Research Article

Principal Component Analysis of Morphological Characteristics in Creole Sheep (*Ovis aries*)

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Abstract | Characterization of creole sheep is essential for the conservation of their genes for breeding purposes as well as to meet future needs. The objective of the study was to determine the analysis of principal components for morphological characteristics in Creole sheep. A population of 380 sheep classified by age was used and body weight data and the following morphological measurements were recorded: Head length; Head width; Head depth; Ear length; Ear width; Neck length; Neck perimeter; Height at the withers; Longitudinal body diameter; Thoracic perimeter; Bicostal diameter; Sternal dorsal diameter; Rump width; Rump length; Height at the rump; Leg perimeter; Height at hock; Metacarpus perimeter and Metatarsus perimeter. Data were processed using R statistical software. The correlation of the main morphological characteristics were significant and high. Age significantly influences morphological characteristics, showing high correlations between characters. Two principal components were obtained for sheep morphological characteristics that were evaluated according to Kaiser's criteria, PCA 1 and PCA 2 had high values for variables related to body size and body shape. The conclusion is that morphological characteristics can be useful for the selection of elite animals and the formulation of genetic improvement programs.

Keywords | Zoometry, sheep, clustering analysis, morphology; correlation

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INTRODUCTION

Currently, sheep are raised for different production purposes contributing to the family economy and since their domestication, they have provided man with meat, wool, skin, in addition to their desirable traits such as hardiness, high prolificacy, precocity, drought tolerance (Taberlet et al., 2011) and adaptability to different environmental conditions (Ormachea et al., 2020). For this reason, many breeders tend to maintain a diversity of species in their production systems (Rege et al., 2011), and Creole sheep are part of the mixed flocks of the families of the rural population in the highlands and also of the small farmers in the valleys of Peru. In the country today, herds have been crossed with genetically improved breeds to obtain better productive characteristics, causing crossbreeding and reduction of purebred breeds, placing them in a status of threatened species with the loss of their genetic qualities (Martinez, 2015).

In sheep breeding, morphological characteristics, together with body weight, are important to determine their productive potential. Therefore, efficiency in meat production and marketing depends on the specific dimensions of the carcass (Kirton et al., 1995). In such a sense the study of morphological traits within a sheep population can provide useful information in conservation programs (Alderson, 2018; Sowande and Sobola, 2008) and from a linear combination of morphological characteristics, it is possible to obtain zoometric indexes, which allow to describe their ethnology and productive capacity of the sheep (Ormachea et al., 2020; Silva-Jarquin et al., 2019), as well as to estimate the body weight of the animals (Musa et al., 2012; Ormachea et al., 2022; Zhang et al., 2016; Canaza-Cayo et al., 2021; Eyduran et al., 2013; Mavule et al., 2013; Widya and Ilham, 2019). In this regard, a morphological evaluation of the animals is obtained using multivariate statistical tools such as principal component analysis (PCA) (Yakubu, 2013).

Principal component analysis (PCA) is a multivariate statistical tool that can be used when morphological traits show exact linear relationship or multicollinearity (Mavule et al., 2013), with which new variables are generated to explain interrelationships through zoometric measurements (Flórez et al., 2018). In any case the results of principal component analysis are used in sheep breed characterization (Akbar et al., 2022; Cerqueira et al., 2011; Legaz et al., 2011; Riva et al., 2004; Salako and Ngere, 2002; Silva-Jarquin et al., 2019; Varun Sankhyan et al., 2018; Yakubu, 2013), in animal breeding programs through selection indexes (Domínguez-Viveros et al., 2019; Karacaören and Kadarmideen, 2008; Kirkpatrick and Meyer, 2004).

Relevant aspects that motivated the study, with the objective of carrying out the morphological characterization, considering the age of the Creole sheep and providing an objective description of the shape and body structure of this population

MATERIALS AND METHODS

Sampling

The research work was carried out at the Chuquibambilla Experimental Center, located in the district of Umachiri, province of Melgar, Puno Region, Peru. We worked with 383 Creole sheep, distributed by age (2 years = 131; 3 years = 88; 4 years = 91: 5 years = 25 and 6 years = 48).

Morphological variables

Body weight data were recorded along with the following morphological characteristics: Head length(cm); Head width (cm), Head depth (cm), Ear length (cm), Neck length (cm), Neck perimeter (cm), Height at the withers (cm), Sternal dorsal diameter (cm), Bicostal diameter (cm), Thoracic perimeter (cm), Longitudinal body diameter (cm), Loin length (cm), Height at the rump (cm), Rump length (cm), Rump width (cm), Leg perimeter (cm), Height at hock (cm), Metacarpus perimeter (cm); Metatarsus perimeter (cm) (Figure 1).

