

APPLICATION OF MULTIVARIATE PRINCIPAL COMPONENT ANALYSIS TO MORPHOLOGICAL CHARACTERIZATION OF INDIGENOUS GOATS IN SOUTHERN NIGERIA

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Application of multivariate principal component analysis to morphological characterization of indigenous goats in Southern Nigeria

Phenotypic variation present in a population arises due to genotypic and environmental effects, and the magnitude of phenotypic variability differs under different environmental conditions, therefore, the purpose of this study was to objectively describe the linear type traits of extensively managed mature indigenous goats of Southern Nigeria and to predict body weight from their orthogonal shape characters using principal component analysis. Body weight and four body measurements namely, height at withers, neck length, body length and heart girth were measured in 265 randomly selected West African Dwarf (WAD) and Red Sokoto (RS) goats of both sexes. RS goats had significantly ($P < 0.05$) higher morphological traits compared to their WAD counterparts. Sexual dimorphism was observed in all the traits with higher values recorded for males. Phenotypic correlations among body weight and biometric traits were positive and highly significant ($r = 0.76-0.91$ versus $0.82-0.97$ and $0.66-0.94$ versus $0.83-0.91$ for WAD and RS female and male goats, respectively). In the varimax rotated principal component factor analysis, two factors were extracted for each sex of the two breeds, although with varying degrees of factor loadings. The principal component based regression models, which are preferable for selecting animals for optimal balance, accounted for 89.00 and 96.00% as well as 81.00 and 91.00% of the variation in body weight of female and male WAD and RS goats, respectively. The information obtained could be useful in designing appropriate management, selection and breeding programmes for utilization of goat genetic resources.

Key words: goats / autochthonous breeds / body traits / multivariate analysis / Nigeria

Uporaba multivariatne analize glavnih komponent pri morfološki karakterizaciji avtohtonih koz v južni Nigeriji

Fenotipska variabilnost v populaciji je pogojena z delovanjem genetskih in okoljskih dejavnikov. Ker je obseg fenotipske variabilnosti različen v različnih okoljih, smo skušali v tej študiji objektivno predstaviti linearne eksterierne lastnosti ekstenzivno vzrejanih avtohtonih koz v južni Nigeriji in z analizo glavnih komponent napovedati telesno maso na osnovi lastnosti, ki opredeljujejo njihovo telesno obliko. Izmerili smo telesno maso in štiri telesne mere (višina v vihru, dolžina vratu, dolžina trupa in obseg prsi) pri 265 naključno izbranih zahodno afriških pritlikavih kozah (West African Dwarf, WAD) in rdečih sokoto kozah (Red Sokoto, RS) obeh spolov. Vrednosti za merjene lastnosti so bile pri RS kozah statistično značilno ($p < 0,05$) večje kot pri WAD kozah. Spolni dimorfizem smo zabeležili pri vseh lastnostih, z večjimi vrednostmi za samce. Fenotipske korelacije med telesno maso in biometričnimi lastnostmi so bile pozitivne in statistično visoko značilne ($r = 0,76-0,91$ in $0,82-0,97$ ter $0,66-0,94$ in $0,83-0,91$ za WAD in RS živali ženskega ter moškega spola). S faktorško analizo z Varimax rotacijo smo za vsako od obeh pasem in vsak spol dobili po dva faktorja. Regresijski modeli, ki temeljijo na analizi glavnih komponent in so primerni za selekcijo živali, so pojasnili 89,00 in 96,00 %, ter 81,00 in 91,00 % variance telesne teže ženskih in moških živali pasem WAD in RS. Zbrane informacije bodo uporabne pri upravljanju, selekciji in načrtovanju rejjskih programov za boljše izkoriščanje genskih virov pri kozah.

