Principal Component Analysis of Morphological Traits in Udaipuri Goats in Uttarakhand

ABSTRACT

Aims: To study the principal component analysis (PCA) of morphometric traits in Udaipuri goats
Place and Duration of Study: Pauri, Garhwal, Uttarakhand, India Between March, 2021 and March, 2022

Methodology: Eight traits were measured in 407 adult females and males goats over a period of 2021-2022. The traits considered in the study were Horn Length (HL), Face length (FL), Ear Length (EL), Height at Withers (HW), Body Length (BL), Chest Girth (CG), Tail Length (TL) and Body Weight (BW). The data were analyzed for the estimation of mean, phenotypic correlation and PCA by using the software SPSS version 24

Results: The descriptive statistics including the mean and coefficient of variation (CV %) were estimated which revealed the lowest average and the highest average for horn length and chest girth, respectively. The horn length and ear length showed the highest and lowest CV %, respectively, and the phenotypic correlations were significant ($P<0.01$) for all the characters included in the study. Principal component analysis (PCA) with varimax rotation method was applied and extracted a total variation of 66.01%. In all adult males and females, HL, HW, BL and CG were loaded as first component while FH, EL, TL and BW were loaded as second component.

Conclusion: Therefore, these findings indicated that PCA could serve as a valuable tool in breeding programmes, allowing for a significant reduction in the number of traits while still effectively capturing morphometric trends in Udaipuri goats.

Keywords: *Morphological traits, PCA, Udaipuri goat, Variation*

1. Introduction

Genetic diversity among living organisms is fundamental to their ability to survive over a wide range of environments. Assessing the morphological conformation of livestock is likely to be the conventional method of gathering information, playing a vital role in many breeding associations and achieving significant success over the years [7]. Although the morphological description of farm animals is largely influenced by environmental factors, this influence can be minimized through good sampling techniques and the use of an adequate sample size [19]. Body weight and body measurements are important parameters for describing growth. Beyond weight, body measurements can comprehensively characterize an individual or a population [14]. The first step in characterizing local genetic resources is to evaluate the variation in morphological traits [4]. Linear body measurements can aid selection for growth by allowing breeders to identify early-maturing and late-maturing animals of various sizes [2; 3]. Correlation and analysis of variance are used to determine relationships among different body measurements. PCA can more effectively explain these relationships when the recorded traits are correlated [13].

The native tract of Udaipuri goat lies in Ajmeri patties spread from Dugadda to Yamkeshwar in Pauri districts of Uttarakhand state. These patties (strips) are named after the settlers who migrated to these areas in the past from Udaipur and Ajmer (Rajasthan) districts of Rajasthan. Thus, the name Udaipuri of these goats has its genesis from Udaipuri Patti where it actually originated and is reared in large numbers by the inhabitants of the area. The breed is distributed from Dugadda to Devrana area of Rathwadhas ranges (Dugadda to Kandi ridge) of Pauri Garhwal district situated between 29^0 48' to 30^0 15' latitude and 78^0 24' to 79^0 23' longitude. Entire area is hilly with an elevation of approximately 1000 to 1500 M above mean sea level. The breeding tract of the Udaipuri goats lies in western part of Pauri Garhwal of Uttarakhand state where the climate is generally semi-temperate to temperate throughout the year.

PCA is a technique used to reduce the number of variables in a dataset while retaining most of the important information. It identifies a new set of uncorrelated variables, called principal components that capture the maximum variance in the data. PCA deals in transforming a high-dimensional dataset into a lower-dimensional one by removing the irrelevant information and focusing on the directions of greatest variation. The amount of variance each principal component explains is quantified and usually represented in a scree plot. Typically, a smaller number of principal components can explain most of the variance, allowing for effective dimensionality reduction. PCA also involves in calculating the eigen values and eigen vectors of the covariance matrix of the data. Eigen values represent the variance explained by each principal component, while eigen vectors define the direction of each principal component in the data set. Hence, PCA is a powerful tool for simplifying complex datasets, enhancing interpretability and uncovering hidden patterns in the data, making it invaluable in various scientific and analytical applications.

