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Research Paper

Multivariate principal component analysis of morphometric traits in Kashir goat

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ABSTRACT

Animal populations are characterized by biometric and morphological traits. Morphometrics are vital for identifying breeds and understanding unknown populations. Principal component analysis (PCA) is a critical statistical tool for analyzing livestock morphology. Therefore, the present study was undertaken to study the morphological structure of the Kashir goat. Accordingly, the morphological data on 187 adult goats were collected for the year 2019. The traits considered were face length (FL), ear length (EL), ear width (EW), body length (BL), chest girth (CG), paunch girth (PG), tail length (TL), height at wither (HW), and body weight (BW). The averages were of 35.63±1.01 kg, 22.5±0.18 cm, 13.32±0.35 cm, 9.04±0.96 cm, 56.1±0.44 cm, 55.65±0.32 cm, 66.13±0.65 cm, 69.84±0.76 cm, and 13.06±0.15 cm for BW, FL, EL, EW, CG, PG, HW, BL, and TL, respectively. BW had a strong positive correlation with CG and BL, whereas moderate correlations with WH and PG. Indicating that taller, fatter, and longer animals had higher body weights. Similarly, positive and moderate to high (>0.25) correlations were observed between CG and BL, CG and WH, BL and WH, and WH and PG. EL, EW, TL, and FL had mostly low and negative correlations with other traits and between them. The Kaiser-Meyer-Olkin (KMO) test yielded a measure of sampling adequacy (MSA) of 0.759 with a significant (P<0.01) Bartlett's test of sphericity. In the present study, communalities ranged from 0.214 (EL) to 0.824 (CG), indicating the proportion of variance explained by each variable. Principal Component Analysis extracted three components (PC1, PC2, and PC3) for Kashir goats, following varimax rotation. These components collectively explained 61.723% of the total variance. In conclusion, the results of the Principal Component Analysis revealed that a few key morphological traits, particularly chest girth, body length, and height at withers (WH), play a key role in defining the body conformation of Kashir goats. This provides a useful basis for breed characterization and selection strategies.

Key words: Analysis, Kashir Goat, morphometric traits, principal component

Due to the varied agro-climatic and geographical conditions, Jammu and Kashmir (J&K) possesses vast native farm animal genetic biodiversity (Rather *et al.*, 2020), including cattle, buffalo, sheep, goats, and horses (Rather *et al.*, 2021a; Alam *et al.*, 2023). Among these native farm animals' genetic biodiversity, the Kashir goat, a highly variable medium-sized goat genetic resource of Kashmir, India, is reared for its production potential and survivability (Rather *et al.*, 2021a). Characterization and description of this valuable germplasm (Kashir goat) will also preserve the cultural heritage, as goat rearing has been practiced in Kashmir since time immemorial (Rather *et al.*, 2021b). The morphological structure of an individual (animal) or population is described using body weight and other morphological traits, such as body length, chest girth, etc. (Bhuarya *et al.*, 2014; Kumar *et al.*, 2024). Morphological traits are also essential in describing genetic resources, diversity, and similarities among breeds (Kissling *et al.*, 2018). Various researchers have utilized morphometric measurements to assess the characteristics of various livestock populations (Mishra *et al.*, 2012; Sharma *et al.*, 2020; Singh *et al.*, 2021). Evaluating the variance in morphological features is the first step in characterizing farm genetic resources (Delgado *et al.*, 2001). Therefore, principal component analysis (PCA) is a multivariate ordination technique used to find a linear combination of data sets that defines the maximum variance (Johnson and Wichern, 2007) and transforms variables in a multivariate dataset into new, uncorrelated variables, which account for decreasing proportions of the total variance of the original variables. The main objective of the study was to analyze the morphological structure of the Kashir goat. It aimed to use biometric measurements to describe the physical traits of the breed. Principal Component Analysis (PCA) was applied to identify the key traits that define body conformation. The study also sought to understand how these traits contribute to breed characterization and differentiation.

