2011), who characterized the Munjal sheep available in Punjab and Haryana state, however, tail length of Kajali ( $54.6 \pm 0.3$ ) is longer than Munjal ( $42.0 \pm 0.6$ ). The H (72.1), BL (72.7), CG (82.9) and PG (84.4) in adult ewes in this study were higher than that reported by Mishra *et al.* (2005) for mutton type Malpura sheep. The maximum CV was noticed for BW (16.33) and minimum was for H (4.60). The CV's were relatively lower than that reported by Mavule *et al.* (2013) for Zulu sheep (8–31.18%) and were similar to Legaz *et al.* (2011) for Spanish sheep (3.73–15.00%). The standard deviations were well within the normal range, showing that in Kajali sheep body measurements were less affected by environment. All biometric traits studied show less variability, indicating that the Kajali sheep are almost similar shape and size in their natural habitat. This might be due to natural selection for better adaptability for particular shape and size. Similar finding was also reported by Tolenthomba *et al.* (2013).

**Phenotypic correlations:** The phenotypic correlations among different biometric traits are presented in Table 2. The magnitude of correlation coefficient ranges between –0.47 (body length and face width) to 0.81 (chest girth and paunch girth). The values of all correlations estimated were found positive, except for correlation between face width and body length. Out of total 36 correlations coefficients estimated, 28 were found to be highly significant. The body length had highly significant positive correlation with height. The correlation of paunch girth with chest girth was

Table 1. Descriptive statistics of adult Kajali sheep (N=395)

Trait	Mean	SD	CV (%)
Body length	72.72 ± 0.27	5.33	7.33
Height at withers	72.18 ± 0.17	3.32	4.60
Chest girth	82.95 ± 0.26	5.20	6.27
Paunch girth	84.48 ± 0.36	7.22	8.55
Ear length	21.28 ± 0.09	1.71	8.03
Face length	21.68 ± 0.07	1.38	6.38
Face width	10.64 ± 0.07	1.35	12.66
Tail length	54.68 ± 0.37	7.39	13.51
Body weight	43.29 ± 0.36	7.07	16.33

Measurements expressed in cm, except for body weight (kg).

Table 2. Phenotypic correlation among different body biometry traits in Kajali sheep

Trait	BL	H	CG	PG	EL	FL	FW	TL	BW
BL	-	0.52**	0.16**	0.04	0.36**	0.31**	-0.47**	0.20**	0.33**
H			0.34**	0.23**	0.32**	0.32**	-0.04	0.32**	0.47**
CG				0.81**	0.16**	0.26**	0.28**	0.07	0.74**
PG					0.17**	0.13	0.35**	0.05	0.66**
EL						0.24**	-0.03	0.24**	0.25**
FL							0.04	0.17**	0.29**
FW								0.05	0.17**
TL									0.24**
BW									-

\*\* , significant at  $P < 0.01$ ; BL, body length; H, height at wither; CG, chest girth; PG, paunch girth; EL, ear length; FL, face length; FW, face width; TL, tail length; BW, body weight.

high (0.81) and significant, but with body length it was lower (0.04) in magnitude. The body weight had significantly high and positive correlation with chest girth (0.74), paunch girth (0.66) and height (0.47). The lower correlation of FW and TL with some of the biometric traits was also noticed. The highly significant and high correlation of body weight with chest girth/heart girth support the theory, why some of the workers (Kunene *et al.* 2009, Yakubu and Ayoade 2009) advocated the use of heart girth as a single predictor of body weight. The results were in full agreement with Mavule *et al.* (2013). It was quite natural that CG, H and BL turn out high correlation with BW. Similar findings had also been reported by Kunene *et al.* (2009), Salako (2006) and Yakubu and Ayoade (2009). The positive and highly significant ( $P < 0.01$ ) correlations among biometry traits indicates high predictability among these traits. Significant correlations of most of these traits have also been reported by Yunusa *et al.* (2013). Salako (2006) reported correlation among body measurement traits even up to 0.99 in a similar study. The lower correlation of FW and TL with some traits (Table 2) was observed. Mavule *et al.* (2013) reported that these traits are determined by non-additive genetic effects, and are presumably less influenced by environment; therefore, selecting them in breeding programmes will not lead to significant improvement of body weight and other biometric traits.

