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# Body indices and principal component analysis of morphometric and wool quality traits of Gurez sheep

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ABSTRACT

Gurez sheep, a dual-purpose breed valued for its meat and fiber, is primarily reared by Dardi tribe of Gurez in Bandipora district, Jammu and Kashmir. To evaluate the breed biometric, body indices, and wool quality traits data of 236 adult sheep were collected and analyzed. The averages values of 35.81±0.24 kg, 73.55±1.28 cm, 61.88±1.18 cm, 74.92±1.69 cm, 10.97±0.43 cm, 60.49±1.01 cm, 18.68±0.78 cm, 77.02±0.32 cm, 29.57±0.71 μ, 4.44±0.47 cm, 11.78±0.6, 14.34±0.86 %,85.36±1.58, 102.64±1.16, 3788.88±9.76, 122.71±1.75, 47.47±1.29, 91.78±1.71 and 98.68±1.14 were calculated for body weight (BW), chest girth (CG), body length (BL), paunch girth (PG), height at withers (HW), ear length (EL), tail length (TL), clean wool yield (CWY), fiber diameter (FD), staple length (SL), number of crimps/ cm (NCPC), medullation % (MP), body index (BI), length index (LI), area index (AI), thoracic development index (TDI), Compact index (CI), conformation index (COMI) and height index, respectively. Phenotypic correlation though positive ranged from moderate to high among BW, CG, PG, and WH, whereas EL, TL, and wool quality traits had no to low correlation among themselves or with BW, CG, PG, and WH. Further, 10 negative and 11 positive correlations were observed among body indices. The principal component analysis applied to 12 traits yielded a Measure of Sampling Adequacy (MSA) of 0.710 and five principal components accounting for a cumulative variance of 70.495%. The study underscores its importance as a selection criterion for improving the productivity and efficiency of the sheep breeding program.

**Keywords:** Gurez, Morphometry, PCA, Sheep

India boasts an impressive genetic diversity of major farm animal species, particularly small ruminants, crucial for sustaining rural economies in hilly and mountainous regions (Khan *et al.* 2022). Among these, the Gurez sheep, a registered breed, exhibits remarkable adaptability to local agro-climatic conditions, showcasing variability in morphology, production, and reproduction traits (Rather *et al.* 2021). Effective conservation and breeding programs rely on accurate morphological evaluation of livestock, a cornerstone of animal breeding (Janssens and Vandepitte, 2004). Morphological indices, calculated from multiple linear and morphometric measurements, provide a percentage-based representation of a breed's characteristics and functionality (Maciejowski and Zieba, 1982). These indices offer a more accurate assessment of animal conformation compared to individual measurements alone (Salako, 2006). Principal Component Analysis (PCA) is a powerful statistical tool for assessing body shape and understanding complex growth processes (Salako, 2006).

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PCA transforms data to identify key components capturing significant variation, reducing dimensionality, and revealing underlying patterns (Manly, 1994). Previous studies have successfully applied PCA to sheep (Mavule *et al.* 2013) and goats (Okpeku *et al.* 2011), demonstrating its potential for predicting body weight. This study applied PCA to phenotypic data of biometric and wool quality traits of Gurez sheep, generating uncorrelated indices for selection approach, diversity identification, and conservation efforts. An aim of this study was to identify the major sources of variation in morphometric and wool-quality traits of Gurez sheep using Principal Component Analysis. Another aim was to derive body indices, interpret the biological meaning of the principal components, and relate them to production traits for potential use in breeding, selection, and conservation programmes.

## MATERIALS AND METHODS

To characterize the breed's morphometric data were collected from 236 adult sheep in 2019. The study recorded twelve key traits, including Body Weight (BW), Ear Length (EL), Body Length (BL), Height at Withers (HW), Chest Girth (CG), Paunch Girth (PG), Tail Length (TL), Number of Horns (HN), Clean Wool Yield (CWY), Fiber Diameter (FD), Staple Length (SL), Number of crimps/ cm (NCPC), (CP), and Medullation % (MP). These measurements aimed to provide a comprehensive understanding of the Gurez sheep's morphological characteristics. Further, seven body indices reflected in Table 1 were computed from biometric traits and analyzed to understand the morphology of this sheep genetic resource of the country.

