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Morphological characterisation of camels in Katsina state, Nigeria, using path analysis

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ABSTRACT

This study assessed relationships between body weight and biometric traits and also the direct and indirect contributions of some biometric traits on body weight in camels. Data was obtained from 51 (27 female and 24 male) camels, including: heart girth (HGT), abdominal girth (ABG), rump height (RPH), shoulder height (SHT), ear length (EAL), fore leg length (FLL), hind leg length (HLL), neck length (NLT) and head length (HDL). Data was subjected to statistical analysis using IBM SPSS version 27.0.0. Female phenotypic correlations indicated that body weight had positive correlations with all the traits, with the highest correlation obtained with HGT and least with FLL. In male camels, correlations between body weight and biometric traits were all positive. The highest correlation was obtained with ABG and the weak with RPH. Path analysis on females showed that SHT had greatest direct effects on body weight and the greatest indirect effects was from HGT via ABG. However, HGT had the greatest direct effect on body weight in male camels and the highest indirect effects were similar to the female camels, observed in HGT via ABG. Information obtained from present research may assist farmers in the rural areas, who may not have access to weighing scales, to predict body weight of animals for management and marketing purposes. The outcome of the study may be useful management decision making and genetic improvement for breeders in selection for body weight improvement in camels.

Keywords: Camel, Body measurements, Body weight, Katsina state, Multivariate analysis

Camels (*Camelus dromedarius*) are used for numerous functions such as milk, meat, riding, packing, etc. thereby contributing significantly to the livelihoods of the pastoralists and agro-pastoralists living in fragile environments (Abbas *et al*. 2000, Tura *et al*. 2010). Furthermore, pastoralists have raised and nurtured camels because of their remarkable ability to endure hunger and thirst for long periods of time in the most hostile ecological environment (Al-Dahash and Sassi 2009).

For livestock pricing, medicine, and breeding purposes, morphometric characteristics and body weight are crucial factors (Sadick *et al*. 2020, Rotimi *et al*. 2023). Live weights of animals can be easily determined traditionally by direct weighing of animals using convetional weighing scales. Lack of access to traditional weighing scales is one of the biggest issues facing camel farmers in the local areas (Vincent *et al*. 2015, Rotimi *et al*. 2023) and this may be time-consuming and laborous (Duguma *et al*. 2010, Tırınk *et al*. 2023). In the absence of weighing equipment, morphometric features can be used to predict body weight of animals (Rotimi *et al*. 2023).

Biometric traits and body weight are important aspects for pricing livestock, medication and breeding purposes (Sadick *et al*. 2020, Rotimi *et al*. 2023). One of the main problems confronting local farmers is the lack of access to conventional weighing scales to determine body weight of animals. Body weight of livestock can be estimated using biometric traits in the absence of weighing scales (Sadick *et al*. 2020). Understanding a livestock's body weight helps with management practices as well as selection for breeding purpose, especially in rural settings (Bila *et al*. 2021). Path analysis is a multivariate statistical tool used to quantify the direct and indirect effects of morphometric traits on body weight in a variety of livestock species (Tyasi *et al*. 2020).

Many authors have documented prediction of body weight using morphometric traits of other livestock, including goats (Mathapo *et al*. 2020, Rotimi *et al*. 2020), chickens (Sabo *et al*. 2020, Negash 2021), cattle (Hlokoe 2022) and sheep (Molabe and Tyasi 2021). Numerous researchers have also used path analysis to predict the body weight of various livestock species, including goats (Rotimi *et al*. 2023), egg quality traits (Rotimi 2023), sheep (Churata-Huacani *et al*. 2024), rabbits (Rotimi *et al*. 2020), grill chickens (Bila *et al*. 2021), Doper sheep (Molabe and Tyasi 2021) and Red Sokoto kids (Shuaibu *et al*. 2020). However, to the best of the authors' knowledge (based on the database searches), no research has been done on the application of path analysis to estimate body weight using camel's biometric traits.

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Hence, this study was undertaken to estimate the correlation between body weight and the biometric traits in camels and to evaluate the direct and indirect effects of biometric traits on body weight of female and male camels. The outcome of the current study may help farmers in management decision and also assist camel breeders for genetic improvement.