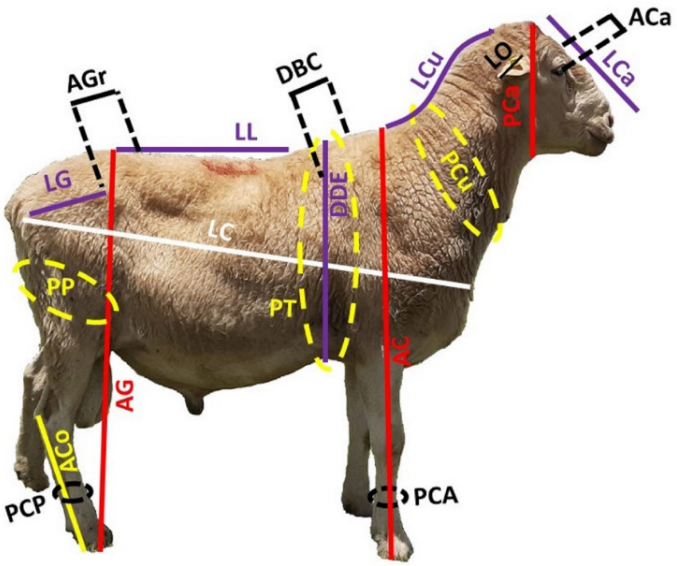

Figure 1: Localization of morphological characteristics in sheep where: Head length (LCa); Head width (ACa), Head depth (PCa), Ear length (LO), Neck length (LCu), Neck perimeter (PCu), Height at the withers (AC), Sternal dorsal diameter (DDE), Bicostal diameter (DBC), Thoracic perimeter (PT), Longitudinal body diameter (LC), Loin length (LL), Height at the rump (AG), Rump length (LG), Rump width (AGr), Leg perimeter (PP), Height at hock (ACo), Metacarpus perimeter (PCA); Metatarsus perimeter (PCP).

The body weight of the sheep was determined using conditioned scales and morphological characteristics were recorded by holding the animals while standing on level ground, using the zoometric ruler; thickness compass and tape measure. Body volume was determined according to the recommendations by (Ccora et al., 2019; Ormachea et al., 2022).

Statistical analysis

The analysis of the effect of age on morphological measurements was obtained first from the matrix of data that were divided according to the age of the sheep, which consisted of records. The analysis of variance of the effect of age on morphological measurements and Pearson's correlation were performed using programming language R.

A principal components analysis (PCA) was performed to reduce the matrix of morphological variables to a small number of non correlated variables called components. The main components obtained were evaluated based on Kaiser

criterion was used to determine the number of factors extracted and it only retained factors that had Eigenvalues greater than 1 (Kaiser, 1960; Manly and Alberto, 2016). Bartlett's test of sphericity was used to verify if the correlation matrix was an identity or a sparse one.

Similarly, a hierarchical analysis of the clusters was performed by Ward's method, using the Euclidean distance to construct a dendogram and evaluate the distances between sheep ages. All statistical analyses were performed using the statistical programming language R (R Core Team, 2020).

RESULTS AND DISCUSSION

Morphological characteristics in Creole sheep

Age significantly influenced body weight and morphological characteristics, as shown in Table 1. Animals from 3 years of age onwards showed increases in body weight; body volume; neck length; neck perimeter; Height at the withers; longitudinal body diameter; thoracic perimeter; rump width; height at the croup; loin length and height at hock. This result is likely to confirm the effect of environmental factors on the morphology of sheep. The results obtained showed important associations between morphological variables, which represents a first approximation for the characterization. Creole sheep are characterized by a marked increase in height at the rump compared to height at the withers, as is the case with other important breeds (Canaza-Cayo et al., 2021; Cerqueira et al., 2011; Gebreyowhens, 2016; Legaz et al., 2011; Silva-Jarquin et al., 2019). The dimensions of the length and width of the head of sheep indicate that they are considered mesocephalic (Ormachea et al., 2020), they have a wide and heavy skull, similar to that of the Creole sheep of Argentina (Peña et al., 2017). The thoracic perimeter is slightly superior to that of the Colombian hair Creole sheep (Flórez et al., 2020), Katjang does of Indonesia (Widya and Ilham, 2019), Immature Uda Sheep (Salako and Ngree, 2006), Zulu sheep (Mavule et al., 2013), this shows that it is an animal with greater thoracic capacity, which allows it to adapt to the adverse environmental conditions of the altiplano and improve its production capacity in a given environment. With reference to the longitudinal body diameter was higher than that reported for West African Dwarf sheep (Campos et al., 2014), Immature Uda Sheep (Salako, 2006). Clearly there are differences found in the morphological characteristics of sheep, we can indicate that this variation is subject to genetic control (Dossa et al., 2007), it is also subject to environmental influences and management practices (Leroy et al., 2016; Mirkena et al., 2010). Figure 2 shows that the cluster analysis was formed by two groups, which would indicate that morphological characteristics have a relationship with growth and development in sheep, reaching its highest value at 4 years of age, after this age these characteristics are maintained.