Ključne besede: koze / avtohtone pasme / telesne mere / multivariatna analiza / Nigerija

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1 INTRODUCTION

Livestock of different species fulfill different functions in the household economy and poor families often keep a diversity of species for this reason (Anderson, 2003). Domestic goats (*Capra hircus*, L.) are important and adaptable domesticated animals (Abdel Aziz, 2010). They provide a full range of useful products to humans including meat, milk, skin and hair. They efficiently survive on available shrubs and trees in adverse harsh environment and in low fertility lands where no other crops can be grown in Nigeria. Goat production over the years is one of the major means of improving the livelihoods of poor livestock keepers, reducing poverty and attaining sustainable agriculture and universal food security (Abdel Aziz, 2010). The population of goats in Nigeria is estimated at 53.8 million (FAOSTAT, 2011) of which traditionally reared stock contributes 99.97%, while 0.03% of the stock is commercially managed. Based on morphology, the two most important goat breeds traditionally recognized in Nigeria are the Red Sokoto (RS) and the West African Dwarf (WAD) goats, respectively (Ebozoje and Ikeobi, 1998). The WAD goat, which is trypanotolerant, is native to the southern rain forest and derived savanah zones while the RS goat, highly reputed for its quality skin (found more in the northern axis) is more widely distributed across the country.

The diversity in gene pool and influence of varied climatic conditions have given rise to different local populations of goats which are repositories of unique genes that should be conserved for local and international future benefits (Adebambo, 2004). According to Groeneveld *et al.* (2010), identifying and understanding a unique genetic resource in a particular region and the development and proper use of the associated diversity is a global responsibility. Breed characterization has accordingly been recognized as the first approach to the sustainable use of animal genetic resource (Lanari *et al.*, 2003). It is believed that various breed characteristics provide to some extent reasonable economic indicators. Body size and shape are important traits in meat animals. The characterization of local genetic resources depends on the knowledge of the variation of morphological traits, which have played a very fundamental role in classification of livestock based on size and shape (Ferra *et al.*, 2010; Agga *et al.*, 2010; Leng *et al.*, 2010; Yakubu *et al.*, 2010a and b). Based on body conformation, meat production can better be estimated than other production properties making body measurements important selection criteria (Bene *et al.*, 2007).

However, the biological relationships among the morphological traits may be different if these body measurements are treated as bivariate rather than mul-

tivariate. Principal component analysis is a multivariate technique which could be used with success when morphological variables are interdependent. Principal components are a weighted linear combination of correlated variables, explaining a maximal amount of variance of the variables (Truxillo, 2003). This aids in data reduction, and breaks multicollinearity which may lead to wrong inferences. Many researchers have used the independent factor scores derived from multivariate technique of principal component factor analysis to estimate body weight (Yakubu and Ayoade, 2009), functional traits (Karacaoren and Kardamideen, 2008), and as a selection criterion for the improvement of body size (Pinto *et al.*, 2006). This technique has also been used to reduce the number of independent variables in the prediction of genomic breeding values (Macciotta and Gaspa, 2009). In Sub-Saharan Africa, there is dearth of information on the interrelationships among body weight and morphometric traits of goats using a multivariate approach.

This study was aimed at providing objective description of body shape of WAD and RS goats in southern Nigeria using principal components. It also tested the hypothesis that the relationships involving body weight and morphological traits may be different when orthogonal conformation traits derived from the principal component factor analysis are used instead of the inter-correlated original morphological variables. The information obtained would be helpful to researchers and livestock producers with policies to assist conservation and sustainable utilization of the local goat genetic resources by the proper use of morphological traits.

2 MATERIALS AND METHODS

2.1 LOCATION OF STUDY AND ANIMALS

The study was carried out in five randomly selected states in southern Nigeria; namely Ogun, Oyo, Bayelsa, Delta and Rivers States, respectively. This region lies between the derived guinea savannah and the dense rain forest, bordered by the Atlantic Ocean.

Two hundred and sixty five mature goats comprising 118 West African Dwarf (WAD) (83 females and 35 males) and 147 Red Sokoto (RS) (37 females and 112 males) goats were randomly sampled in towns and villages. The animals were up to 24 months old as determined by dentition as described by Wilson and Durkin (1984). The goats originated from different flocks and were reared under the traditional extensive system.