Therefore, the present investigation was undertaken to study the means, coefficient of variation and correlation among different body measurements and to develop latent factors to define which of these measures best represent body conformation in Udaipuri goats.

2. MATERIAL AND METHODS

2.1 Description of Data

The present study was conducted on Udaipuri goat, a lesser known goat breed reared for meat production, by the goat keepers of Pauri district of Uttarakhand state. The morphometric traits on 407 adult goats were measured from the goat keepers' herds during 2021-2022.The measurements included in the study were Horn Length (HL), Face length (FL), Ear Length (EL), Height at Withers (HW), Body Length (BL), Chest Girth (CG), Tail Length (TL) and Body Weight (BW).

2.2 Statistical Analysis

Means, standard errors and coefficients of variation of the morphological traits were estimated by using SPSS version 24. The phenotypic correlations (r) were calculated by using Pearson correlation [15] to determine the degree of association among the morphological measurements. The Kaiser Meyer-Olkin (KMO) test was used to examine the adequacy of the data and further to verify the accuracy of the factor analysis of the data sets, Bartlett's Test of Sphericity was used. The dataset with 407 animals and eight traits was initially tested using Bartlett's test [1] to see if factorization could be applied, as suggested by Maxwell [11]. The validity of the data set was verified at a significance level of 1% using the Kaiser-Meyer-Olkin (KMO) test for sample adequacy. The number of factors was determined using the Kaiser rule criterion [8], which retained only factors with eigen values greater than 1. The suitability of the common factor model was evaluated using Kaiser's measure of sampling adequacy (MSA), where a value of less than 0.5 was considered undesirable. Traits showing high correlation were then subjected to multivariate principal component analysis. The percentage of the overall variation and the eigen values were calculated. Moreover, factor patterns, eigen vectors along with the loading of variables were estimated. The appropriateness of PCA was carried out by using SPSS version 24. Principal component analysis is a method that transforms variables in a multivariate dataset (X1, X2,..., Xn) into a set of uncorrelated variables (Y1, Y2,..., Yn). These new variables account for a lesser proportion of the overall variance found in the initial variables [5], which were specified as:

$Y_1 = a_{11}X_1+a_{12}X_2+\ldots+ a_{1n}X_n.$

$Y_2 = a_{21}X_1+a_{22}X_2+\ldots+ a_{2n}X_n.$

$Y_n = an_1X_1+an_2X_2+\ldots+ a_nX_n$

The principal components $Y_1, Y_2, ..., Y_n$ represents reduced fractions of the overall variance observed in the original variables $X_1, X_2, ..., X_n$. The factor pattern matrix was linearly transformed using an orthogonal rotation that maximized variance and this is done in order to enable a clear and transparent interpretation of the extracted principal components.

3. RESULT AND DISCUSSION

3.1 Mean and Coefficient of Variation

The morphological traits of the sampled population (n=407) were analyzed, and the descriptive statistics for each trait have been presented in Table 1. Each trait was evaluated for mean, standard error (SE), coefficient of variation (CV) and communality. The findings reveal important insights into the variability and relationships among these traits.

Table 1: Mean, standard error (SE), coefficient of variation (CV) and communality of different morphological traits (n=407)

S.No.	Trait	Mean±S.E.	CV %	Communality
1	Horn Length	10.32±0.23	45.63	0.705
2	Face Length	14.07±0.11	16.84	0.656
3	Ear Length	13.76±0.09	13.73	0.518
4	Height at Withers	54.75±0.43	15.89	0.770
5	Body Length	55.35±0.47	17.45	0.768
6	Chest Girth	64.29±0.55	17.43	0.728
7	Tail Length	11.40±0.09	16.49	0.551
8	Body Weight	18.21±0.33	37.12	0.585

