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PATH COEFFICIENT AND PATH ANALYSIS OF BODY WEIGHT AND BIOMETRIC TRAITS IN YANKASA LAMBS

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ABSTRACT

Direct and indirect effects of seven predictor variables (withers height, body length, heart girth, shoulder width, head width, rump width and rump length) on body weight of 92 extensively managed Yankasa lambs aged 11.8±3.02 (females) and 12.5±2.56 (males) months were investigated using path analysis. Sex-associated difference was significant ($P<0.05$) only for withers height, with higher value recorded for male lambs. Pairwise correlations between body weight and zoometrical traits ranged from 0.59-0.95 and 0.61-0.92 for male and female lambs, respectively. The direct effect of heart girth on body weight was the strongest in both sexes (path coefficient of 0.81 and 0.87 in males and females, respectively). Head width (males) and body length (females) also positively ($P<0.05$) influenced body weight. The direct effects of other linear type traits on body weight in both sexes were non-significant as revealed by t-test. These traits were indirectly realized mostly via heart girth. Thus, they were expunged from the final regression equations to obtain much more simplified prediction models. The optimum multiple regression equation for male lambs included heart girth and head width, with a determination coefficient (R^2) of 0.919 and determination coefficient of error of 0.081. In female lambs, however, the variables included in the final prediction model were heart girth and body length, with a determination coefficient of 0.893 and determination coefficient of error of 0.107. The forecast indices obtained in this study could aid in weight estimation, selection and breeding programmes.

Key words: Body weight; body dimensions; path analysis; Yankasa lambs; Nigeria

INTRODUCTION

Body weight is an important economic trait in the selection of animals. The main purpose of animal breeding practices is to improve traits of economic value (Mendes *et al*., 2005). These traits have close association with explanatory variables such as age, breed and morphological characters. Body measurements have been used in animals to estimate body weight (Topal and Macit, 2004; Yakubu *et al.,* 2005), especially in rural communities where scales are not readily available. However, using simple correlation coefficients between body weight and morphometric measures may not explain the relationships in all aspects and may be inadequate in investigating the causal effects among biologically related variables. In order to address this limitation, path coefficient and path analysis could be more suitable.

Path analysis measures a direct and indirect effect of one variable on another and also separates the correlation coefficients into components of direct effect, indirect effect and compound path (Topal and Esenbuga, 2001; Keskin *et al*., 2005). It is an extension of the multiple regression model, which permits the determination of the explanatory variables that affect mostly the response variable.

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Yankasa sheep is one of the prominent sheep breeds in Nigeria. However, multivariate analysis technique involving the use of path analysis has not been exploited in showing the relationship between its body weight and body measurements. The present investigation therefore aimed at establishing direct and indirect causal effects between body weight and some linear body measurements of Yankasa lambs. The results so obtained could be used to predict body weight in the field and for selection purposes.

MATERIAL AND METHODS

Location of study and experimental animals

Data were obtained from 92 randomly selected Yankasa lambs (37 males and 55 females) between May and July, 2008. The animals were reared through the extensive system in certain smallholder farms in Nasarawa State, north central Nigeria. The state is located between latitude 08^{0}35'N and longitude 08^{0}33'E. The animals were <15.5 months old (milk-tooth age) following non-eruption of permanent incisors as described by Wilson and Durkin (1984). The average age (Mean±standard deviation) of the female animals was 11.8±3.02 months with minimum and maximum values of 4.0 and 15.3 months, respectively. However, the males were 12.5±2.56 months old with minimum and maximum values of 4.5 and 15.4 months, respectively. There was no significant sex difference in the ages of the lambs (F = 1.399; P<0.240). The animals grazed during the day on natural pasture containing forages such as northern gamba grass (*Andropogon gayanus*), stylo (*Stylosanthes gracilis*), leucaena (*Leucaena leucocephala*) and guinea grass (*Panicum maximum*), and returned to the homestead in the evening. Occasionally, they were given cassava peels, *dusa* (fermented sorghum waste), groundnut haulms, cowpea hulls and kitchen wastes as supplements.