Table 1: Effect of age on body weight and morphological characteristics in Creole sheep.

Morphological characteristics	Age in years				
	2 (nº = 131)	3 (nº = 88)	4 (nº = 91)	5 (nº = 25)	6 (nº = 48)
Body weight (Kg)	45.31 [a]	45.68 [a]	46.46 [ab]	46.8 [b]	47.06 [b]
Body volume (liters)	39.91 [a]	40.19 [a]	40.61 [ab]	41.46 [b]	41.66 [b]
Head length (cm)	22.14 [a]	22.23 [a]	22.26 [a]	22.45 [a]	22.54 [a]
Head width (cm)	12.9 [a]	13.06 [a]	13.12 [a]	13.48 [a]	13.18 [a]
Head depth (cm)	16.68 [a]	17.01 [a]	17.14 [a]	16.76 [a]	16.44 [a]
Ear length (cm)	11.78 [a]	11.80 [a]	11.60 [a]	11.52 [a]	11.19 [a]
Ear width (cm)	6.10 [a]	6.15 [a]	5.97 [a]	5.76 [a]	5.84 [a]
Neck length (cm)	19.38 [a]	19.91 [a]	20.23 [ab]	20.91 [b]	20.89 [b]
Neck perimeter (cm)	32.21 [a]	32.91 [a]	33.99 [ab]	34.32 [b]	34.0 [b]
Height at the withers (cm)	62.23 [a]	62.88 [a]	63.31 [ab]	64.12 [b]	63.48 [b]
Longitudinal body diameter (cm)	67.87 [a]	68.34 [a]	69.03 [ab]	70.14 [b]	70.88 [b]
Thoracic perimeter (cm)	84.19 [a]	84.65 [a]	84.84 [ab]	85.54 [b]	85.21 [b]
Bicostal diameter (cm)	24.54 [a]	24.67 [a]	24.81 [a]	24.36 [a]	24.33 [a]
Sternal dorsal diameter (cm)	32.05 [a]	32.6 [a]	32.19 [a]	32.30 [a]	31.71 [a]
Rump width (cm)	18.22 [a]	19.01 [b]	19.77 [b]	19.24 [b]	19.11 [b]
Rump length (cm)	22.01 [a]	21.98 [a]	21.95 [a]	22.16 [a]	21.74 [a]
Height at the rump (cm)	63.12 [a]	64.12 [a]	64.89 [ab]	65.5 [b]	65.12 [b]
Loin length (cm)	15.10 [a]	15.96 [a]	16.10 [ab]	16.44 [b]	16.20 [b]
Leg perimeter (cm)	42.21 [a]	41.68 [a]	42.02 [a]	41.18 [a]	41.63 [a]
Height at hock (cm)	19.06 [a]	20.12 [a]	20.81 [ab]	20.90 [b]	20.63 [b]
Metacarpus perimeter (cm)	7.8 [a]	7.73 [a]	7.8 [a]	7.66 [a]	7.68 [a]
Metatarsus perimeter (cm)	9.31 [a]	9.22 [a]	9.49 [a]	9.44 [a]	9.31 [a]

Different superscripts within rows indicate that the values were statistically significant ($p<0.05$).

