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Assessment of morphometric traits of camels using principal component analysis

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Abstract

This study assessed the morphometric traits of camels in Katsina State, Nigeria. 51 camels (24 females and 27 males) were selected randomly for the study. Data were collected on individual camels, including; heart girth (HG), abdominal girth (AG), rump height (RH), shoulder height (SH), neck length (NL) and head length (HL), and subjected to statistical analysis procedures of SPSS version 23.0.0, for descriptive statistics, phenotypic correlation, and Principal Component Analysis (PCA). Results revealed that the overall mean body weight of the camels was 230.73 kg, with females averaging 216.15 kg and males 243.70 kg. Phenotypic correlation indicated a strong positive correlation between body weight and HG (r = 0.877 for females, r = 0.911 for males; p<0.01), suggesting that HG is a reliable predictor of body weight in camels. Two principal components (PCs) extracted in male and female camels explained 77% and 84% of the total variation, respectively. For females, PC1 accounted for 57.768% of the variance and was strongly associated with HG, AG, SH, and NL. In males, PC1 explained 65.714% of the variance, with similar trait loadings. HG, AG, and SH emerged as key variables influencing overall body size, while rump height was distinct, potentially linked to mobility and endurance. These findings suggest that heart and abdominal girth, are essential indicators of body weight and conformation in camels, highlighting the potential for using these traits in selective breeding programs aimed at improving camel productivity.

Keywords: Body weight, Camel, Morphometric traits, Principal component analysis

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1. Introduction

Camels (*Camelus dromedarius*) are integral to the socio-economic and agricultural systems of arid and semi-arid regions, including northern Nigeria. They were valued for their adaptability to harsh climates, endurance, and utility in transportation, milk, and meat production (Abdelhadi & Babiker, 2020).

World Camel population is estimated to be about 35.5 million, while about 1.05 million are found within Nigeria's border (FAOSTAT, 2018). Katsina State, located in the northern part of Nigeria, has a significant camel population that contributes to the livelihoods of many pastoralists and smallholder farmers (Gafar et al., 2022). However, morphological characterization of these camels, essential for improving breeding, management, and conservation strategies, remains underexplored. Morphological traits, including body size, shape, and conformation, provide critical information for evaluating breed diversity, adaptability, and productivity (Abdulahi et al., 2021).

Principal Component Analysis (PCA), offers a robust framework for analyzing morphological traits by reducing data complexity and identifying the most informative characteristics contributing to overall variation (Girma et al., 2023).

Quantitative measurements for size and shape are essential for understanding genetic and phenotypic diversity, leading to more effective selection and breeding programs (Chineke, 2000). Morphometric traits are inexpensive measurements correlated with body weight (Mondini et al., 2009; Ajayi et al., 2012). Thus, morphometric traits could be used as markers in body weight improvement programs and body weight prediction (Musa et al., 2018)

In animal breeding, these tools are increasingly used to enhance the understanding of genetic and phenotypic diversity, leading to more effective selection and breeding programs (Salem & El-Tayeb, 2022).

Despite the economic and cultural significance of camels in northern Nigeria, particularly in Katsina State, limited scientific research exists on the morphological traits that define camel populations in the region. Previous studies have either focused on camel productivity or general management practices without paying adequate attention to the detailed analysis of morphological variations. This gap in knowledge hinders the development of targeted breeding and conservation strategies that could improve the productivity and sustainability of camel populations in the area.

PCA has been used to evaluate different phenotypic characters by other authors; in Uda Sheep (Salako, 2006), hairy sheep (Lopez-Carlos et al., 2010), Djallonke sheep in northern Ghana (Birteeb et al., 2012), Yankasa sheep (Yakubu, 2013), Zulu sheep (Mavule et al., 2013) and Thalli sheep in Pakistan (Akbar et al., 2022). However, the application of multivariate statistical methods, such as Principal Component Analysis, to characterize these morphological traits is largely unexplored on camels in Nigeria. Without such analysis, the ability to identify and preserve key genetic resources for future generations may be compromised.