The mean values and their associated standard errors provide a measure of the central tendency and the precision of the estimates for each trait. As per the findings, the lowest average is 10.32 with standard error of 0.32 and the highest average reported as 64.29 with standard error of 0.55 for horn length and chest girth, respectively. Therefore, these precise estimates indicated reliable measurements across the sample population. Moreover, the coefficient of variation (CV) is a standardized measure of dispersion of the trait values, providing insights into the relative variability. Horn length exhibited the highest CV at 45.63%, indicating substantial variability within the population. Body weight also showed considerable variation with a CV of 37.12%. In contrast, ear length had the lowest CV at 13.73%, suggesting it is the most consistent trait among the individuals studied. Other traits such as face length, height at withers, body length, chest girth, and tail length displayed moderate variability. The high CV observed for horn length and body weight suggested that these traits were highly variable within the population, which could be attributed to genetic diversity, environmental influences, or both. The low CV for ear length implied that this trait was relatively stable, potentially indicating strong genetic control or uniform environmental conditions affecting this trait.

[9] reported the lowest and highest averages for cannon bone length and paunch girth along with the lowest and highest CV of 4.37% (body length) and 14.99% (body weight), respectively. [12] performed a study and reported mean coefficient of variation in female and male Boer goats. The summary indicated that males had higher averages for all traits compared to females, except for sternum height. In females, the traits body weight, heart girth, and body length exhibited high variation, with coefficients of variation ranging from 11 to 34. In males, the variation ranged from 7 to 41, with body weight, heart girth and body length contributing most to this variation. [18] reported mean and CV in Malabari goats of India which explained the coefficient of variation for the different morphometric traits varied from 3.42% for chest girth at 9 months to 11.91% for body weight at the same age and described the lowest and highest averages for body weight and chest girth at 6 months, respectively. In a similar study on mean and CV estimation, [17] reported that in male Kalahari red goats, the mean for cannon circumference and heart girth was lowest and the mean for body condition scores and ear length was highest. In female Kalahari red goats,

the mean for heart girth and body condition scores was lowest and the mean for wither height and body condition scores was highest.

Communality values indicate the proportion of variance in each trait that can be explained by common factors. Height at withers (0.770) and body length (0.768) showed the highest communalities, suggesting that these traits are strongly influenced by common underlying factors. Chest girth (0.728) and horn length (0.705) also had high communality values. Traits with lower communalities included ear length (0.518) and tail length (0.551), indicating that a significant portion of the variance in these traits is due to unique or specific factors rather than common influences. The communality values highlight the extent to which certain traits are related to common factors. The high communality of height at withers and body length suggests that these dimensions might be influenced by similar genetic or environmental factors, which could be important for selection in breeding programmes. Conversely, the lower communalities for ear length and tail length suggested that these traits might be more independently controlled.

3.2 Phenotypic Correlation

The Table 2 presents the phenotypic correlation coefficients among different morphological traits in the population. Pearson's correlation analysis was conducted to evaluate the relationships among morphological traits and all the correlation coefficients were found to be significant. The correlation coefficient ranged from 0.575 to 0.902. Body length had a higher correlation with chest girth (0.902). Low correlation coefficient was observed between body weight and tail length (0.588). Moreover, body weight with ear length was poorly correlated.

[9] reported the highest correlation coefficient was observed between body weight and body length (0.86), while the lowest was between rump width and paunch girth (-0.32). Another study conducted by [12] in female and male Boer goats reported that, in females, the associations among traits ranged from 0.11 to 0.74, with withers height and rump height showing a highly significant positive correlation. In males, the correlations ranged from 0.10 to 0.75, with body weight and body length being highly significantly positively correlated. [18] reported phenotypic correlation in Indian Malabari goats. The estimated correlation coefficients among various morphometric traits ranged from -0.019 (between body height at 12 months and body length at 9 months) to 0.681 (between body height at 9 months and body height at 12 months). A total of 78 correlations (across all combinations) were calculated, with 59 of these showing significant correlations. All significant correlations were positive. The negative correlation between body height at 12 months and body length at 9 months was found to be non-significant. [17] Reported a high positive correlation was found for body weight with all other morphometric traits, with the exception of sternum height, which showed a negative correlation with body weight in Kalahari red bucks. Body weight in Kalahari red does exhibited a positive and strong correlation with heart girth, canon circumference, rump height, body length, rump width, head width, rump length, body condition scores and wither height, as well as a positive correlation with sternum height, ear length and head length.