Traits measured

Body weight was measured along with seven biometric traits on each animal following standard procedure and anatomical reference points as indicated in Figure 1 (Yakubu, 2009). They were withers height (WH), body length (BL), heart girth (HG), shoulder width (SW), head width (HW), rump width (RW) and rump length (RL). A graduated measuring stick was used for the height measurements, while the length and circumference measurements were done using a flexible tape; and a special wooden calipers was used for the width measurements. In order to avoid intra-individual variations, all measurements were taken by the same person.

Statistical analysis

Means, standard deviations (SD) and coefficients of variation (CV) of the body weight and linear body measurements of Yankasa lambs were computed. Pairwise correlations among body weight and morphometric characters were also determined separately for each sex. Standardized partial regression coefficients called path coefficients (beta weights) were calculated, too. This was to allow direct comparison of values to reflect the relative importance of independent variables in order to explain variation in the dependent variable (Seker and Serin, 2004). Path analysis is a subset of Structural Equation Modeling (SEM), the multivariate procedure, which, as defined by Ullman (1996), allows examination of a set of relationships between one or more independent variables, either continuous or discrete, and one or more dependent variables, either continuous or discrete. SEM deals with measured and latent variables. Measured variables are also known as observable variables. A latent variable (factor), however, is a variable which cannot be observed directly and must be inferred from measurable variables. SEM is a combination of multiple regression and factor analysis. Path analysis, on the other hand, deals only with measured variables (in the present study, the observed variables were body weight, withers height, body length, heart girth, shoulder width, head width, rump width and rump length). Path analysis model is not a substitute for regression analysis; rather it is a complementary methodology to regression analysis (Jeonghoon, 2002). In path analysis, it is assumed that the residuals (error terms) are uncorrelated with the variables in the model and with each other.

The path coefficient from an explanatory variable (X) to a response variable (Y) as described by Mendes *et al*. (2005) is shown below:

$$\mathbf{P_{Y.Xi} = b_i \frac{S_{Xi}}{S_Y}}$$

where:

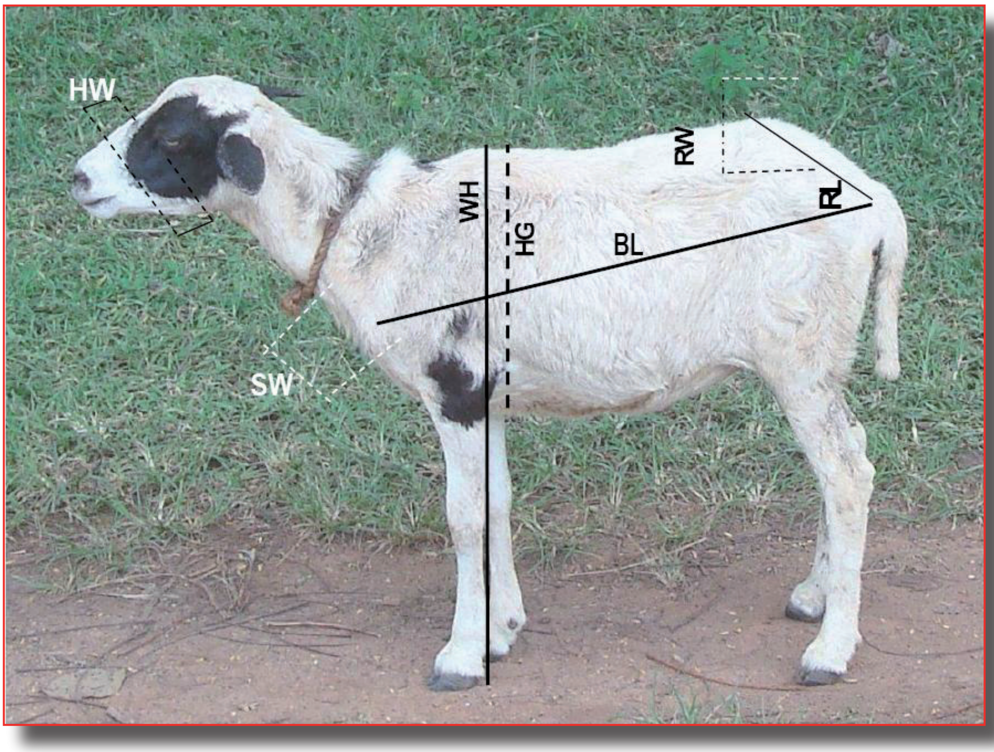
$P_{Y.Xi}$ = path coefficient from X_i to Y (i= WH, BL, HG, SW, HW, RW, RL),
b_i = partial regression coefficient,
S_{Xi} = standard deviation of X_i ,
S_Y = standard deviation of Y.