*Statistical Analysis:* The descriptive statistics were computed by Snedecor and Cochran (1994) method by IBM SPSS Statistics software (IBM, 2016). To examine the relationships among different traits, phenotypic correlations were estimated using Pearson's correlation coefficient. The suitability of the dataset for factor analysis was verified through the Kaiser-Meyer-Olkin (KMO) test and Bartlett's Test of Sphericity. Initially, Bartlett's test confirmed the dataset's suitability for factorization, comprising 236 animals and 12 traits, at a 1% significance level. The KMO test further validated the sample adequacy, yielding a Measure of Sampling Adequacy (MSA) value greater than 0.5, indicating satisfactory data quality. Following this criterion, highly correlated traits were subjected to multivariate principal component analysis (PCA).

## RESULTS AND DISCUSSION

The averages for body weight (BW), ear length (EL), body length (BL), height at withers (HW), chest girth (CG), paunch girth (PG), tail length (TL), clean wool yield (CWY), fiber diameter (FD), staple length (SL), number of crimps/cm (CP) and Medullation percentage (MP), body index (BI), length index (LI), area index (AI), thoracic development index (TDI), compact index (CI), conformation index (COMI) and proportionality (PR) are reflected in Table 2. The CV% % ranged from 11.87 for BW to 19.51 % for PG.

*Biometric traits:* The descriptive statistics of biometric traits, wool quality traits, and body indices considered for the study, along with respective standard deviations and coefficient of variation (CV%), are reflected in Table 2. The averages of body biometry revealed that the Gurez sheep is a medium-sized sheep among Indian breeds. Higher estimates for body biometry have been reported in Kajli sheep, Madgyal sheep, and Kashmir Merino sheep (except EL) by Yadav *et al.* (2011), Mishra *et al.* (2017), Kumar *et al*. (2016), and Rather *et al.* (2021), respectively. The biometric traits of Gurez sheep presented consistency about variability, with lower and upper limits of 8.77 for BW to 19.51 % for PG. The biometric traits analyzed exhibited minimal variability, suggesting that Gurez sheep possess relatively uniform shape and size characteristics in their natural environment. These findings suggest that Gurez sheep possess a uniform morphological profile, indicative of adaptive convergence in their native habitat. Only adult sheep above 1.5 years age of both genders were include in study and data was corrected for significant effects of sex prior to PCA.

Table 1. Procedures used to compute body indices from the morphometric data

| S. No | Variable | The formula used to calculate the index |
|---|---|---|
| 1 | Body index (BI) | Body length / Heart girth * 100 |
| 2 | Length index (LI) | Body length / Wither height * 100 |
| 3 | Area index (AI) | Wither height * Body length*100 |
| 4 | Thoracic development index (TDI) | Heart girth / Wither height*100 |
| 5 | Compact index (CI) | Weight / Wither height * 100 |
| 6 | Conformation index (COMI) | (Heart girth)2 / With height |
| 7 | Height index | Wither height / Body length * 100 |

*Wool quality traits*: The averages for wool quality traits of Gurez sheep aligned with the findings of Ahanger *et al.* (2020) and Rather *et al.* (2021) in Gurez sheep and Taggar *et al.* (2018) in Poonchi sheep concerning CWY, crimps, and Medulation (%). Similar estimates for FD were observed by Nehra *et al.* (2005) and Mehta *et al.* (2004) in Marwari sheep and Magra sheep breeds, respectively. However, higher estimates for FD were reported by Dass and Singh (2001) in Marwari sheep whereas lower estimates were reported by Sarkar *et al.* (2008) in Corriedale sheep, Poll Dorset sheep, South Down sheep, Crossbred sheep, Das *et al.* (2014) and Rather *et al.* (2019 a;2020) in Kashmir Merino and Rather *et al.* (2019b) in Kashmir Merino x NARI Swarna Merino sheep. Dass