MATERIALS AND METHODS

Study location and experimental animals: The study was carried out in two Local Government Areas (LGA) of Katsina state in Nigeria. Katsina state is boardered to Niger republic. The LGAs involved were Charanchi LGA and Mai'Adua LGA. Charanchi is located within latitude 12°43' N and longitude 7°44' E, while Mai'Adua is within latitude 13°8' N and longitude 8°31' E (Rotimi *et al.* 2023). For this study, 51 camels, including 24 females and 27 males, were randomly sampled from different parts of the study area. Study areas were purposively selected based on the prepondency of camels and level of security in the area. Most of the areas with high proportion of camels were bedevilled with high levels of insecurity. Apparently healthy, unrelated and non-pregnant camels were involved in this study. Camels sampled for linear body measurements were adult, above five years of age. The study covered the raining period of the year 2023.

Data collection: Nine morphometric traits namely, heart girth (HGT), abdominal girth (ABG), rump height (RPH), shoulder height (SHT), ear length (EAL), fore leg length (FLL), hind leg length (HLL), neck length (NLT) and head length (HDL), were measured following the standard procedures (FAO 2012). Simple Tailors' tapes were used to take the linear body measurements:

Heart girth (HGT): Measured as the circumference of the body immediately behind the shoulder blades in a vertical plane, perpendicular to the long axis of the body.

Abdominal girth (ABG): Measured as the distance around the abdomen over the highest part of the hump.

Rump height (RHT): Distance from the surface of a platform to the rump using a measuring stick as described for height at withers

Shoulder height (SHT): Also known as whither height or height at the shoulder. This is the height (vertical) from the bottom of the front foot to the highest point of the withers.

Ear length (EAL): The distance between the beginning or the lower ear to the tip of the ear

Fore leg length (FLL): This is the distance from the surface of the ground level to the front of the sternum.

Hind leg length (HLL): Measured as the distance from the bottom of the leg to the pin bone of the hip.

Neck length (NLT): Neck length was measured as the distance from the lower part of the mandible to the sternum and.

Head length (HDL): The distance between the occipital and the line between the forehead and the nose.

Body weight (kg) was estimated from the formula described by Yagil (1994) and adopted by Rotimi *et al*. (2023):

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

Trait	Sex	N	Mean	SE	CV (%)
BWT	Female	24	216.15	15.07	34.17
	Male	27	243.70	16.80	35.83
	Overall	51	230.73	11.43	35.38
HGT	Female	24	169.00	4.86	14.08
	Male	27	171.67	5.18	15.69
	Overall	51	170.42	3.54	14.84
ABG	Female	24	141.33	4.28	14.84
	Male	27	151.57	4.85	16.63
	Overall	51	146.75	3.31	16.12
RPH	Female	24	171.07	4.54	13.01
	Male	27	166.69	5.95	18.54
	Overall	51	168.75	3.78	16.01
SHT	Female	24	165.52	4.75	14.07
	Male	27	170.15	4.59	14.01
	Overall	51	167.97	3.29	13.97
EAL	Female	24	15.76	1.04	32.17
	Male	27	16.85	1.08	33.18
	Overall	51	16.34	0.75	32.62
FLL	Female	24	120.87	4.50	18.26
	Male	27	123.40	4.18	17.60
	Overall	51	122.21	3.04	17.76
HLL	Female	24	134.57	3.11	11.32
	Male	27	137.37	4.08	15.42
	Overall	51	136.05	2.59	13.59
NLT	Female	24	127.23	7.51	28.92
	Male	27	131.78	7.30	28.78
	Overall	51	129.64	5.19	28.62
HDL	Female	24	51.53	1.64	15.56
	Male	27	53.04	1.88	18.38
	Overall	51	52.33	1.25	17.05

BWT, body weight; HGT, heart girth; ABG, abdominal circumference; RPH, rump height; SHT, shoulder height; EAL, ear length; FLL, fore-leg length; HLL, hind leg length; NLT, neck length; HDL, head length; SE, standard error; CV(%), coefficient of variation (%).

$$BWT\ (kg) = 50 \times SHT \times ABG \times HGT$$

Statistical analysis: Descriptive statistics was conducted where means, standard errors (SE) and standard deviations (SD) of body weight (kg) and linear body measurements were evaluated using SPSS version 23.0.0. Bivariate correlations between body weight and biometric traits were obtained for female and male camels. This was used to evaluate the level of relationships between body weight and morphometric traits measured.