The multiple linear regression model adopted was:

$$\mathbf{Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + e}$$

where:

Y = endogenous variable (body weight),
a = intercept,
b's = regression coefficients,
X's = exogenous variables (WH, BL, HG, SW, HW, RW, RL),
e = error term, normally distributed with mean zero and variance .



WH = Withers height, BL = Body length, HG = Heart girth, SW = Shoulder width,
HW = Head width, RW = Rump width and RL = Rump length

Fig. 1: Yankasa sheep showing the anatomical parts measured in this study

The significance of each path coefficient in the multiple linear regression model was tested by t-test using the following model (Sangun *et al*., 2009):

$$t_j = \frac{b_j - \beta_j}{\sqrt{var(b_j)}} \sim t_{\alpha\,(n-p-1)\,;\; j = 1,2,\ldots,P}$$

where:

$var(b_j)$ = the diagonal member of matrix $s^2\,(X'X)^{-1}$, s^2 = mean square of residual obtained from ANOVA.

The indirect effects of X_i on Y through X_j were calculated as follows:

$$IE_{YXi} = r_{XiXj} P_{Y.Xj}$$

where:

IE_{YXi} = the direct effect of X_i via X_j on Y,
r_{XiXj} = correlation coefficient between ith and jth independent variables,
$P_{Y.Xj}$ = path coefficient that indicates the direct effect of jth independent variable on the dependent variable.

Coefficient of determination (R^2) was partitioned into its components using path analysis as follows:

$$R^2 = P^2_{Y.X1} + P^2_{Y.X2} + P^2_{Y.X3} + P^2_{Y.X4} + P^2_{Y.5} + P^2_{Y.6} + P^2_{Y.X7} + 2r_{X1X2}P_{Y.X1}P_{Y.X2} + 2r_{X1X3}P_{Y.X1}P_{Y.X3} + 2r_{X1X4}P_{Y.X1}P_{Y.X4} + 2r_{X1X5}P_{Y.X1}P_{Y.X5} + 2r_{X1X6}P_{Y.X1}P_{Y.X6} + 2r_{X1X7}P_{Y.X1}P_{Y.X7} + 2r_{X2X3}P_{Y.X2}P_{Y.X3} + 2r_{X2X4}P_{Y.X2}P_{Y.X4} + 2r_{X2X5}P_{Y.X2}P_{Y.X5} + 2r_{X2X6}P_{Y.X2}P_{Y.X6} + 2r_{X2X7}P_{Y.X2}P_{Y.X7} + 2r_{X3X4}P_{Y.X3}P_{Y.X4} + 2r_{X3X5}P_{Y.X3}P_{Y.X5} + 2r_{X3X6}P_{Y.X3}P_{Y.X6} + 2r_{X3X7}P_{Y.X3}P_{Y.X7} + 2r_{X4X5}P_{Y.X4}P_{Y.X5} + 2r_{X4X6}P_{Y.X4}P_{Y.X6} + 2r_{X4X7}P_{Y.X4}P_{Y.X7} + 2r_{X5X6}P_{Y.X5}P_{Y.X6} + 2r_{X5X7}P_{Y.X5}P_{Y.X7} + 2r_{X6X7}P_{Y.X6}P_{Y.X7}$$

where:

$P^2_{Y.Xi}$ = direct effects of explanatory variables (WH, BL, HG, SW, HW, RW, RL) in contributing to the variation of Y (body weight); $2r_{XiXj}\,(P_{Y.Xi})(P_{Y.Xj})$ = combined effects of explanatory variables (WH, BL, HG, SW, HW, RW, RL) in contributing to the variation of Y (body weight).