Table 2. Phenotypic correlation coefficients among different morphological traits

Traits	**HL**	**FL**	**EL**	**HW**	**BL**	**CG**	**TL**	**BW**
HL	1	0.829**	0.623**	0.799**	0.808**	0.845**	0.650**	0.681**
FL	0.829**	1	0.731	0.779**	0.805**	0.854**	0.722**	0.691**
EL	0.623**	0.731**	1	0.666**	0.708**	0.748**	0.620**	0.575**
HW	0.799**	0.779**	0.666	1	0.893**	0.865**	0.612**	0.676**
BL	0.808**	0.805**	0.708**	0.893**	1	0.902**	0.633**	0.695**
CG	0.845**	0.854**	0.748**	0.865**	0.902**	1	0.658**	0.736**
TL	0.650**	0.722**	0.620**	0.612**	0.633**	0.658**	1	0.588**
BW	0.681**	0.691**	0.575**	0.676**	0.695**	0.736**	0.588**	1

*** Correlation is significant at 0.01 level*

3.3 Principal Component Analysis

The Table 3 presents the results of the Kaiser-Meyer-Olkin (KMO), Measure of Sampling Adequacy and Bartlett's Test of Sphericity. These tests assess the suitability of the data for factor analysis. The present study reported KMO value as 0.873. A measure of sampling adequacy below 0.5 is considered to be inadequate [9]. A value above 0.8 is considered very good, indicating that the sample is adequate and the correlations between pairs of variables can be explained by other variables. Bartlett's test yielded an approximate chi-square value of 1031.176 with 28 degrees of freedom and a significance level of 0.000. Bartlett’s test [1] checks whether the correlation matrix is an identity matrix, which would indicate that the variables are unrelated and unsuitable for structure detection. A significance level of 0.000 indicates that the correlation matrix is not an identity matrix, suggesting that the variables have significant correlations and are suitable for factor analysis. Together, these tests indicate that the dataset is well-suited for factor analysis, allowing for the identification of underlying factors that explain the correlations among the morphological traits.

Table 3. KMO and Bartlett’s Test

Kaiser-Meyer-Olkin	Measure of Sampling Adequacy	0.873
	Approx. Chi-Square	1031.176
Bartlett’s Test of Sphericity	Df	28
	Sig.	.000

The varimax rotation method was utilized to maximize the sum of squared loadings [6]. The sum of squared loadings was derived from a Principal Component Analysis (PCA), revealing the variation explained by each component, as shown in Table 4, with eigenvalues presented in Figure 1. According to the Kaiser Rule Criterion [8], two out of the eight components were selected to determine the significant number of components. These two principal components (PC1 and PC2) together accounted for a cumulative variance of 66.018%, each having eigen values greater than 1. The variance for each trait was explained according to PCA [10].

Table 4: Total Variance Explained

Component	Initial Eigen Values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% Variance	Cummulative %	Total	% Variance	Cummulative %	Total	% Variance	Cummulative %
1	4.176	52.201	52.201	4.176	52.201	52.201	2.838	35.478	35.478
2	1.105	13.816	66.018	1.105	13.816	66.018	2.443	30.540	66.018
3	0.702	8.781	74.799						
4	0.610	7.624	82.423						
5	0.471	5.892	88.314						
6	0.340	4.244	92.558						
7	0.331	4.138	96.697						
8	0.264	3.303	100.000						

In the present study, the first principal component (PC1) explained for 35.47% of the total variance (Table 4). First principal component (PC1) described the high component loading for HL, HW, BL and CG. Similarly, the second principal component (PC2) explained for 30.54% of total variance which described the high component loading for FH, EL, TL and BW. Table 5 and Table 6 represent the component matrix and rotated component matrix of of principal component analysis of various morphometric traits. The different weights were assigned by PC1 and PC2 showing different component loadings in Udaipuri goats.