Path coefficient was calculated as suggested by Mendes *et al*. (2005) and Ulukan *et al*. (2003) as given below:

$$PY.X_i = bi^{Sxi}_{SY}$$

where, $PY.X_i$, Path coefficient from X_i to Y (i = linear body measurements); SE, Standard error; CV (%), coefficient of variation (%); b_i, Partial regression coefficient; SX_i, Standard deviation (SD) of X_i; SY, Standard deviation (SD) of Y.

Multiple linear regression model adopted was:

$$Y = a + b_1X_1 + b_2X_2 + \dots + b_iX_i + e$$

where, Y, Criterion variable (bodyweight); a, Intercept; b_1, b_2, … b_i, Regression coefficients; X_1, X_2, … X_i, Explanatory variables; e, Residuals/error variance.

Indirect effects (IE) of X_i on Y through X_j were estimated following the procedures suggested by Rotimi *et al*. (2020):

$$IE(YX_i) = (rX_iX_j).(PY.X_j)$$

where, $IE(YX_i)$, Indirect effect of X_i via X_j on Y; rX_iX_j, Correlation coefficient (r) between i^{th} and j^{th} independent variables; $PY.X_j$, Path coefficient indicating the direct effect of j^{th} independent variable on the dependent variable.

RESULTS AND DISCUSSION

Table 1 shows results of the descriptive analysis of body weight (kg) and morphometric traits (cm) of female and male camels. The findings indicate that sex had no significant (P>0.05) effect in the values recorded for male and female camels. Overall mean values estimated for the traits were 230.73 kg (BWT), 170.42 cm (HGT), 146.75 cm (ABG), 168.75 cm (RPH), 167.97 cm (SHT), 16.34 cm (EAL), 122.21 cm (FLL), 136.05 cm (HLL), 129.64 cm (NLT) and 52.33 cm (HDL). Body weight is important for livestock management practices (Bila *et al*. 2021). The descriptive results reported in this study agree with observations of Rotimi *et al*. (2023). However, the average value obtained in this study are lower than the report of Yosef *et al*. (2014) and Tandoh *et al*. (2018). The variation may be due to breed differences, sample size and sampling procedures employed by the researchers.

Tables 2 and 3 show the results of the phenotypic correlation among measured traits for female and male camels. All the correlation values between body weight and biometric traits were positive for female and male camels. Results showing correlations in female camels (Table 2) indicated that body weight had positive correlations with HGT ($r = 0.877^{**}$), ABG ($r = 0.845^{**}$), RPH ($r = 0.720^{**}$), SHT (0.765^{**}) and NLT (r = 0.610**) as well as HDL (r = 0.420*). Non-significant correlations exist with EAL ($r = 0.382^{NS}$), HLL ($r = 0.380^{NS}$) and HDL ($r = 0.125^{NS}$). Results showed that strongest correlation value was obtained between body weight and HGT. Relationship among the morphometric traits showed that HGT and ABG had the highest correlation. However, negative relationships were observed between SHT and FLL ($r = 0.114^{NS}$) as well as between HDL and HLL ($r = 0.217^{NS}$).

The correlation results for male camels demonstrated that body weight had highly positive correlations with all the traits measured (Table 3). Relationship between body weight and ABG, HGT, SHT, HLL, NLT, FLL, EAL and HDL (r = 0.872**, 0.845**, 0.789**, 0.740**, 0.645**, 0.573**, 0.540** and 0.511** respectively). Strongest correlation value was obtained between body weight and

Table 2. Phenotypic correlations coefficients between body weight and body measurements of female camels

	BWT	HGT	ABG	RPH	SHT	EAL	FLL	HLL	NLT	HDL
HGT	0.877**	--								
ABG	0.845**	0.759**	--							
RPH	0.720**	0.583**	0.566**	--						
SHT	0.765**	0.449*	0.418*	0.642**	--					
EAL	0.382	0.204	0.571**	0.187	0.271	--				
FLL	0.125	0.042	0.363	0.103	-0.114	0.390	--			
HLL	0.380	0.344	0.296	0.490*	0.357	0.002	0.065	--		
NLT	0.610**	0.456*	0.666**	0.525**	0.420*	0.755**	0.328	0.012	--	
HDL	0.420*	0.312	0.506*	0.006	0.202	0.515**	0.469*	-0.217	0.305	--

BWT, body weight; HGT, heart girth; ABG, abdominal circumference; RPH, rump height; SHT, shoulder height; EAL, ear length; FLL, fore-leg length; HLL, hind leg length; NLT, neck length; HDL, head length; **, Correlation is significant at the 0.01 level (2-tailed); *, Correlation is significant at the 0.05 level (2-tailed).

