

Application of principal component factor analysis to identify key morphological traits in Garut ewes

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ABSTRACT

This research utilized principal component factor analysis (PCA) to pinpoint significant morphological characteristics affecting the body structure of Garut ewes, a native Indonesian breed crucial for smallholder agriculture. The study analyzed data from 85 mature ewes, focusing on body weight (BW) and six linear measurements: body length (BL), chest depth (CD), chest girth (CG), rump width (RW), rump height (RH), and withers height (WH). Descriptive statistics indicated moderate variability in BW (mean = 47.84 kg, CV = 3.75%) and greater variation in skeletal traits (RH and WH CV > 20%). Correlation analysis revealed notable relationships between BW and BL (*r* = 0.294) and RW (*r* = 0.296), with RW and WH showing the strongest correlation (*r* = 0.429). PCA reduced dimensionality, with PC1 (35.7% variance) heavily loading on RW (0.776), WH (0.665), and RH (0.622), highlighting their significance in structural size. Regression models showed that PCA-derived components (PC1 and PC2) were more effective than individual traits, accounting for 52% of BW variability compared to just 9% for BL alone. These results emphasize the value of multivariate analysis in breeding programs, suggesting that composite indices (e.g., PC1 as a "size" factor) improve prediction accuracy over single-trait methods. Focusing on RW, WH, and RH in selection could boost productivity, while PC-based models provide practical BW estimation tools for resource-constrained farms. This study highlights the significance of integrated morphological analysis for the sustainable management of Garut sheep.

Introduction

Originating from West Java, Indonesia, Garut sheep are a native breed traditionally reared by smallholder farmers for both meat production and cultural events, such as livestock competitions. This breed is notable for its unique convex facial profile, dense coarse wool, relatively large body size, and robust legs, which are well suited to the region's mountainous and tropical climate. Garut ewes are recognized for their resilience to heat stress, disease resistance, and ability to thrive with minimal management inputs (Mayasari *et al.*, 2023; Wijayanti *et al.*, 2025). Understanding the morphological traits of Garut ewes is crucial for breeding enhancement, conservation efforts, and development of sustainable sheep farming practices in Indonesia. These traits are valuable indicators for breed identification, adaptability, and productivity across various agro-ecological settings (Inounu and Mulyono, 2013; Maulana *et al.*, 2022).

Principal component factor analysis (PCA) is a powerful statistical method for analyzing complex morphological data. This technique enables researchers to condense a large number of correlated variables into a smaller set of uncorrelated factors, simplify data interpretation, and uncover the underlying structure of trait variation (Mavule *et al.*, 2013; Mooi *et al.*, 2018). Principal component factor analysis is particularly effective in reducing dimensionality while preserving the maximum variability in the data, enhancing clarity through factor rotation, and aiding in trait classification (Akbar *et al.*, 2021; Salih Hasan and Abdulazeez, 2021; Khan *et al.*, 2023; Schreiber, 2021). This method has been extensively used to assess morphological traits in various small ruminant breeds, such as the Yankasa sheep in Nigeria (Christiana Ojonegecha *et al.*, 2020), Lori-Bakhtiari sheep in Iran (Posht-e Masari *et al.*, 2019), Djallonké sheep in West Africa (Akounda *et al.*, 2023), and Kacang Goat (Lestari *et al.*, 2024).

The aim of this study was to quantify the relationships between different linear body measurements and body weight of adult Garut ewes using principal component factor analysis. By identifying key morphological components, this study sought to deepen the understanding of structural diversity in Garut sheep and support informed decisions in breeding, conservation, and sustainable management of this important

indigenous breed.

Materials and methods

The data were collected from 85 adult Garut ewes. The animals were chosen based on the criteria that required them to be over 12 months old and not pregnant during the measurement period (Wijayanti *et al.*, 2025). Seven morphological traits were assessed: body weight (BW), body length (BL), chest depth (CD), chest girth (CG), rump width (RW), rump height (RH), and withers height (WH). Standardized procedures were employed to ensure consistency and accuracy of the measurements. Table 1 displays the descriptive statistics for body weight and linear body measurements.