2.2 TRAITS MEASURED

The following measurements were taken on each animal:

Body weight (BWT): This was taken using a hanging scale. The animals were turned on their back in a Hessian bag and the weight taken as the difference between the final combined weight and the weight of the bag.

Height at withers (HW): A flat platform was used upon which the animal was placed. The height at withers was measured as the distance from the surface of the platform to the withers using a measuring stick.

Neck length (NL): The neck length was taken as a measure from the base of the skull to the point of connection with the trunk using a tape-rule.

Body length (BL): Body length was measured using a tape-rule, as the distance from the occipital protuberance to the base of the tail.

Heart girth (HG): The heart girth was measured by taking the measurement of the circumference of the chest with a tape-rule.

2.4 STATISTICAL ANALYSIS

The morphological traits were subjected to analysis of variance to determine genotype and sex effects. Means were separated using the two-tailed, two-sample t-test. Pearson's coefficients of correlation (r) among body weight and the four morphometric traits were estimated. From the correlation matrix, data were generated for the principal component (PC) factor analysis. The determinant of the correlation matrix was used to test for multicollinearity and singularity. Anti-image correlations, Kaiser-Meyer-Olkin measures of sampling adequacy and Bartlett's Test of Sphericity (to test the null hypothesis that the original correlation matrix is an identity matrix) were computed to test the validity of the factor analysis of the data sets. The appropriateness of the factor analysis was further tested using communalities and ratio of cases to variables. Principal component analysis according to Everitt *et al.* (2001) is a method for transforming variables in a multivariate data set into new variables, which are uncorrelated with each other and account for decreasing proportions of the total variance of the original variables. The components themselves are merely weighted linear combinations of the original variables. Cumulative proportion of variance criterion was employed in determining the number of principal components to extract. Reproduced and residual correlations were used to test the validity of the number of factors extracted. The varimax criterion of the orthogonal rotation method was employed in the rotation of the factor

matrix to enhance the interpretability of the principal components.

The stepwise multiple regression procedure was used to obtain models for predicting body weight from body measurements (1) and from principal component factor scores (2):

$$BW = a + B_i X_i + \dots + B_k X_k \quad (1)$$

$$BW = a + B_i PC_i + \dots + B_k PC_k \quad (2)$$

where BW is the body weight, a is the regression intercept, B_i is the i -th partial regression coefficient of the i -th linear body measurement, X_i or the i -th principal component (PC).

The factor programme of SPSS (2001) statistical package was used for the principal component analysis.

3 RESULTS AND DISCUSSION

3.1 BODY WEIGHT AND MORPHOLOGY TRAITS

Descriptive statistics of body weight and morphometric traits of WAD and RS goats are presented in Table 1. Average body weight was significantly ($P < 0.05$) higher in RS than in WAD goats. Overall body linear measurements for the RS were also higher ($P < 0.05$) for the RS goats compared to their WAD counterparts. All morphometric traits estimated in this study were higher in males compared to female animals. The higher body measures of RS goats imply that they are heavier, taller and longer breed compared to WAD. Dossa *et al.* (2007) reported higher average values of 56.57 cm and 79.23 cm for HW and BL respectively for Benin goat populations compared to 54.46 cm and 49.89 cm respectively in Nigerian goats. The large differences in BL between Nigerian and Benin goats may be partially explained by both different methodologies used in measurements and inherent genetic and gene-by-environment differences.

Sexual dimorphism can be phenotypically expressed as differences in skeletal size and/or body mass. The larger values reported for the conformation traits of males compared to females are in agreement with earlier reports on goats (Vargas *et al.*, 2007), sheep (Yakubu and Akinyemi, 2010) and cattle (Polak and Frynta, 2010), respectively. The influence of sex on the body weight and morphometric traits in this study are likely connected with the usual between-sex hormonal action which leads to differential growth rates. Isaac *et al.* (2005) reported that sexual dimorphism in body size is clearly widespread among many mammalian taxa, with male-biased dimorphism being the more common, but certainly not the exclusive pattern. However, Bacchi *et al.*, (2010) found no