Morphological characterization is a fundamental step in understanding the genetic diversity and adaptability of livestock species. The application of PCA in this context provides a data-driven approach to identifying critical morphological traits that can influence breeding and selection processes (Kebede et al., 2021). In a region where camels play a crucial role in agriculture and pastoral livelihoods, such as Katsina State, the need for efficient and scientifically informed breeding strategies is paramount. This study is justified by the growing demand for sustainable livestock management in response to environmental changes and increasing pressure on agricultural systems (Musa et al., 2023). It is therefore crucial to describe the phenotypic characteristics of camel populations in Katsina state, Nigeria, using the FAO guidelines (FAO, 2012). By identifying key morphological traits that correlate with productivity and adaptability, this research can contribute to enhancing camel production systems and ensuring the long-term sustainability of camel populations in Katsina State. Therefore, this study uses multivariate PC analysis to assess the variability and relationships among body measurements, and to deduce components that describe these traits.

2. Material and Methods

2.1. Locations of the study area

This study was carried out in two LGAs in Katsina state, namely, Charanchi (12°43'N and Longitude 7°44'E) and Mai'Adua (latitude 13°8'N and longitude 8°13'E), Northern region Nigeria. The description of the study location was earlier given by Rotimi et al. (2023).

2.2. Experimental animals

The study involved 51 (24 females and 27 males), apparently healthy and non-pregnant camels, randomly selected across the study area. Data collected included; heart girth (HG), abdominal girth (AG), rump height (RH), shoulder height (SH), neck length (NL) and head length (HL). Data were measured following FAO (2012) descriptors standard using simple measuring tapes. Body weight was estimated using the Barymetric weight estimation formula of Yagil (1994).

2.3. Statistical analysis

Data obtained were subjected to statistical analyses using the statistical procedures of SPSS version 23.0.0 (IBM SPSS 23.0.0).

Principal Components

The principal components are the new variables obtained by projecting the original variables onto the eigenvectors.

$$PC = X * V$$

Where,
PC: the matrix of principal components,
X: the data matrix,
V: the matrix of the eigenvectors.

Explained Variance

The explained variance (*EV*) is the proportion of variance explained by each principal component.

$$EV = \left(\lambda_i / \sum \lambda_j\right) * 100$$

Where,
EV: Explained variance,
λ_i: the eigenvalue corresponding to the ith principal component,
$\sum\lambda_j$: the sum of all eigenvalues.

Orthogonality

The principal components are orthogonal to each other, meaning that their covariance is zero.

$$\text{cov}\left(PC_i, PC_j\right) = 0 \text{ for } i \neq j$$

Data set validity for PCA analysis was evaluated using Kaiser-Meyer-Olkin and Bartlett's sphericity tests. Eigenvalue values ≥1.000 were used to select the number of components to retain.

Table 1. Descriptive statistics of body weight and body measurements of the pooled population of camels

Traits	Sex	N	Mean	SE	*p*
Body weight (kg)	Female	24	216.15	15.07	0.233
	Male	27	243.70	16.80	
	Overall	51	230.73	11.43	
Heart girth (cm)	Female	24	169.00	4.86	0.522
	Male	27	173.30	4.55	
	Overall	51	171.28	3.30	
Abdominal girth (cm)	Female	24	143.95	3.45	0.076
	Male	27	153.72	4.06	
	Overall	51	149.12	2.75	
Rump height (cm)	Female	24	171.07	4.54	0.707
	Male	27	168.35	5.44	
	Overall	51	169.63	3.56	
Shoulder height (cm)	Female	24	167.14	4.10	0.235
	Male	27	173.30	3.16	
	Overall	51	170.40	2.56	
Neck length (cm)	Female	24	127.23	7.51	0.666
	Male	27	131.78	7.30	
	Overall	51	129.64	5.19	
Head length (cm)	Female	24	51.53	1.64	0.549
	Male	27	53.04	1.88	
	Overall	51	52.33	1.25	