MATERIALS AND METHODS

Study area: A study was undertaken in the Budgam district of the Kashmir valley to describe the Kashmir goat based on morphological traits. The area was intentionally selected owing to the good population of the Kashir goat. Budgam is located at 740 46' 48'' East Longitude and 340 1' 12'' North Latitude. It is bounded by the Baramula, Srinagar, Pulwama, and Poonch districts of Kashmir. The study involved 187 adult goats, comprising 150 females and 37 males. Age was assessed via dentition (one year and above selected), and body measurements were taken using a tape measure in a normal standing position.

The traits under study: The morphological data on 187 adult goats of both sexes were collected for the current study in the year 2019. The traits considered were face length (FL), ear length (EL), ear width (EW), body length (BL), chest girth (CG), paunch girth (PG), tail length (TL), height at wither (HW), and body weight (BW).

Statistical Analysis: Descriptive analysis was used to estimate the magnitude of averages. Pearson's correlation analysis was conducted to investigate the relationships between biometric traits, identifying phenotypic correlations and assessing data suitability for PCA, enabling the potential consolidation of highly correlated variables into independent factors. Additionally, the validity of the dataset was established through Bartlett's test of sphericity (Bartlett, 1950) and the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy, both conducted at a 1% significance level. The KMO test also assessed data suitability for PCA, with values ≥ 0.7 considered satisfactory, 0.5-0.69 acceptable, and <0.5 unacceptable. The study began with a dataset of 187 animals and nine traits, which was subjected to Bartlett's test to confirm factorability at a 1% significance level (Maxwell, 1959). Additionally, the Kaiser-Meyer-Olkin (KMO) test verified sample adequacy. The Kaiser criterion was applied to determine the number of factors, selecting those with eigenvalues > 1. Kaiser's MSA assessed model adequacy, with values < 0.5 considered unsuitable. Traits showing high correlations were further analyzed using multivariate principal component analysis. The percentage of cumulative variation, eigenvalues, factor patterns, eigenvectors, and variable loadings were calculated. The appropriateness of PCA was verified using SPSS version 24 (SPSS, 2021).

RESULTS AND DISCUSSION

The descriptive statistics for all the biometric traits of the Kashir goat, along with the coefficient of variation (CV), are reflected in Table 1. The coefficient of variation (CV%) for different morphometric traits ranges between 10.27 (chest girth) to 37.30 (body weight). All the biometric traits illustrated higher consistency except for ear length (EL), ear width (EW), and body weight (BW), which were comparatively more variable. The present findings were higher for BW, CG, and BH, whereas lower for PG than the Assam hill goat (Khargharia, 2015). The estimates of different biometric traits are comparable to different goat genetic resources of India (Rather *et al.*, 2021a; Alam *et al.*, 2023). The substantial variability in body weight (CV% = 37.30) underscores its importance as a selection parameter. This finding concurs with previous studies on goat populations (Khargharia, 2015).

Table 1: Descriptive statistics of morphological traits of Kashir goat (N = 187)

Trait	Mean±S.E. (cm)	Standard deviation (cm)	CV%
BW	35.63±1.01	13.29	37.30
FL	22.5±0.18	2.4	10.67
EL	13.32±0.35	4.62	34.68
EW	9.04±0.96	2.59	28.65
CG	56.1±0.44	5.76	10.27
PG	55.65±0.32	7.18	12.90
HW	66.13±0.65	8.52	12.88
BL	69.84±0.76	9.93	14.22
TL	13.06±0.15	1.95	14.93

Phenotypic Correlation: Table 2 displays the phenotypic correlation coefficients among various morphological traits in the population. The correlation analysis revealed that BW had a strong positive correlation with CG (0.80) and BL (0.62), whereas moderate correlations with WH and PG, indicating that taller, fatter, and longer animals had higher body weights. Similarly, positive and moderate to high (>0.25) correlations were observed between CG and BL, CG and -, BL and HW, and PG. EL, EW, TL, and FL had mostly low and negative correlations with other traits and between them.