Statistical Analysis

Data collected from Garut ewes were analyzed using SAS OnDemand for Academics (SAS, 2021). To explore the connections between the morphological traits, the CORR procedure was employed to calculate the correlation coefficients among the variables. Principal component analysis was executed using the FACTOR procedure to uncover latent variables and simplify the dimensionality of the dataset. The principal components derived from this analysis were then used to select the independent variables for further examination. A linear regression analysis, conducted using the REG procedure, was used to create a predictive model, where body weight served as the dependent variable and selected body measurements acted as predictors. The following formula was applied for factor analysis to minimize the total variance of multivariate data by extracting a smaller set of underlying components:

$$Y_1 = a_{11}X_1 + a_{12}X_2 + \dots + a_{1p}X_p$$

$$Y_2 = a_{21}X_1 + a_{22}X_2 + \dots + a_{2p}X_p$$

$$Y_p = a_{p1}X_1 + a_{p2}X_2 + \dots + a_{pp}X_p$$

where $Y_1, Y_2, \dots, Y_p$ a decline in the proportion of variance attributed to overall body measurements in Garut ewes, $X_1, X_2, \dots, X_p$.

By applying stepwise regression analysis, predictive models for body

measurements were developed, along with the identification of principal contributing factors:

$$BW = a + B_1X_1 + \dots + B_kX_k$$

$$BW = a + B_1PC_1 + \dots + B_kPC_k$$

where: BW stands for body weight, a for regression intercept, B_i is the i -th regression coefficient of the principal component or linear body measurements.

Results

The descriptive statistics presented in Table 1 indicate a moderate level of variability in the morphological characteristics of the Garut ewes. The average body weight (BW) was 47.84 kg with a standard deviation of 12.75. Linear measurements, such as the rump height (RH) and withers height (WH), exhibited higher coefficients of variation ($CV > 20\%$), suggesting a greater degree of dispersion. Table 2 shows strong correlations between certain traits: BW was significantly correlated with BL ($r = 0.294$) and RW ($r = 0.296$), whereas the strongest pairwise correlation was between RW and WH ($r^* = 0.429$).

Table 1. Descriptive statistics of bodyweight and linear body measurements of Garut Ewes.

Traits	N	Mean	SD ¹	CV ²
Body weight	85	47.84	12.75	3.75
Body length	85	79.02	7.59	10.39
Chest depth	85	45.87	2.9	15.8
Chest girth	85	83.72	5.38	15.55
Rump width	85	20.35	1.68	12.12
Rump height	85	69.55	3.44	20.21
Withers height	85	71.47	4.08	17.5

¹SD: Standard Deviation; ²CV: Coefficients Variant

Principal component analysis (PCA) (Table 3) reduced the dimensionality of the data, with the first principal component (PC1) accounting for 35.7% of the total variance and having high loadings on RW (0.776), WH

(0.665), and RH (0.622), indicating that these traits are key to structural size. The regression models in Table 4 show that PC1 alone accounted for 28% of the variability in BW ($R^2 = 0.28$); however, the inclusion of PC2 increased the explanatory power ($R^2 = 0.52$), underscoring the advantage of using PCA-derived components over individual measurements for predicting BW.

Discussion

A morphological study of Garut ewes revealed significant variability in body measurements, especially in skeletal features such as rump height (RH) and withers height (WH), which showed high coefficients of variation ($CV > 20\%$) (Table 1). This indicates considerable phenotypic diversity, likely due to genetic influences, environmental factors, or nutritional differences (Wijayanti *et al.*, 2022a, 2022b). Although body weight (BW) was less variable ($CV = 3.75$), it demonstrated meaningful correlations with linear traits such as body length (BL) and rump width (RW) (Table 2). These correlations suggest that linear measurements could be useful as practical substitutes for estimating BW, particularly in field settings where direct weighing is not feasible (Kunene *et al.*, 2009; Macedo-Barragán *et al.*, 2024). Such relationships are beneficial for breeding programs because they enable the indirect selection of growth-related traits without the need for specialized equipment.

The correlation matrix presented in Table 2 demonstrates significant links between RW and WH ($r^* = 0.429$), as well as between RH and WH ($r^* = 0.495$), suggesting synchronized skeletal growth. These connections might indicate functional adaptations, such as the influence of the pelvic and shoulder structures on movement or reproductive success. The moderate correlation observed between BW and RW ($r^* = 0.296$) implied that a wider rump could be associated with increased muscle mass or fat accumulation, traits that are important for meat production. These results underscore the necessity of considering a range of morphological traits in breeding programs, as concentrating solely on BW may neglect crucial structural features that enhance overall productivity and adaptability (Rakib *et al.*, 2022; Besufkad *et al.*, 2024).