3. Results and Discussion

Table 1 shows the results of the descriptive statistics of body weight (kg) and morphometric traits (cm) of the camels. The results show a non-significant (p>0.05) difference in values obtained for female and male camels. However, the overall mean values obtained for the traits were 230.73 kg (BWT), 149.12 cm (AG), 171.28 cm (HG), 169.63 cm (RH), 170.40 cm (SH), 129.64 cm (NL) and 52.33 cm (HL). Results obtained in this study agree with earlier reports by Rotimi et al. (2023)

3.1. Correlations

Table 2 shows that all the correlation values between body weight and linear body parameters and among the linear body measurements were positive, for both female and male camels. In female camels, the highest correlation value was observed between body weight and HG (0.877) while the lowest exists between body weight and HL (0.420). Similarly in male camels, the highest correlation value was obtained between body weight and HG (0.911) with the lowest existing between body weight and TL (0.125). In the pooled data, the highest was also obtained between body weight and AG (0.866). In same trend, the lowest was observed between body weight and RH (0.416). This implies that selection for HG and AG can result in rapid improvement in body weight in both female and male camels. Correlations among the linear body measurements were all positive. The result is similar to the records of Rotimi et al. (2023) and Kebede et al., (2022), who also obtained positive values for the linear body measurements in their study. Other researchers also reported positive correlation values in chickens (Yosef et al., 2014).

3.2. PC Factor Analysis

The result of the KMO measure was found to be adequately high with values ranging from 0.722 to 0.809 for females, males and the pooled data (Table 3). However, Kebede et al. (2022) reported a higher value of KMO (0.94) in their study. A KMO measure of ≥0.60 indicates that the data set is adequate for PCA analysis (Eyduran et al., 2010).

3.3. Eigenvalues, percentage of total variances and communalities

Table 4 shows the total variance of the observed traits explained by each of the PCs after varimax rotation of the component for female, male and the pooled data. In both female camels, two (2) PCs were extracted with eigenvalues of 3.466 (PC1) and 1.153 (PC2), explaining total variability of about 76.992% of the total variances. PC1 explained 57.768% of the total variances while PC2 explained about 19.224% of the total variances. Similarly in male camels, two (2) PCs were also extracted with eigenvalues of 3.943 (PC1) and 1.084 (PC2), contributing about 84.503% total variability. PC1 explained 65.714% while PC2 explained 18.059% of the total variability. From the pooled data, only one (1) PCs was extracted with eigenvalues of 3.610 and about 60.166% total variance explained.

Table 2. Phenotypic correlations between body weight and body measurements by sex in camels

Sex	Traits	Body weight	Heart girth	Abdominal girth	Rump height	Shoulder height	Neck length
Female	Heart girth	0.877**	---				
	Abdominal girth	0.830**	0.745**	---			
	Rump height	0.720**	0.583**	0.575**	---		
	Shoulder height	0.804**	0.517**	0.526**	0.815**	---	
	Neck length	0.610**	0.456*	0.642**	0.525**	0.428*	---
	Head length	0.420*	0.312	0.503*	0.006	0.145	0.305
Male	Heart girth	0.911**	---				
	Abdominal girth	0.847**	0.695**	---			
	Rump height	0.416*	0.434*	0.167	---		
	Shoulder height	0.877**	0.718**	0.821**	0.427*	---	
	Neck length	0.645**	0.479*	0.793**	0.018	0.683**	---
	Head length	0.740**	0.691**	0.715**	0.294	0.761**	0.668**
Both sex	Heart girth	0.892**	---				
	Abdominal girth	0.844**	0.708**	---			
	Rump height	0.511**	0.484**	0.289*	---		
	Shoulder height	0.833**	0.614**	0.681**	0.573**	---	
	Neck length	0.629**	0.471**	0.719**	0.217	0.550**	---
	Head length	0.622**	0.532**	0.636**	0.183	0.468**	0.518**

***Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed).*

Table 3. Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) and Bartlett's test