Table 1: Descriptive statistics of the morphological traits of Nigerian goats based on genotype and sex
Preglednica 1: Opisna statistika morfoloških lastnosti nigerijskih koz ob upoštevanju genotipa in spola

Traits Lastnosti	WAD			Red Sokoto			Female Ženske			Male Moški		
	Mean	SE	SD	Mean	SE	SD	Mean	SE	SD	Mean	SE	SD
BW	15.37 ^b	0.38	4.14	18.99 ^a	0.36	4.41	15.58 ^b	0.34	3.76	18.86 ^a	0.40	4.79
HW	47.88 ^b	0.50	5.47	61.04 ^a	0.54	6.64	50.74 ^b	0.68	7.42	58.89 ^a	0.70	8.48
NL	19.06 ^b	0.37	3.99	24.15 ^a	0.57	6.99	19.43 ^b	0.35	3.80	23.91 ^a	0.60	7.29
BL	44.86 ^b	0.50	5.40	57.89 ^a	0.53	6.47	47.32 ^b	0.65	7.11	56.05 ^a	0.67	8.16
HG	58.21 ^b	0.60	6.47	65.95 ^a	0.69	8.44	59.12 ^b	0.65	7.13	65.31 ^a	0.71	8.60

BW – body weight / telesna masa, WH – withers height / višina vihra, NL – neck length / dolžina vratu, BL – body length / dolžina trupa, HG – Heart girth / obseg prsi, SE – standard error / standardna napaka, SD – standard deviation / standardni odklon

^{a,b} Means in the same row bearing different superscripts are significantly different ($P < 0.05$) / Povprečja v vsaki vrsti, označena z različnimi črkami, se značilno razlikujejo ($p < 0,05$).

sexual dimorphism in the morphometric characters considered in *Lama guanicoe guanicoe* in Argentina. Yakubu (2009) reported that the morphological traits of male and female goats were similar, although this submission were for kids compared to data reported for relatively mature animals in the present study.

3.2 PHENOTYPIC CORRELATIONS

Pearson's coefficients of correlation among the various linear type traits for WAD and RS goats are shown in Tables 2 and 3, respectively. In WAD goats, the highest correlation between BW and linear body measurements was recorded for BW and HW in males ($r = 0.97$) and between BW and HG in females ($r = 0.91$). In RS goats, however, the highest correlation was between BW and chest circumference in both sexes ($r = 0.94$ and 0.91 ;

Table 2: Phenotypic correlations among body weight and linear body measurements of WAD goats according to sex ***Preglednica 2:** Fenotipske korelacije med telesno maso in linearnimi meritvami pri WAD kozah glede na spol *

Traits	BW	WH	NL	BL	HG
BW		0.86	0.76	0.91	0.91
WH	0.97		0.80	0.93	0.81
NL	0.82	0.88		0.86	0.72
BL	0.95	0.98	0.91		0.84
HG	0.95	0.93	0.80	0.90	

BW – body weight / telesna masa, WH – withers height / višina vihra, NL – neck length / dolžina vratu, BL – body length / dolžina trupa, HG – Heart girth / obseg prsi;

* Significant at $P < 0.01$ for all correlation coefficients / Značilno pri $p < 0,01$ za vse korelacijske koeficiente.

Upper matrix: Female goats / Zgornja matrika: ženske živali.

Lower matrix: Male goats / Spodnja matrika: moške živali.

Table 3: Phenotypic correlations among body weight and linear body measurements of RS goats according to sex ***Preglednica 3:** Fenotipske korelacije med telesno maso in linearnimi meritvami pri RS kozah glede na spol *

Traits	BW	WH	NL	BL	HG
BW		0.76	0.66	0.81	0.94
WH	0.85		0.71	0.80	0.80
NL	0.90	0.79		0.57	0.67
BL	0.83	0.85	0.76		0.83
HG	0.91	0.84	0.81	0.86	

BW – body weight / telesna masa, WH – withers height / višina vihra, NL – neck length / dolžina vratu, BL – body length / dolžina trupa, HG – Heart girth / obseg prsi;

* Significant at $P < 0.01$ for all correlation coefficients / Značilno pri $p < 0,01$ za vse korelacijske koeficiente.