**Principal component analysis:** The principal component analysis was applied on nine body biometry traits in Kajali sheep. The Kaiser Meyer-Olkin (KMO) test gave measure of sampling adequacy (MSA) as 0.736. The Varimax rotation (Fernandez 2002) was applied as it maximizes the sum of variances of the squared loadings (squared correlation between variable and component). The Bertlett's test of sphericity was used to test the overall significance of correlation matrix and chi-square value for test was highly significant ( $P < 0.01$ ) and estimated as 1412.5. The estimated components loading extracted by PCA, Eigenvalues (Fig. 1) and variation explained by each component are given in Table 3. Three components were extracted out of nine principal component using Kaiser Rule criterion (Johnson and Wichern 1982) to determine the

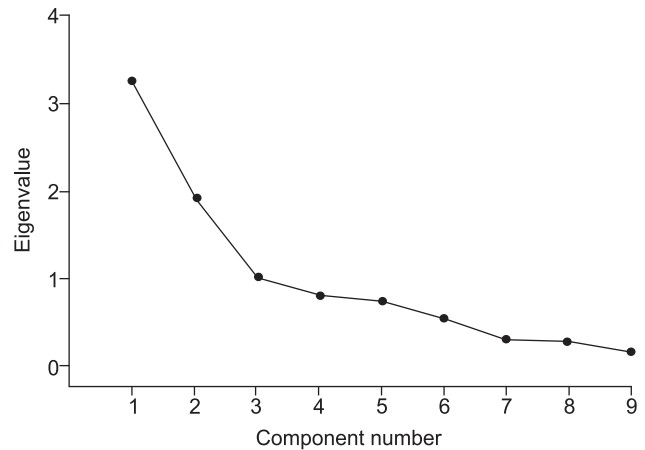


Fig. 1. Scree plot showing component number with Eigenvalues.

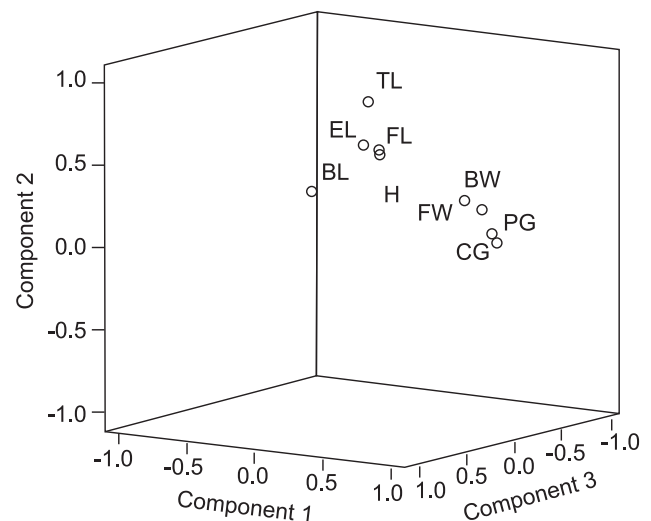


Fig. 2. Component plot in rotated space. BL, Body length; H, height at wither; CG, chest girth; PG, paunch girth; EL, ear length; FL, face length; FW, face width; TL, tail length; BW, body weight.