Table 2. Means ± standard errors, standard deviations, and coefficients of variation (%) of morphometric, wool-quality traits, and body indices of Gurez sheep

| Trait type | Trait | Mean±SE | Std. Deviation | CV% |
|---|---|---|---|---|
| Biometric trait | BW (kg) | 35.81±0.24 | 3.42 | 8.77 |
| | CG (cm) | 73.55±1.28 | 11 | 14.96 |
| | BL (cm) | 61.88±1.18 | 9.31 | 15.05 |
| | PG (cm) | 74.92±1.69 | 14.62 | 19.51 |
| | WH (cm) | 60.49±1.01 | 7.86 | 12.99 |
| | EL (cm) | 10.97±0.43 | 1.43 | 13.04 |
| | TL (cm) | 18.68±0.78 | 3.35 | 17.93 |
| Wool quality trait | CWY (%) | 77.02±0.32 | 2.84 | 3.69 |
| | FD (μ) | 29.57±0.71 | 3.86 | 13.05 |
| | SL (cm) | 4.44±0.47 | 0.98 | 22.07 |
| | NCPC | 11.78±0.65 | 2.24 | 19.02 |
| | Medulation (%) | 14.34±0.86 | 3.25 | 22.66 |
| Body indices | BI | 85.36±1.58 | 14.6 | 17.10 |
| | LI | 102.64±1.16 | 11.73 | 11.43 |
| | AI | 3788.88±9.76 | 600.56 | 15.85 |
| | TDI | 122.71±1.75 | 19.34 | 15.76 |
| | CI | 47.47±1.29 | 8.91 | 18.77 |
| | COMI | 91.78±1.71 | 16.35 | 17.81 |
| | PR | 98.68±1.14 | 11.28 | 11.43 |

and Singh (2001) in Marwari and Sarkar *et al.* (2008) reported similar averages for SL in Corriedale sheep. The wool quality traits exhibited varying degrees of variability, with Clean Wool Yield showing uniformity due to its low CV, indicating consistent wool yield across samples. In contrast, Fiber Diameter displayed moderate variation, making it suitable for breeding programs targeting specific fiber diameter ranges. On the other hand, Staple Length and Medulation exhibit substantial variation, as reflected in their high CV values, which indicate diverse staple lengths and medullation percentages, offering potential for selective breeding. Furthermore, Crimp Frequency (NCPC) also showed significant variation, with its high CV value suggesting diversity in crimp frequency that influences wool's texture and quality.

*Body indices:* The body indices exhibited moderate variability, with coefficient of variation (CV%) values ranging from 11.43% for LI and PR, indicating relatively high consistency, to 18.77% for CI, suggesting somewhat higher variation. Contrary to the results of the present study, lower estimates for different body indices were reported by Banerjee (2017) in Garrol sheep. Tyasi and Tada (2023) reported BI, LI, AI, TDI, CI, COMI and HI of 89.92 ± 1.15, 118.48 ± 1.18, 6518.00 ± 259.08, 132.29 ± 2.07, 81.71 ± 2.57, 129.24 ± 3.58, 96.71 ± 1.25 and 84.62 ± 0.82 in South African Kalahari Red goats with CV % ranging from 5.08 (PR) to 20.68 (AI). The average Body Index (BI) of Gurez sheep, were estimated at 85.36 ± 1.58, indicating a breviline conformation characterized by a relatively short, compact, and deep body structure. This suggests that Gurez sheep are robust and compact, with a body type well-suited for efficient grazing and potentially superior meat production with well well-developed internal respiratory system, as indicated by COMI of 91.78±1.71. According to the BI classification system, sheep body types are categorized as follows: longiline (BI ≤ 0.90), mediline (BI = 0.88-0.86), and breviline (BI ≈ 0.85). The average BI of 85.36 for Gurez sheep confirmed their breviline conformation, highlighting their desirable physical attributes (Banerjee, 2017).