Table 3. Phenotypic correlations coefficients between body weight and body measurements of male camels

	BWT	HGT	ABG	RPH	SHT	EAL	FLL	HLL	NLT	HDL
HGT	0.845**	--								
ABG	0.872**	0.642**	--							
RPH	0.421*	0.543**	0.161	--						
SHT	0.789**	0.450*	0.635**	0.315	--					
EAL	0.540**	0.365	0.594**	-0.089	0.423*	--				
FLL	0.573**	0.290	0.767**	-0.292	0.379	0.707**	--			
HLL	0.511**	0.237	0.583**	-0.114	0.505**	0.306	0.621**	--		
NLT	0.645**	0.324	0.771**	-0.069	0.547**	0.670**	0.893**	0.555**	--	
HDL	0.740**	0.549**	0.764**	0.217	0.646**	0.799**	0.615**	0.274	0.668**	--

BWT, body weight; HGT, heart girth; ABG, abdominal circumference; RPH, rump height; SHT, shoulder height; EAL, ear length; FLL, fore-leg length; HLL, hind leg length; NLT, neck length; HDL, head length; **, Correlation is significant at the 0.01 level (2-tailed); *, Correlation is significant at the 0.05 level (2-tailed).

ABG and the weakest with RPH. Relationship among the biometric traits showed that highest correlation was observed between FLL and NLT (r = 0.893**) while negatively non-significant correlations were observed between RPH and EL, FLL, HLL and NLT (r = -0.089, -0.292, -0.114 and -0.069 respectively).

The results were similar to the observations of Rotimi *et al*. (2023) and Kebede *et al*. (2022), who also obtained positive values for linear body measurements in camels. Other researchers also reported positive correlation values in chickens (Yosef *et al*. 2014). Positive corrrelation values indicate a direct relationship between these variables, as one variable increases, the other variable also tends to increase which implies a genetic component influencing these traits.

Results of direct and indirect contributions of biometric traits on body weight of female and male camels were evaluated using path analysis procedures. Table 4 shows the path analysis for female camels. Results revealed that SHT (0.437***) had largest direct effects on body weight next by HGT (0.395***) while HGT (0.300) had the greatest indirect influence on body weight via ABG followed by SHT (0.281) via RPH. The strongest correlation with body weight was obtained with HGT (r = 0.877***). This result implies that selection for SHT and HGT in female camels will lead to improvement in body weight.

Table 5 shows the path analysis for male camels. The highest direct effect on body weight was obtained in HGT (0.460***) followed by SHT (0.409***). The highest indirect contribution on body weight was recorded in HGT (0.294) via ABG next is SHT (0.264) via HDL. The highest correlation was estimate between body weight and ABG (r = 0.872***). Path analysis results showed that SHT and HGT can be used for genetic improvement of body weight in both sexes of camels. Selection for SHT and HGT will lead to considerable improvement in the body weight in camels. Several researchers had employed path analysis procedures to evaluate the direct and indirect influence of body measurements on body weight in other livestocks. Bila *et al*. (2021) concluded that body length could be used to predict body weight in Ross 308 breed of broiler chickens, while Liswaniso *et al*. (2020) observed that chest girth had the highest indirect influence on body weight in free-range chickens in Zambian. Yakubu and Mohammed (2012) had also applied analysis procedures to reveal the relationship between body weight and body linear mesurements in Red Sokoto goats in Nigeria and concluded that body length had the greatest direct contribution on body weight. Egena *et al*. (2014) also reported similar result on indigenous chickens in Nigeria where they observed that body length

Table 4. Path coefficient of morphometric traits and body weight of female camels