Table 2. Coefficients of correlation among body weight and linear body measurements for Garut Ewes.

Traits ¹	BW	BL	CD	CG	RW	RH	WH
BW	-						
BL	0.294**	-					
CD	0.261*	0.17	-				
CG	0.18	0.20	0.276*	-			
RW	0.296**	0.232*	0.294**	0.347**	-		
RH	0.15	0.04	0.224*	0.13	0.402**	-	
WH	0.09	0.09	0.262*	0.234*	0.429**	0.495**	-

¹BW: Body Weight; BL: Body Length; CD: Chest Depth; CG: Chest Girth; RW: Rump Width; RH: Rump Height; WH: Withers Height

Table 3. Principal component for bodyweight and linear body measurements of Garut ewes.

Traits ¹	PC 1	PC 2	Communality
BW	0.5	0.53	0.53
BL	0.42	0.59	0.53
CD	0.58	0.08	0.34
CG	0.57	0.26	0.40
RW	0.78	-0.07	0.59
RH	0.62	-0.52	0.66
WH	0.67	-0.49	0.68
Eigenvalues	2.50	1.22	
%Total variance	35.70	17.45	

¹BW: Body Weight; BL: Body Length; CD: Chest Depth; CG: Chest Girth; RW: Rump Width; RH: Rump Height; WH: Withers Height

Table 4. Multiple regression of body weight on the original body measurements and on their principal components.

Traits ¹	Model	R ²	SE
BL	BW=8.85+0.49BL	0.09	13.97
BL and CG	BW=-29.23+0.43BL+0.51CG	0.13	22.89
CP 1	BW=47.84+0.68PC1	0.28	1.39
CP 1 and CP 2	BW=47.84+0.68PC1+9.22PC2	0.52	0.96

¹BW: Body Weight; BL: Body Length; CG: Chest Girth

Principal component analysis (PCA) (Table 3) successfully minimized data dimensionality, with the first principal component (PC1) accounting for 35.7% of the variance and showing strong associations with RW, WH, and RH. This indicated that PC1 embodies a combined "structural size" factor, encompassing essential skeletal dimensions. Conversely, the second principal component (PC2), which explained 17.5% of the variance, displayed contrasting associations for traits, such as RH and WH, potentially reflecting a balance between vertical and horizontal growth patterns. The high communality values (exceeding 0.5 for most traits) affirm that PCA captured the bulk of the underlying variability, justifying its application in streamlining complex datasets (Rüdiger *et al.*, 2022). These findings illustrate how multivariate techniques can uncover hidden patterns that might be overlooked by univariate analyses, thereby offering deeper insights into trait interrelationships.

Regression models, as shown in Table 4, revealed that the components derived from PCA were more effective than individual linear measurements in forecasting BW. Whereas BL alone accounted for only 9% of the variation in BW, PC1 explained 28%, and the combination of PC1 and PC2 enhanced the predictive capability to 52%. This highlights the superiority of composite indices over single-trait models as they reflect the complex nature of body conformation more accurately (Bolormaa *et al.*, 2017; Olasege *et al.*, 2019). The intercept in the model based on PC (BW = 47.84 + 0.68PC1) corresponds to the population mean, emphasizing its biological significance. These results indicate that breeding programs may achieve more precise selection by incorporating PCA-based indices, especially when focusing on growth-related traits.

This study has practical applications for both breeding and farm management. The prominence of RW, WH, and RH in PC1 indicated that these traits should be prioritized in selection programs focused on enhancing body structure. Moreover, the excellent predictive ability of PC-based models presents a cost-effective option for BW estimation in environments with limited resources (Rashamol *et al.*, 2019; Kasap *et al.*, 2021; Silva *et al.*, 2022). For smallholder farmers who may not have access to weighing scales, these models can support data-driven decision making. Future studies should investigate the genetic foundations of these morphological patterns and validate these models across different populations to ensure wider applicability.

Conclusion

This study offers an in-depth evaluation of the morphological characteristics of Garut ewes, illustrating the effectiveness of multivariate methods for analyzing trait interconnections. The significant correlations found between skeletal measurements and the enhanced predictive capability of PCA-based models underscore the value of integrated strategies in breeding initiatives. By focusing on essential traits, such as RW, WH, and RH, and utilizing composite indices, breeders can improve selection efficiency and productivity. Future research should aim at genetic validation and practical application to fully capitalize on these insights for sustainable sheep farming.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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