Table 2: Pearson correlation coefficients morphological characteristics in Creole sheep.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Body weight																
Body volume	0.96**															
Head length	0.93*	0.98**														
Head width	0.76	0.80	0.74													
Neck length	0.96**	0.97**	0.95*	0.87												
Neck perimeter	0.94*	0.86	0.80	0.85	0.93*											
Height at the withers	0.88*	0.87	0.81	0.96*	0.94*	0.95*										
Longitudinal body diameter	0.96*	0.99**	0.99**	0.73	0.96*	0.84	0.82									
Thoracic perimeter	0.90*	0.92*	0.89*	0.95*	0.97*	0.92*	0.98**	0.88*								
Bicostal diameter	0.48	0.68	0.72	0.49	0.56	0.27	0.41	0.66	0.54							
Sternal dorsal diameter	0.44	0.46	0.47	0.07	0.29	0.18	0.03	0.52	0.12	0.50						
Rump width	0.66	0.46	0.39	0.53	0.60	0.82	0.69	0.46	0.60	0.31	0.12					
Rump length	0.28	0.23	0.32	0.35	0.15	-0.04	0.15	0.35	0.06	0.08	0.65	-0.07				
Height at the rump	0.94*	0.88*	0.83	0.89*	0.95*	0.98**	0.97**	0.86	0.96**	0.33	0.11	0.78	0.03			
Loin length	0.85	0.80	0.77	0.86	0.90*	0.92*	0.94*	0.77	0.92*	0.23	0.08	0.805	0.00	0.96**		
Leg perimeter	0.63	0.73	0.73	0.91*	0.80	0.67	0.85	0.67	0.88*	0.59	0.19	0.33	0.28	0.76	-0.0	
Height at hock	0.87	0.76	0.71	0.80	0.87	0.96**	0.91*	0.74	0.87*	-0.10	0.00	0.90*	-0.05	0.97	0.96	0.76

Where statistically significant * indicates p < .05. ** indicates p < .01.

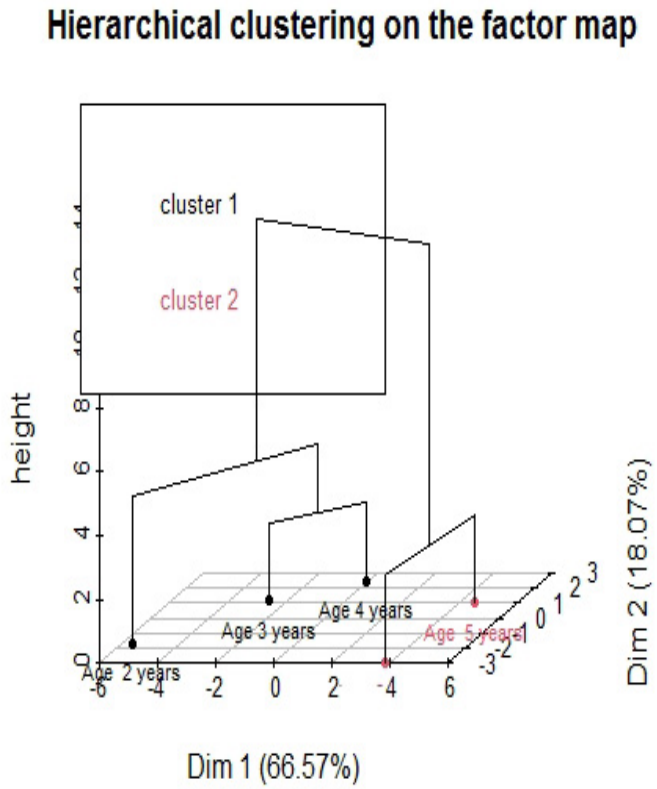

Figure 2: Dendrogram of clusters of morphological characteristics by the effect of age in creole sheep.

Pearson correlation of morphological characteristics in Creole sheep

The Pearson correlation coefficients obtained between body measurements are presented in Table 2. There are body measurements that correlated significantly with body weight (body volume r = 0.96; head length r = 0.93; neck length r = 0.96; longitudinal body diameter r = 0.96; thoracic perimeter r = 0.90). Likewise, very significant correlations were obtained for body volume with head length r=0.98; neck length r = 0.97; longitudinal body diameter r = 0.99 (p< 0.01), and significant with thoracic perimeter r=0.92 and height at the rump r=0.88 (p< 0.05). The results show that head length presents high correlations with significant correlations with neck length r=0.95; longitudinal body diameter r= 0.99, thoracic perimeter r= 0.89 (p< 0.05). Similarly, low associations were obtained between height at hock and bicostal diameter, sternal dorsal diameter and rump length. Los resultados obtenidos muestran correlaciones entre medidas corporales (altura a la cruz, diámetro longitudinal, perímetro torácico) presentaban altas correlaciones entre sí y con el peso corporal (Akbar et al., 2022; Canaza-Cayo et al., 2021; Mavule et al., 2013; Sabbioni et al., 2020; Sowande and Sobola, 2008). The high correlations found between morphological characteristics demonstrate that body measurements can be useful for selection of animal body weight.

Principal component analysis of morphological characteristics in Creole sheep

In the study, four principal components were obtained for the morphological characteristics in sheep as shown in the scarplot of Figure 3. The proportion of variance for component 1 (PCA1= 66.57%) and (PCA2= 18.07%). indicating that it identifies a more subtle pattern of

variation in body shape.