Trait	Correlation with BWT	Direct effect	Indirect effect									Total effect
			HGT	ABG	RPH	SHT	EAL	FLL	HLL	NLT	HDL	
HGT	0.877**	0.395***	-	0.251	-0.005	0.196	-0.023	0.001	0.002	0.040	0.019	0.876
ABG	0.845**	0.331***	0.300	-	-0.005	0.183	-0.064	0.009	0.002	0.059	0.031	0.846
RPH	0.720**	-0.008NS	0.230	0.187	-	0.281	-0.020	0.002	0.002	0.046	0.000	0.720
SHT	0.765**	0.437***	0.177	0.138	-0.005	-	-0.030	-0.003	0.002	0.037	0.013	0.764
EAL	0.382	-0.112**	0.081	0.189	-0.001	0.118	-	0.009	0.000	0.066	0.032	0.382
FLL	0.125	0.024NS	0.017	0.120	0.000	-0.050	-0.044	-	0.000	0.029	0.029	0125
HLL	0.380	0.005NS	0.136	0.098	-0.004	0.156	-0.000	0.002	-	0.001	-0.013	0.381
NLT	0.610**	0.088NS	0.180	0.220	-0.004	0.184	-0.085	0.008	0.000	-	0.019	0.610
HDL	0.420*	0.062NS	0.123	0.168	0.000	0.088	-0.058	0.011	-0.001	0.027	-	0.420

BWT, body weight; HGT, heart girth; ABG, abdominal circumference; RPH, rump height; SHT, shoulder height; EAL, ear length; FLL, fore-leg length; HLL, hind leg length; NLT, neck length; HDL, head length; ; *, Correlation is significant at the 0.05 level (2-tailed); NS, non-significant.

Table 5. Path coefficient of morphometric traits and body weight of male camels

Trait	Correlation with BWT	Direct effect	Indirect effect									Total effect
			HGT	ABG	RPH	SHT	EAL	FLL	HLL	NLT	HDL	
HGT	0.845**	0.460***	-	0.159	0.047	0.184	0.005	0.066	-0.008	-0.012	-0.056	0.845
ABG	0.872**	0.247**	0.294	-	0.014	0.260	0.011	0.173	-0.020	-0.029	-0.078	0.872
RPH	0.421*	0.086NS	0.250	0.040	-	0.129	-0.002	-0.066	0.004	0.003	-0.023	0.421
SHT	0.789**	0.409***	0.207	0.157	0.027	-	0.008	0.086	-0.018	-0.021	-0.066	0.789
EAL	0.540**	0.018NS	0.168	0.147	-0.008	0.172	-	0.160	-0.011	-0.025	-0.081	0.540
FLL	0.573**	0.226NS	0.133	0.189	-0.025	0.155	0.013	-	-0.022	-0.033	-0.063	0.573
HLL	0.511**	-0.035NS	0.110	0.143	-0.010	0.206	0.006	0.140	-	-0.021	-0.028	0.511
NLT	0.645**	-0.038NS	0.149	0.190	-0.006	0.224	0.012	0.202	-0.019	-	-0.068	0.646
HDL	0.740**	-0.102NS	0.253	0.189	0.019	0.264	0.014	0.139	-0.010	-0.025	-	0.741

BWT, body weight; HGT, heart girth; ABG, abdominal circumference; RPH, rump height; SHT, shoulder height; EAL, ear length; FLL, fore-leg length; HLL, hind leg length; NLT, neck length; HDL, head length; ; *, Correlation is significant at the 0.05 level (2-tailed); NS, non-significant.

gave greatest direct influence on body weight. However, studies involving camels are unavailable in the literature to compare with this result.

The present work evaluated the correlation coefficient between body weight and morphometric parameters of camels using phenotypic correlation coefficients, and the work also used path analysis procedures to estimate direct and indirect influence of biometric parameters on body weight. It was observed that improvement of HGT, ABG, RPH and SHT might lead to increase in body weight of camels. Path analysis revealed that HGT, ABG and SHT in female camels contributed highest direct effects on body weight, while HGT and SHT in males are the important traits in improving body weight. Information obtained from this work can help rural farmers to predict body weight of their animals for purpose of medications, breeding, feeding and marketing purposes. The results will also help camel breeders in selection for linear body measurements for body weight imprtovement.

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