Test		Female	Male	Pooled data
KMO		0.722	0.809	0.794
Bartlett's Test	Chi-square	71.423	105.754	153.601
	df	15	15	15
	p	<0.001	<0.001	<0.001

Table 4. Variance contributions of each trait in camels

Traits	Female			Male			Pooled data	
	PC1	PC2	Communality	PC1	PC2	Communality	PC1	Communality
Heart girth	**0.675**	0.373	0.670	0.389	0.152	0.752	0.335	0.687
Abdominal girth	**0.708**	0.060	0.851	**0.810**	0.305	0.879	**0.763**	0.798
Rump height	0.124	**0.761**	0.908	0.068	**0.682**	0.920	-0.044	0.305
Shoulder height	**0.847**	0.138	0.776	-0.133	0.021	0.864	-0.062	0.707
Neck length	**0.812**	-0.010	0.567	**0.603**	0.349	0.841	0.438	0.583
Head length	0.489	-0.579	0.848	**0.847**	-0.174	0.770	**0.862**	0.530
Eigenvalue	3.466	1.153	-	3.943	1.084	-	3.610	-
Variance contribution (%)	57.768	19.224	-	65.714	18.059	-	60.166	-
Cumulative variance contributions (%)	-	76.992	-	-	83.773	-	60.166	-

Communalities show the proportion of variance in each variable explained by the extracted PCs. In the female camels, the communality values ranged from 0.567 (NL) to 0.908 (RH). However, in male camels, the communality values were 0.752 (HG) to 0.920 (RH) while in the pooled data, the communality ranged from 0.305 (RH) to 0.798 (AG). These values further indicate that the data set is adequate for PCA. The ranges of communality values obtained are within the acceptable communality values for PCA (0.60 - 0.80). communalities are crucial in assessing the adequacy of the PCA model and the retained components' ability to capture the variability of the original data.

3.4. PC loadings

Table 4 shows the PC loadings of each linear body measurements in the camels. In female camels, PC1 loaded highly on HG, AG, SH and NL while PC2 loaded highly on RH only. Factor loadings heavily on HG, AG, SH, and NL in camels suggesting that these variables are strongly related to overall body size or conformation. HG, AG, and SH are strongly correlated, suggesting a relationship between body circumference and overall size. NL is also related, potentially indicating a connection between neck proportions and body size. Body size is crucial for camel's thermoregulation, mobility, and load-carrying capacity. HG and AG may be related to digestive efficiency and energy reserves, thereby influencing body size whereas, shoulder height and neck length might influence the camel's ability to browse and reach food sources. PC2 factor might be labeled as Rump Size or Hindquarters Development" factor, suggesting that RH is a distinct characteristic, separate from overall body size and may be related to muscle mass, strength, or fat reserves in the hindquarters. RH could influence the camel's locomotion and mobility (e.g., stride length, agility), load-carrying capacity and endurance.

Other researchers have used PCA to examine different phenotypic traits; in Uda Sheep (Salako, 2006), Djallonke sheep in northern Ghana (Birteeb et al., 2012), Yankasa sheep (Yakubu, 2013), Zulu sheep (Mavule et al., 2013) and Thalli sheep in Pakistan (Akbar et al., 2022).

4. Conclusion

This study highlighted that HG, AG, and SH had strong correlations with body weight, particularly HG which showed the highest correlations in both male (r = 0.911; p<0.01) and female (r = 0.877; p<0.01) camels.

Principal component analysis (PCA) revealed that in both male and female camels, two principal components explained a much proportion of the total variability. In females, PC1 and PC2 accounted for 57.77% and 19.22% of the variance, respectively, while in males, these components explained 65.71% and 18.06% of the total variance. Traits such as HG, AG, SH, and neck length (NL) contributed heavily to PC1 in both sexes, indicating that these traits are key indicators of body size and overall conformation in camels.

The positive correlations observed between body weight and morphometric traits suggest that selection based on HG and AG can result in rapid improvement of body weight in camels. These findings are consistent with earlier reports and confirm that these traits are reliable predictors of body size in camels.

Conflict of interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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