Phenotypic correlation analysis (Table 3) revealed significant ($P < 0.01$) positive correlations ranging from moderate to high among BW, CG, PG, and WH, whereas EL, TL, and wool quality traits had no to low correlation among themselves and with BW, CG, PG, and WH. The strong positive correlations of BW with CG, BL, PG, and WH indicated that taller, fatter, and longer animals yielded higher body weights. The improvement in BW through selection can potentially enhance other traits, given that genetic correlations align with phenotypic correlations, triggering correlated genetic gains. The positive correlation of BW with biometric traits is aligned with Yadav *et al.* (2016) and Mishra *et al.* (2017) in Madgyal sheep and Kajli sheep. Yadav *et al.* (2016) and Mishra *et al.* (2017) in Madgyal sheep and Kajli sheep also observed positive correlations among CG, BL, PG, and WH. Highly significant ($P < 0.01$) and strong correlations between BW and CG were also reported by Salako (2006), Kunene *et al.* ( 2009), Yakubu and Ayoade (2009), and Yunusa *et al.* (2013) in different sheep genetic resources. The no to low correlation of TL, EL and wool quality traits (except between FD and CWY) among themselves and with BW, CG, PG and WH indicated that selection for improvement of growth performance will have little or no effect on these traits and selection for wool quality will not affect growth performance in Gurez sheep. The very low phenotypic correlation between FD and SL in the present study aligned with the findings of Rather *et al.* (2020) in Kashmir Merino sheep. Dixit *et al.* (2009) in in 3/4 x bred Bharat Merino, Khan et al. (2015) in Rambouillet, Mahajan *et al.* (2018) in Rambouillet and (Lalit *et al.* 2017) in Harnali sheep reported a phenotypic correlation coefficient of 0.20±0.03 (low), -0.03±0.02 (very low), -0.05 (very low) and 0.30±0.03, respectively between FD and SL. Low phenotypic correlations between NCPC and SL, NCPC and CWY, NCPC and FD, and very high phenotypic correlation between FD and CWY were also observed by Tagger *et al.* (2018) in Poonchi sheep. Positive correlations between CWY and FD were also observed by Khan *et al.* (2015) in Purky sheep.

Out of 21 correlations observed among body indices

Table 3. Phenotypic correlations among biometric traits of Gurez sheep

| | CG | BL | PG | WH | EL | TL | CWY | FD | SL | CRIMPS | Medulation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BW | 0.63** | 0.46** | 0.44** | 0.37** | 0.06 | 0.26** | -0.04 | -0.05 | 0.03 | -0.06 | -0.17** |
| CG | | 0.34** | 0.54** | 0.28** | -0.01 | 0.21** | -0.04 | -0.07 | 0.03 | 0.03 | -0.12** |
| BL | | | 0.46** | 0.63** | 0.02 | 0.09 | -0.07 | -0.03 | -0.05 | -0.08 | -0.21** |
| PG | | | | .44** | -0.03 | 0.11 | -0.01 | -0.07 | -0.01 | -0.09 | -0.13 |
| WH | | | | | 0.01 | -0.04 | -0.02 | 0.01 | 0.01 | -0.09 | -0.14* |
| EL | | | | | | 0.14* | -0.07 | -0.01 | 0.03 | 0.07 | 0.13* |
| TL | | | | | | | -0.07 | -0.08 | 0.03 | -0.02 | -0.11 |
| CWY | | | | | | | | 0.78** | -0.10 | -0.08** | 0.11 |
| FD | | | | | | | | | -0.13* | -0.21** | 0.17* |
| SL | | | | | | | | | | -0.11 | -0.04 |
| NCPC | | | | | | | | | | | -0.08 |

Table 4. Phenotypic correlations among body indices of Gurez sheep

| Trait | LI | AI | TDI | CI | COMI | PR |
|---|---|---|---|---|---|---|
| BI | 0.39** | 0.54** | -0.75** | -0.27** | -0.70** | -0.34** |
| LI | | 0.23** | 0.29** | 0.28** | 0.23** | -0.98** |
| AI | | | -0.34** | 0.19** | -0.03 | -0.17** |
| TDI | | | | 0.48** | 0.93** | -0.34** |
| CI | | | | | 0.56** | -0.27** |
| COMI | | | | | | -0.24** |

of Gurez sheep (Table 4), 10 were positive and 11 were negative. PR was observed to have a negative correlation with all traits. Similarly, BI had a negative association with other traits except LI and AI and AI had a negative association with TDI and COMI. The study suggested that a selective improvement program based on body indices through a restricted selection index can effectively enhance the Gurez sheep breed. Except for the correlations between PR and LI, and PR and AI, our findings align with the results reported by Tyasi and Tada (2023) in their study on Kalahari Red goats.