The findings of [9] described PCA in morphological traits in Assam Hill goat explaining the variation for four principal components as 40.37%, 65.30%, 75.88% 85.84%, respectively, by applying the varimax rotated method. The KMO measure of sample adequacy was 0.60 and the Bartlett’s test for sphericity yielded a Chi-square value of 169.10, with a significance level of P<0.01.The communality ranging from 0.71 to 0.95, encompassing chest depth and paunch girth. [12] conducted a study on PCA in morphological traits of Boer goats. The PCA of morphological traits in female goats identified two principal components with eigen values of 3.46 and 1.23, explaining 57.75% and 20.56% of the variance for PC1 and PC2, respectively. In male goats, PC1 had an eigen value of 3.41, accounting for 56.83% of the variation. The communality for the females ranged from 0.85 (Height at Wither) to 0.72 (Heart Girth) and for the males the common variance is ranging from 0.19 (Sternum Height) to 0.84 (Body Weight). Similar study conducted by [18] in Malabari goats of India, extracted four principal components with total variation of 67.77% by applying varimax rotation method. PCA was applied to twelve traits, yielding KMO measure of sampling adequacy of 0.697. The significance of the correlation matrix for all traits was confirmed with Bartlett's test of sphericity, which produced a chi-squared value of 4027.320 (p < 0.01), indicating statistical significance. The communality ranging from 0.562 (Body length at 12 months) to 0.848 (Height at Wither at 9 months' age). [17] carried out PCA in Kalahari red male and female goats with varimax rotation and further extracted two components in both buck and does with a variation of 87.31% and 62.32%, respectively. The communality in males and females ranges from 0.94 (body weight) to 0.72 (rump height) and from 0.81 (body weight) to 0.30 (head length), respectively.

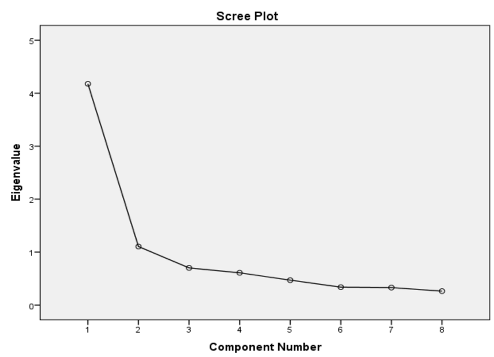

Fig. 1 Scree Plot

Table 5: Component matrix of different factors for morphological traits

Traits	Component 1	Component 2
HL	0.832	-0.113
FH	0.784	0.202
EL	0.552	0.462
HW	0.683	-0.552
BL	0.781	-0.399
CG	0.836	-0.170
TL	0.575	0.469
BW	0.677	0.355

Table 6: Rotated Component Matrix of different factors for morphological traits

Traits	Component 1	Component 2
HL	0.699	0.464
FH	0.456	0.670
EL	0.109	0.711
HW	0.877	0.036
BL	0.850	0.216
CG	0.740	0.425
TL	0.122	0.732
BW	0.274	0.714

4. CONCLUSION

The PCA of morphological traits in Udaipuri goats from Uttarakhand revealed significant insights into the breed's phenotypic diversity. The study identifies key traits that contribute most to variation within the population, providing a comprehensive understanding of the morphological structure of Udaipuri goats. The PCA results highlight the primary components that should be considered in breeding and conservation programsme, ensuring the maintenance of genetic diversity and the enhancement of desirable traits. These findings not only contribute to the existing body of knowledge on Udaipuri goats but also offer practical implications for goat farmers and breeders in optimizing the management and selection strategies for this indigenous breed.

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