Upper matrix: Female goats / Zgornja matrika: ženske živali.

Lower matrix: Male goats / Spodnja matrika: moške živali.

$P < 0.01$ for both female and male animals, respectively). The relationship between BW and NL was lowest in both sexes of WAD goats ($r = 0.76$ and 0.82 in female and male animals, respectively). While the lowest correlation was equally reported for BW and NL in female RS goats ($r = 0.66$), that between BW and BL was observed to be lowest in their male counterparts ($r = 0.83$). The correlation coefficients among body measurements were positive and significant ($P < 0.01$) in both sexes of the two goat breeds. The present estimates are comparable to the range of values recorded for goats in earlier researches (Yakubu, 2009; Sowande *et al.*, 2010). The positive correlations between BW and morphological traits obtained in the present study indicate that an increase in any one body measurement would result in a corresponding increase in live body weight. The strong relationship existing between BW and body measurements suggests that either or the combination of these morphological traits

could be used to estimate live weight in goats fairly well in the situation where weighbridges or scales are not available. The association may also be useful as selection criterion since positive correlations of traits suggest that the traits may be under the same genetic influences.

3.3 PRINCIPAL COMPONENT MATRIX

The determinants of the correlation matrix (0.011 versus 0.001, and 0.044 versus 0.018 for female and male WAD and RS goats, respectively) (Tables 4 and 5) were greater than 0.00001 (minimum requirement) while anti – image correlations computed showed that partial correlations were low, indicating that true factors existed in the data of both sexes of the two goat breeds. This was supported by Kaiser-Meyer- Olkin measure of sampling adequacy studied from the diagonal of partial

correlation, revealing the proportion of the variance in the body measurements caused by the underlying factor. This was found to be sufficiently high for all the morphometric traits in WAD (0.84 and 0.81 for female and male animals) and RS (0.81 and 0.86) goats, respectively. The overall significance of the correlation matrices tested with Bartlett's Test of Sphericity for the body dimensions of the WAD goats (chi-square = 361.38 versus 217.75 for female and male animals; $P < 0.01$) and for RS goats (chi-square = 105.78 versus 436.65; $P < 0.01$) provided enough support for the validity of the factor analysis of the data set. The communalities, which represent the proportion of the variance in the original variables that is accounted for by the factor solution, ranged from 0.91–0.99 in WAD and 0.86–0.99 in RS goats, respectively. These further lend credence to the appropriateness of the factor analysis. The ratio of cases to variables (24 to 1 in WAD and 29 to 1 in RS goats far exceeding the minimum of 5 to 1 standard) was also met as sample size requirement, while estimates of the residual correlation matrix were low enough.

After varimax rotation of the component matrix in WAD goats, two factors were extracted for each sex, and these accounted for 94.15% (females) and 97.65% (males) of the total variance. The factor pattern coefficients were used to assess the relative contributions of the various body measurements in determining the numerical value of the corresponding factor (principal component). In female WAD goats, NL and BL were more associated with the first PC while the second PC had its loadings for HW and HG, respectively. In their male counterparts, PC1 had its loadings for HG, BL and HW while PC2 was solely related to neck length. However, in RS goats, measurements most highly correlated with PC1 were BL, HG and HW (this explained 79.89% and 86.38% of the generalized variance of females and males, respectively), and could be termed "body size factor". PC2 was primarily determined by neck length, which accounted for 11.36% (females) and 6.46% (males) of the variation. The principal components obtained in the present study could be used alongside other economic parameters in evaluating animals for management purposes. Similar findings have earlier been reported (Sadek *et al.*, 2006; Yakubu *et al.*, 2009; Yakubu *et al.*, 2011). Principal com-

Table 4: Eigenvalues and share of total variance along with factor loadings and communalities of the body measurements of WAD goats based on sex

Preglednica 4: Eigen vrednosti in delež celokupne variance s korelacijskimi koeficienti ter skupno varianco faktorjev za telesne mere pri obeh spolih WAD koz