*Principal component analysis:* The principal component analysis was applied to 12 phenotypic traits of Gurez sheep. Table 5 presents the results of the Measure of Sampling Adequacy (KMO), eigen-values, percentage of total variance, factor loadings, and communalities for the measured traits. The Measure of Sampling Adequacy (MSA) from the KMO test was 0.710, similar to the value obtained by Mishra *et al.* (2017) in their study on Kajli sheep. MSA evaluates the data's suitability for PCA, with values below 0.5 indicating inadequate sampling (Khargharia *et al.* 2015). Bartlett's test confirmed the significance of the correlation matrix, producing a highly significant ($P < 0.01$) chi-square statistic of 896.748. Mishra *et al.* (2017) reported a highly significant ($P<0.01$) chi-square statistic of 1412.5 in Kajli sheep. PC 1 (≈25 % of variance) is defined by high positive loadings on body weight, chest girth, body length, wither height and paunch girth, indicating that this axis reflected the overall body size and robustness in Gurez sheep. PC 2 (≈16 %) contrasted clean wool yield and staple length against fibre diameter, capturing variation in wool-production potential independent of conformation. Subsequent PCs (3–5; each ~12%) emphasized tail and ear length, medullation versus ear length contrasts, and crimp frequency, respectively, highlighting finer morphological and fiber-structure differences. The biplots and scree plots of eigen-values is given in Figures 1 and 2.

To explore multivariate structure among the 12 measured traits (body weight [BW], chest girth [CG], body length [BL], wither height [WH], paunch girth [PG], ear length [EL], tail length [TL], clean wool yield [CWY], fibre diameter [FD], staple length [SL], percent medullation [Med], and crimp frequency [CF]), we performed PCA on the standardized trait matrix. The first five principal

Table 5. Varimax rotated factor loadings, eigenvalues, share of total variance, and loading and communalities of the morphometric traits of the Kashir goat

| Trait | PC1 | PC 2 | PC 3 | PC 4 | PC 5 | Communalities |
|---|---|---|---|---|---|---|
| BW | 0.782 | 0.076 | 0.221 | 0.071 | 0.048 | 0.673 |
| CG | 0.774 | 0.015 | 0.319 | -0.171 | 0.055 | 0.733 |
| BL | 0.730 | 0.159 | -0.369 | 0.118 | 0.049 | 0.711 |
| PG | 0.722 | 0.152 | -0.126 | 0.041 | -0.007 | 0.562 |
| WH | 0.649 | 0.217 | -0.505 | 0.144 | -0.031 | 0.746 |
| EL | 0.012 | -0.092 | 0.154 | 0.789 | 0.342 | 0.772 |
| TL | 0.299 | -0.142 | 0.688 | 0.210 | 0.089 | 0.635 |
| CWY | -0.172 | 0.878 | 0.200 | -0.102 | 0.048 | 0.853 |
| FD | -0.195 | 0.865 | 0.157 | -0.026 | 0.152 | 0.835 |
| SL | 0.039 | -0.170 | 0.145 | 0.25 | -0.785 | 0.730 |
| NCPC | -0.042 | -0.492 | -0.079 | -0.198 | 0.568 | 0.612 |
| Medulation | -0.465 | 0.19 | -0.253 | 0.528 | 0.064 | 0.599 |
| Eigen-value | 3.062 | 1.956 | 1.21 | 1.129 | 1.102 | |
| % of total variance | 25.519 | 16.299 | 10.087 | 9.405 | 9.185 | |
| Cumulative variance | 25.519 | 41.819 | 51.906 | 61.31 | 70.495 | |
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy | | | | | 0. 710 | |
| | | | | | Chi-Square | 896.748 |
| Bartlett's Test of Sphericity | | | | | DF | 78 |
| | | | | | Sig. | 0.000 |