Table 3. Total variance explained by different components in adult Kajali ewes

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loading total
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	
1	3.24	36.04	36.04	3.24	36.04	36.04	2.65
2	1.91	21.26	57.30	1.91	21.26	57.30	1.97
3	1.02	11.36	68.66	1.02	11.36	68.66	1.56
4	0.81	8.98	77.64				
5	0.75	8.33	85.96				
6	0.54	6.01	91.98				
7	0.29	3.22	95.19				
8	0.26	2.94	98.13				
9	0.17	1.87	100.00				

Table 4. Varimax rotated component matrix showing different component loadings, communalities and unique factor for biometric traits in adult Kajali ewes

Trait	Principal component			Communalities	Unique factors
	1	2	3		
Chest girth	0.929	0.117	-0.044	0.836	0.164
Paunch girth	0.897	0.039	-0.167	0.602	0.398
Body weight	0.820	0.328	0.090	0.879	0.121
Tail length	-0.091	0.803	-0.193	0.834	0.166
Height at withers	0.351	0.611	0.325	0.405	0.595
Ear length	0.126	0.601	0.166	0.333	0.667
Face length	0.210	0.526	0.113	0.812	0.188
Face width	0.301	0.083	-0.845	0.690	0.310
Body length	0.164	0.433	0.788	0.788	0.212

number of significant components. There were three components with Eigenvalue greater than one and accounted for 68.66% of total variance. PCA determines the variability of individual traits and how these traits contribute towards the total morpho-structural variance of animal (Mavule *et al.* 2013). Kaiser (1958) reported that the estimate of sampling adequacy KMO revealed the proportion of the variance in different body biometric traits/characters caused the by underlying components. Kaiser (1974) recommended the acceptable value for MSA as 0.5. Yunusa *et al.* (2013) reported it as 0.932 for Uda sheep and Pundir *et al.* (2011) reported value of sampling adequacy as 0.891 for Kankrej cow. However, MSA estimate of Vohra *et al.* (2015) was in agreement with present study (0.736). The highly significant Chi-square value for Bertlett's test of sphericity reveals that correlation matrix is not an identity matrix and principal component analysis used in present study was appropriate.

In the present study, the first principal component (PC1)

accounted for 36.04% of the total variance. It was represented by positive and significant high loading for CG, PG and BW. The PC1 appear to be explaining maximum of body conformation and size in Kajali sheep. In a similar study, Yunusa *et al.* (2013) reported that PC1 explained 54.81% and 48.07% variance in Balami and Uda sheep, respectively. The second component (PC2) explained 21.26% of total variance in which high loading for TL, H and EL were observed. The third component (PC3) explained 11.36% with high loading for BL and FL. The PC1 and PC2 gave different weights with positive sign to all the biometric traits except to TL (-0.091) by PC1. The lower coefficients (<0.4) in PC1 and PC2 and negative coefficient value in PC3 of FW was an indication of the fact that this trait had very little contribution in total variance. Mavule *et al.* (2013) in his study reported that ear length had coefficients less than 0.4 for either of the extracted components in young sheep. The component plot of the three components in rotated space is shown in Fig. 2.

The coefficients of the PCA of rotated component matrix of the three extracted components are given in Table 4. The PC1 gave different weights with positive sign to all the biometric traits except tail length. The PC2 assigned positive sign to all the traits studied. In PC1, negative coefficient (-0.091) of TL was noticed while FW had coefficients less than 0.4 in PC1 and PC2 and negative coefficient value in PC3. The PC3 assigned negative weights to CG, PG, TL and FW and positive sign to other measurements. The communalities range between 0.333 (FL) to 0.879 (CG) and unique factors ranges from 0.121 to 0.667 for all the studied traits (Table 4). It shows that most of the variances are shared between the variables allowing the application of PCA to classify them. In this study, three components with Eigenvalue greater than 1 were estimated and they cumulatively accounted for 68.66% of total variance. The remaining unexplained variation may ascribe to segregation of casual alleles at contributory loci, measurement error and environmental factors (Brooks *et al.* 2010). However, Salako (2006) extracted two components from 10 traits in Uda sheep which accounted for higher (75%) variation. Similarly, Yunusa *et al.* (2013) also extracted two