Table 2. Phenotypic correlation among different biometric traits

Trait	CG	BL	HW	PG	EL	EW	TL	FL
BW	0.80**	0.62**	0.49**	0.30**	0.14	-0.08	0.25**	-0.26**
CG		0.59**	0.60**	0.04**	0.16*	-0.05	0.12	-0.25**
BL			0.42**	0.19*	0.13	0.00	0.14	-0.13
HW				0.28**	0.09	-0.08	-0.02	-0.17*
PG					0.12	0.13	0.23**	-0.31**
EL						0.09	0.13	-0.11
EW							-0.14	-0.08
TL								-0.21**

***Correlation is significant at the 0.01 level; *Correlation is significant at the 0.05 level*

The high and positive correlation of BW with BL agreed with the results of Khargaria *et al*. (2015), who reported a correlation coefficient of 0.86 between body weight and body length in the Assam Hill goat. Mokoena and Tyasi (2021) reported phenotypic associations ranging from 0.11 to 0.74 and 0.10 to 0.75 in female and male Boer goats. Valsalan *et al.* (2020) reported 78 phenotypic correlations in Indian Malabari goats, with values ranging from –0.019 to 0.681. The high correlation between BL and CG and the low correlation between BW and TL aligned with the findings of Sarma *et al.* (2024) in Udaipuri goats. The positive associations between BW and CG, BL, HW, PG, and TL were in agreement with findings of Okpeku et *al.* (2011) in indigenous goats of South Nigeria, Tyasi and Tada (2023) in Kalahari Red bucks.

Principal Component Analysis: Principal Component Analysis (PCA) was employed on nine biometric traits to investigate the variability of individual characteristics and their relative contributions to the overall morpho-structural variation in the Kashir goat. The Kaiser-Meyer-Olkin (KMO) test yielded a measure of sampling adequacy (MSA) of 0.759, which is far higher than the suggested MSA value of 0.50 by Kaiser (1958), thus confirming the reliability of the data for further analysis. The MSA value obtained in the present study was in agreement with the MSA estimate of 0.736 reported by Vohra *et al.* (2015).The KMO measure of sample adequacy ranged from moderate to strong across various studies, specifically: 0.60 (Khargharia *et al.*, 2015 for Assam Hill goats), 0.87 (Sarma *et al.*, 2024, for Udaipuri goats), 0.84-0.81 (Okpeku *et al.*, 2011, for West African Dwarf goats), 0.81-0.86 (Okpeku *et al.*, 2011, for Red Sokoto goats), 0.697 (Valsalan *et al.*, 2020, for Malabari goats), indicating moderate sampling adequacy, and strong sampling adequacy was indicated by a KMO measure of 0.87. Measures of sample adequacy of 0.932, 0.891, and 0.60 were reported by Pundir *et al.* (2011), Yunusa *et al.* (2013), and Khargharia *et al.* (2015) in Kankrej cow, Uda sheep, and Assam hill goat, respectively. Further, the varimax rotation (Fernandez, 2002) was applied to maximize the sum of variances of the squared loadings. The Bartlett's test of sphericity was used to test the overall significance of the correlation matrix, and a highly significant ($P<0.01$) chi-square value of 7614.486 was estimated (Table 3). Khargharia *et al.* (2015) reported a chi-square value of 169.10 ($P < 0.01$) for Assam Hill goats, Sarma *et al.* (2024) reported a chi-square value of 1031.17 ($P < 0.01$) for Udaipuri goats, Okpeku *et al.* (2011) reported chi-square values of 361.38 and 217.75 ($P < 0.01$) for female and male West African Dwarf goats and 105.78 and 436.65 ($P < 0.01$) for female and male Red Sokoto goats, Valsalan *et al.* (2020) reported a chi-square value of 4027.320 ($P < 0.01$) for Malabari goats.