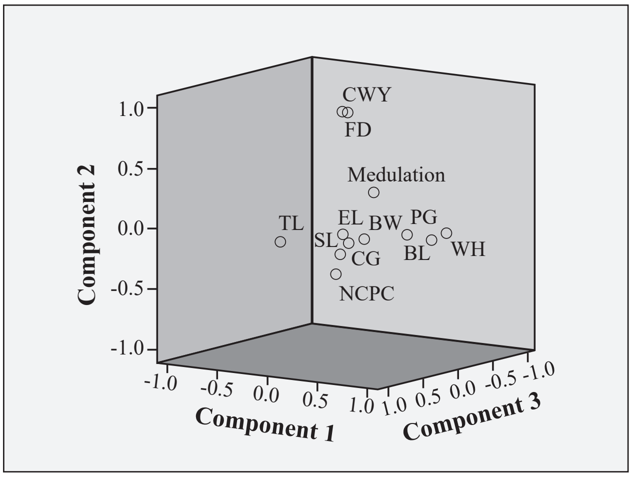


Fig. 1. Component Plot in Rotated Space

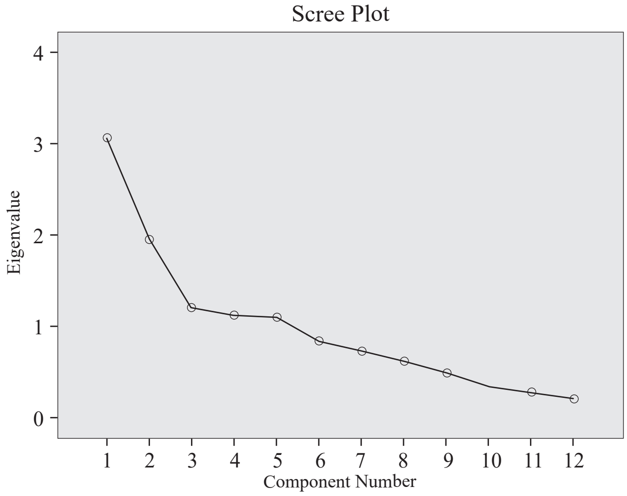


Fig.2. Scree Plot

components (PCs) together accounted for 78.2 % of the total variance (PC1 = 25.5 %, PC2 = 16.3 %, PC3 = 12.8 %, PC4 = 11.4 %, PC5 = 12.2 %).

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). PC1 was represented by a positive and significant high loading (>0.40) with an eigen-value of 3.062 for CG, BW, BL, WH, and PG; therefore, it appears to be explaining the maximum of body conformation and size in Gurez sheep. PC2 was represented by a positive and significant high loading (>0.40) for CWY and FD; therefore, it appears to explain wool quality production potential. The PC3 was represented by a positive and significant high loading (>0.40) for tail length, whereas PC4 and PC5 were represented by positive and significant high loading (>0.40) for EL and NCPC, respectively. Mishra *et al*. (2017) in Kajli sheep reported significant positive loadings for CG, PG, and BW. Yunusa *et al.* (2013) reported that PC1 explained 54.81% and 48.07% variance in Balami and Uda sheep, respectively. The percentage of variation explained by PCA in Gurez sheep in the current study was higher than those reported by Mavule *et al.* (2013) in Zulu sheep and Yadav *et al.* (2016) in Madgyal sheep. In contrast, Ormachea (2023) study PC1 and PC2 accounted for 66.57% and 18.07% of variance, respectively, explaining a total of 84.65% variation in the morphological traits of Creole sheep. The lower coefficients (<0.40) in PC1, PC3 & PC4 and negative coefficients in PC2 and PC5 indicated that SL had very little contribution to the total variance, whereas a high coefficient (>0.40) in PC1 and a positive coefficient in PC2 to PC5 indicated that BW has a significant contribution to total variance. The communalities, ranging from 0.562 to 0.853, indicated that more than half of the variable's variability is shared with other variables.

It is concluded that body weight is a key indicator of an animal's overall size and growth potential, which are crucial factors in sheep production. The significant loading of body weight on the principal components underscores its importance as a selection criterion for improving the productivity and efficiency of sheep breeding programs. Moreover, body weight's positive correlation with body size traits and minimal correlations with wool quality traits suggested that selecting for increased body weight can lead to significant size improvements without compromising wool quality.

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