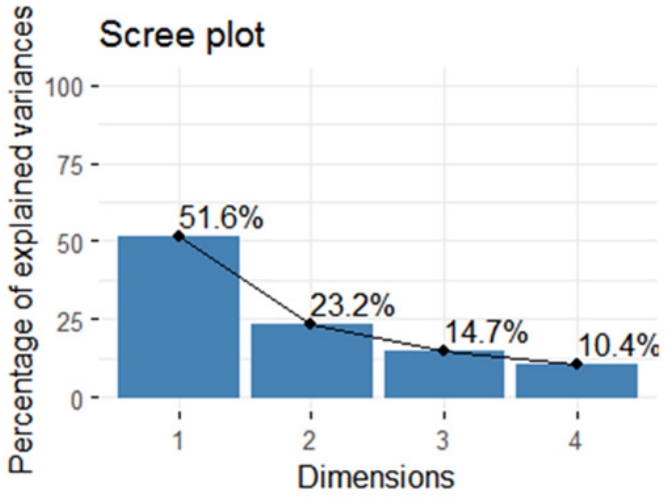

Figure 3: Scarplot of principal component analysis for morphological characteristics in creole sheep.

Table 3: Eigenvalue, proportion of total variance of and principal component analysis for morphological characteristics in Creole sheep.

Morphological characteristics	PCA1	PCA2
Body weight (Kg)	0.291	0.091
Body volume (liters)	0.294	0.256
Head length (cm)	0.060	0.069
Head width (cm)	0.073	-0.039
Head depth (cm)	-0.024	-0.313
Ear length (cm)	-0.080	-0.144
Ear width (cm)	-0.059	-0.040
Neck length (cm)	0.259	0.069
Neck perimeter (cm)	0.344	-0.210
Height at the withers (cm)	0.267	-0.151
Longitudinal body diameter (cm)	0.468	0.483
Thoracic perimeter (cm)	0.200	-0.019
Bicostal diameter (cm)	-0.038	-0.182
Sternal dorsal diameter (cm)	-0.035	-0.297
Rump width (cm)	0.154	-0.413
Rump length (cm)	-0.008	-0.083
Height at the rump	0.370	-0.206
Loin length (cm)	0.188	-0.185
Leg perimeter (cm)	-0.119	0.020
Height at hock (cm)	0.278	-0.335
Metacarpus perimeter (cm)	-0.019	-0.021
Metatarsus perimeter (cm)	0.020	-0.051
Eigenvalues	14.64	3.97
Standard deviation	3.8271	1.9939
Proportion of Variance	0.6657	0.1807
Cumulative Proportion	0.6657	0.8465

The variation explained by the two components is shown in Table 3 and Figure 3. Variables that could not be explained by the first component could be picked up by the second. The variables that had the greatest contribution in component 1 were: longitudinal body diameter; height at rump; body weight; body volume; height at withers and thoracic perimeter. Component 2 consisted of longitudinal body diameter; sternal dorsal diameter; rump width and body volume. Showing the results of the principal component analysis (PCA), which identifies the variability of individual traits and their contribution to the morphological variance of Criollo sheep in general, these data provide valuable information on those traits that can be improved with great success through selection schemes. The percentages of accumulated variance in PCA 2 is 84.65%, these results are higher than the PCA obtained in Corriedale sheep (Canaza-Cayo et al., 2021). Principal component 1 (PCA1) explains 66.57% of the variance and principal component 2 (PCA2) explains 18.07%. Each of the 21 body measurements has a positive and negative factor loading on PCA1, indicating a positive and negative correlation (Table 3). However, PCA1 quantifies the body size of the sheep, where the head, neck, trunk and limbs increase in size in a coordinated manner (Brooks et al., 2010). The results show that the first factor explains the largest percentage of the total variance (Canaza-Cayo et al., 2021; Mavule et al., 2013; Riva et al., 2004; Salako, 2006; Silva-Jarquin et al., 2019; Yakubu, 2013).

CONCLUSION

Creole sheep adapted very well to the environmental conditions of the altiplano and to an extensive grazing system; in addition, the skeletal conformation of these animals mainly influenced the morphostructural development of these sheep. In principal component analysis, there are morphological traits that can be used in selection programs because they contribute significantly to the morphological variance of sheep.

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NOVELTY STATEMENT

The research work highlights the analysis of principal components in Creole sheep, based on the results of morphological characteristics, for their conservation and productive characterization of this animal genetic resource.

AUTHOR'S CONTRIBUTION

EOV and YMMG investigation, methodology, writing original draft, supervision, statistical analyses. BCC and BOV reviewing, formal analysis, and editing. HGC and EAS conceptualization, resources, writing, review.

Conflicts of interest

The authors have declared no conflict of interest.

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