Traits	Female			Male		
	PC1	PC2	Communality	PC1	PC2	Communality
WH	0.66	0.68	0.91	0.77	0.62	0.98
NL	0.91	0.37	0.96	0.45	0.88	0.99
BL	0.71	0.67	0.95	0.70	0.69	0.97
HG	0.37	0.90	0.96	0.89	0.43	0.98
Eigenvalue	3.48	0.29		3.70	0.21	
% Variance	87.00	7.15		92.46	5.19	

WH – withers height / višina vihra, NL – neck length / dolžina vratu, BL – body length / dolžina trupa, HG – Heart girth / obseg prsi;
PC – principal component / glavna komponenta

Table 5: Eigenvalues and share of total variance along with factor loadings and communalities of the body measurements of Red Sokoto goats based on sex

Preglednica 5: Eigen vrednosti in delež celokupne variance s korelacijskimi koeficienti ter skupno varianco faktorjev za telesne mere pri obeh spolih RS koz

Traits	Female			Male		
	PC1	PC2	Communality	PC1	PC2	Communality
WH	0.77	0.52	0.86	0.82	0.47	0.89
NL	0.34	0.93	0.99	0.45	0.89	0.99
BL	0.93	0.25	0.92	0.88	0.39	0.93
HG	0.84	0.42	0.88	0.77	0.55	0.90
Eigenvalue	3.20	0.45		3.46	0.26	
% Variance	79.89	11.36		86.38	6.46	

WH – withers height / višina vihra, NL – neck length / dolžina vratu, BL – body length / dolžina trupa, HG – Heart girth / obseg prsi;
PC – principal component / glavna komponenta

ponent analysis has also been employed in determining sex-specific differences in size and morphology of bones of North African gazelle species (Andres *et al.*, 2008) and carcass traits of goats (Bonvillani *et al.*, 2010).

Table 6: Principal component factor scores coefficients for the estimation of body weights of breed 1 and breed 2 goats based on sex

Preglednica 6: Regresijski koeficienti glavnih komponent za oceno telesne mase dveh pasem koz glede na spol

Traits	WAD		Red Sokoto					
	Female	Male	Female	Male				
WH	0.15	0.24	0.44	-0.08	0.27	0.13	0.52	-0.23
NL	1.11	-0.75	-0.93	1.37	-0.51	1.16	-0.81	1.46
BL	0.26	0.14	0.09	0.29	0.66	-0.44	0.79	-0.57
HG	-0.75	1.13	1.15	-0.86	0.43	-0.10	0.31	0.05

WH – withers height / višina vihra, NL – neck length / dolžina vratu, BL – body length / dolžina trupa, HG – Heart girth / obseg prsi;

Table 7: Stepwise multiple regression of body weight on original body measurements and on their principal components factor scores of WAD goats

Preglednica 7: Postopna multipla regresija telesne mase na originalne telesne mere in na faktorske vrednosti glavnih komponent pri WAD kozah

Model	Explanatory variables (predictors)	Intercept	Regression Coefficient	SE	R ²
Female					
(i)	Original body measurements as predictors				
1	Heart girth	-18.59	0.58	0.03	83.00
2	Heart girth	-20.96	0.32	0.04	90.00
	Body length		0.39	0.05	
(ii)	Orthogonal traits as predictors				
1	PC1	14.77	2.93	0.25	63.00
2	PC1	14.77	2.93	0.14	89.00
	PC2		1.89	0.14	
Male					
(i)	Original body measurements as predictors				
1	Height at withers	-17.12	0.68	0.03	94.20
2	Height at withers	-19.57	0.44	0.07	96.00
	Heart girth		0.24	0.06	
(ii)	Orthogonal traits as predictors				
1	PC2	16.81	4.00	0.46	70.00
2	PC2	16.81	4.00	0.16	96.40
	PC1		2.48	0.16	

SE – standard error / standardna napaka, R² – coefficient of determination / determinacijski koeficient, PC – principal component / glavna komponenta

3.4 PRINCIPAL COMPONENT FACTOR SCORES

The principal component factor score coefficients of female and male WAD and RS goats are presented in Table 6. The factor score coefficients could be used in instead of the original interdependent morphological traits in predicting the body weight of goats.