Table 3: KMO and bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.759
Bartlett's Test of Sphericity	**Approx. Chi-Square**	7614.486
	DF	36
	Sig.	0.000

The varimax rotated factor loadings, eigenvalues, and variation explained by each factor and cumulative variation of these factors of the Kashir goat are reflected in Table 4. The communalities ranging from 0.214 for ear length to 0.824 for chest girth were obtained in the present study, indicating the corresponding variance shared by the variable. Three principal components (PC1, PC2, and PC3) were extracted for the Kashir goat, after varimax rotation of the component matrix. These three PCs accounted for 61.723 % of the total variance. The PC1, PC2, and PC3 accounted for 35.140, 14.086, and 12.497 with corresponding eigenvalues of 3.163, 1.268, and 1.125, respectively. Using the Kaiser rule criterion, three principal components were extracted out of nine components to determine the number of significant components (Johnson and Wichern, 1982). PC1 was represented by positive and significantly high loading for CG, BW, BL, HW, and PG; therefore, it appears to explain the maximum of body conformation and size in the Kashir goat. PC2 was represented by positive and significantly high loading for PG, TL, and EW, whereas PC3 was represented by positive and significantly high loading for EW only. The lower coefficients (<0.4) for EL in PC1, PC2, and PC3 indicated that the trait had very little contribution to total variance. Mavule *et al.* (2013) reported that the trait had little contribution to total variance in young sheep. PC1 assigned negative weight to EW and FL, whereas PC2 assigned negative weight to CG, BW, BL, -HW, and FL. Similarly, PC3 assigned a negative weight to only BW. Khargharia *et al.* (2015) found four PCs explaining 40.37%, 65.30%, 75.88%, and 85.84% of variation in Assam Hill goats, while Sarma *et al.*(2024) found two PCs explaining 66.01% of variation in Udaipuri goats. Mokoena and Tyasi (2021) identified two PCs explaining 57.75% and 20.56% of the variance in female Boer goats and one PC explaining 56.83% in males. Okpeku *et al.* (2011) extracted two factors accounting for 94.15% and 97.65% of variance in West African Dwarf goats and 79.89% and 86.38% in Red Sokoto goats. Valsalan *et al.* (2020) found four PCs explaining 67.77% of the variation in Malabari goats, and Tyasi and Tada (2023) identified two PCs explaining 87.31% and 62.32% of the variation in Kalahari Red male and female goats. Communalities ranged from 0.71 to 0.95 in Assam Hill goats, 0.51 to 0.77 in Udaipuri goats, 0.72 to 0.85 in female Boer goats, and 0.19 to 0.84 in male Boer goats. In West African Dwarf goats, communalities ranged from 0.91 to 0.99, and in Red Sokoto goats, from 0.86 to 0.99. Malabari goats had communalities ranging from 0.562 to 0.848, while Kalahari Red goats ranged from 0.30 to 0.94 in males and 0.30 to 0.81 in females. The unexplained variation may be due to the random combination of different alleles at causal loci, errors in measurements and data recording, and environmental effects (Brooks *et al.*, 2010).

Table 4. Varimax rotated factor loadings, eigenvalues, and share of total variance, and loading and communalities of the morphometric traits of the Kashir goat

Trait	Component			Communalities
	PC1	PC2	PC3	
BW	0.870	-0.155	-0.062	0.784
CG	0.883	-0.194	0.085	0.824
BL	0.733	-0.240	0.080	0.601
WH	0.694	-0.301	0.170	0.602
PG	0.521	0.481	0.069	0.508
EL	0.263	0.364	0.112	0.214
EW	-0.044	0.441	0.770	0.789
TL	0.304	0.450	-.682	0.759
FL	-0.416	-0.546	0.055	0.474
Eigenvalue	3.163	1.268	1.125	
Percentage of total variance	35.140	14.086	12.497	
Cumulative variance	35.140	49.226	61.723	

CONCLUSION

It is concluded that the Kashir goat is a medium-sized goat genetic resource for the country. Furthermore, body weight, chest girth, body length, body height and paunch girth are essential biometric traits that explain the morphological structure of the Kashir goat. Also, these traits accounted for most of the variance in the first three principal components (PCs). Therefore, the extracted principal components from different linear body measurements represent the general body size and shape of the goat population.

CONFLIT OF INTEREST

All the authors affirm that there is no conflict of interest among them. All research activities comply with relevant legal, institutional and ethical standards.

AUTHOR CONTRIBUTION

All the authors contributed equally in the present study.

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