Table 5. Stepwise multiple regression of body weight on original body measurements and their factor score in Kajali sheep

Model	Predictors	Model	R <sup>2</sup>	SE
<i>Body measurements as predictors</i>				
1	CG	BW = 0.744CG - 40.675	0.55	3.81
2	CG, H	BW = 0.659CG + 0.246H - 68.909	0.61	0.53
3	CG, H, PG	BW = 0.497CG + 0.256H + 0.197 PG - 68.476	0.62	5.19
4	CG, H, PG, BL	BW = 0.476CG + 0.178H + 0.227PG + 0.149BL - 71.036	0.64	5.13
5	CG, H, PG, BL, TL	BW = 0.483CG + 0.142H + 0.224PG + 0.144BL + 0.116TL - 71.554	0.65	5.05
<i>Principal components as predictors</i>				
1	PC1	BW = 0.889 PC1 - 45.606	0.79	2.32
2	PC1 and PC2	BW = 0.766PC1 + 0.221PC2 - 59.815	0.82	2.68
3	PC1, PC2 and PC3	BW = 0.778PC1 + 0.190PC2 + 0.063PC3 - 61.455	0.83	2.73

BW, body weight; CG, chest girth; H, height at wither; PG, paunch girth; BL, body length; TL, tail length.

components which accounted for 66.91% of total variation in Balami sheep. In accordance with the present study, Pundir *et al.* (2011) extracted three components which accounted for 66.02% of total variance in Kankrej cows. Mavule *et al.* (2013) and Vohra *et al.* (2015) extracted four components accounting for 62.13% and 70.86% of total variance in adult Zulu sheep and Gojri buffalo, respectively.

The communalities after extraction give the common variance that is shared between the variables (Yunusa *et al.* 2013). The values of communalities show that most of the variances are shared between the variables allowing the application of PCA to classify them. The results were in agreement with Yunusa *et al.* (2013). The lower communality of FL and EL indicates that these traits are less effective to explain the body conformation.

#### *Predictions of body weight of Kajali sheep from linear body biometric traits and their principal components score*

The result of multiple regression analysis (Table 5) reveals that CG alone accounted for 55% of the variation in adult body weight. The results were in full agreement with Mavule *et al.* (2013) who reported that heart girth alone accounted for 55% variation in adult Zulu sheep. The importance of CG in predicting body weight may be due to fact that muscle, some fat along with bone structure contribute to its formation (Mavule *et al.* 2013). The inclusion of H in model increases the proportion of variation to 61%. The inclusion of PG and BL in model further improved the accuracy to 64%. The use of PC1 as a single predictor explained maximum variance (79%) of total variance which was higher than (69.3%) that reported by Mavule *et al.* (2013). The inclusion of PC2 in model increased the proportion of explained variance to 82%. After inclusion of PC3 in the model, best prediction equation  $BW = 0.778PC1 + 0.190PC2 + 0.063PC3 - 61.455$  ( $R^2=0.83$ ) was obtained. However, only 1% improvement was noticed after adding PC3 in model. The study reveals that use of principal component factors is more appropriate in predicting adult body weight than correlated body measurements as PCA factor scores are orthogonal and uncorrelated (Ogah 2011, Yakubu and Ayodade 2009) in contrast to original correlated body measurements where multi-collinearity problems exist which in turn leads to unstable regression coefficients. The results of Keskin *et al.* (2007) and Mavule *et al.* (2013) also support present findings.

The three extracted principal components in adult ewes determine the source of shared variance to explain body conformation in Kajali sheep. The communalities estimate indicates that chest girth, body length, paunch girth and body weight contributed effectively. The results of PCA suggest that principal components provided a means of reduction in number of biometric traits to be recorded in Kajali sheep which could be used in explaining body conformation and it may be used in breeding programme for phenotypic selection of females. The results

also suggest that in predicting body weight of Kajali sheep, the use of principal components as regressor is more appropriate than to the make use of original correlated body measurements.

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