3.5 ESTIMATION OF BODY WEIGHT OF GOATS FROM INTERDEPENDENT BODY MEASUREMENTS AND THEIR INDEPENDENT PRINCIPAL COMPONENT FACTOR SCORES

The interdependent original body measurements and their independent principal component scores were used to predict body weight of goats (Tables 7 and 8). The results of the stepwise multiple regression analysis revealed that HG was the single variable of utmost importance in the prediction of BW in both breeds, with the exception of male WAD goats, where HW alone account-

Table 8: Stepwise multiple regression of body weight on original body measurements and on their principal components factor scores of Red Sokoto goats**Preglednica 8:** Postopna multipla regresija telesne mase na originalne telesne mere in na faktorske vrednosti glavnih component pri RS kozah

Model	Explanatory variables (predictors)	Intercept	Regression Coefficient	SE	R ²
Female					
(i)	Original body measurements as predictors				
1	Heart girth	-6.58	0.39	0.02	89.00
(ii)	Orthogonal traits as predictors				
1	PC1	17.42	2.57	0.33	63.00
2	PC1	14.42	2.57	0.24	81.00
	PC2		1.34	0.24	
Male					
(i)	Original body measurements as predictors				
1	Heart girth	-13.94	0.50	0.02	83.00
2	Heart girth	-6.94	0.29	0.03	91.10
	Neck length		0.29	0.03	
(ii)	Orthogonal traits as predictors				
1	PC2	19.50	3.23	0.32	49.00
2	PC2	19.50	3.23	0.14	91.00
	PC1		3.00	0.14	

SE – standard error / standardna napaka, R² – coefficient of determination / determinacijski koeficient, PC – principal component / glavna komponenta

ed for 94.20% of the variation in body weight. However, a combination of HG and BL (females) and HW and HG (males) of WAD goats increased the proportion of the explained variance to 90.00% and 96.00%, respectively. Similarly, the accuracy of the prediction model was improved (91.10%) in male RS goats when NL was added to HG.

The possibility of using simple body measurements that can be carried out in the field to predict important economic traits have been demonstrated (Vargas *et al.*, 2007; Ozkaya and Bozkurt, 2009; Yakubu 2010a and b). Badi *et al.* (2002) and Leng *et al.* (2010) recommended the use of heart girth as the most reliable variable to predict BW under field conditions. The importance of HG in weight estimation could be as a result of the fact that muscle, some fat along with bone structure contribute to its formation. However, the use of interdependent explanatory variables should be treated with caution since multicollinearity has been shown to be associated with unstable estimates of regression coefficients (Malau-Adu-li *et al.*, 2004), rendering the estimation of the unique effects of the predictors impossible. This justifies the use of principal component factor scores for prediction. These

factors are orthogonal to each other and are more reliable in weight estimation. PC1 and PC2 together accounted for 89.00% and 96.40% of the variation in body weight of female and male WAD goats, respectively. In RS goats, a combination of PC1 and PC2 explained 81.00% (females) and 91.00% (males) of the total variability in body weight. Similarly, Keskin *et al.* (2007) and Eyduran *et al.* (2009) used factor score coefficients to predict carcass and weaning weights, respectively in small ruminants.

4 CONCLUSIONS

The principal component factor analysis led to an objective simultaneous analysis of WH, NL, BL and HG of WAD and RS goats rather than on individual basis. This resulted in the reduction of the body dimensions to two PCs in each sex of the two goat breeds. The resultant factor score coefficients could be used to predict body weight with more accuracy than the original interdependent variables. This is because multicollinearity of two or more independent body measurements could lead to unstable regression coefficients, thereby leading to er-

roneous inferences. Results of the present investigation could assist farmers and genetic improvement specialists when conducting management, selection and preservation programs in Nigerian goats.

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