The explanatory variables were screened for multicollinearity problems using variance inflation factors (VIF) and tolerance (T) values. SPSS (2001) statistical package was used for the analysis.

RESULTS AND DISCUSSION

Morphological traits

The means, standard deviations and coefficients of variation of each of body weight and linear body measurements of Yankasa lambs of both sexes are presented in Table 1. Although the males had higher numerical mean values for all the morphometric measurements, significant sex-associated difference (P<0.05) was only evident in withers height. The body weight values obtained in this study are higher than the overall productivity index of 11.0±0.87kg recorded for Tswana lambs in Botswana (Economides, 1983). However, the withers height, body length, heart girth, shoulder width, rump width and rump length values are lower than the 66.02, 59.75, 72.30, 14.52, 12.98 and 22.27cm recorded for Uda lambs (Yakubu, 2003). This is not quite surprising as Uda sheep, ranked second among Nigerian breeds of sheep, is a bigger animal in terms of body configuration compared to their Yankasa counterparts. The body weight (18.0±3.5kg) of Landim lambs in Mozambique less than 15.5 months old (Rochas *et al*., 1991) is higher than that of Yankasa lambs. While the present biometric estimates are higher than those reported for 12 months old Garole lambs in India (Sahana *et al*., 2001), they are lower than the values recorded for Awassi lambs in Jordan (Jawasreh and Khasawney, 2007).

The present results revealed that morphometric characters of sheep are genetically controlled and unique to each breed of sheep. The tall and leggy conformation of Yankasa lambs is attributable to its suitability to the almost free and wide-ranging mode of grazing in search of pasture and water under subtropical conditions of north central Nigeria. The sexual dimorphism observed in the present study could be as a result of the usual inter-sex differential hormonal action, which invariably leads to differential growth rates in male and female animals. Sexual differences in Awassi lambs had also been reported (Al-Tarayrah and Tabbaa, 1999). However, Thiruvenkadan (2005) and Yakubu (2009) found no significant sex differences in body weight and body measurements of goat kids. Body weight and rump width appeared to be more variable in both sexes; and this might not be unrelated with the influence of the environment on these parameters.

Bivariate correlations

Pairwise correlations among body weight and linear type traits of the two sexes are presented in Table 2. The association existing between body weight and biometric traits was observed to be strong in both sexes (r =0.59-0.95 and 0.61-0.92; P<0.01 for male and female lambs, respectively). However, the highest correlation was between body weight and heart girth in both sexes, while the lowest correlation was observed between body weight and head width in males and body weight and rump width in females. The body dimensions were also positively and significantly correlated with each other (r = 0.42-0.88 and 0.49-0.92; P<0.01 for males and females, respectively). There were no multicollinearity problems among the body measurements, since preliminary analysis revealed that the variance inflation factor (VIF) value was smaller than 10 (Pimentel *et al*., 2007) and the tolerance (T) value was greater than 0.1 (Gill, 1986) in all cases.

Estimates of correlation obtained in this study reflect active growth of body size and conformation at this age. Given that the majority of genes influencing the configuration of an animal are of common action and not local, the formation of one part is found narrowly correlated with the formation of the other (Lener and Donald, 1996). Thiruvenkadan (2005) reported high correlations between body weight and morphometric measurements of Kanni Adu kids under farmers' management. Aziz and Sharaby (1993) reached similar inferences regarding correlations between body weight and body dimensions of Nadji ram lambs. The varying phenotypic correlation coefficients in the two sexes suggest sexual differences in the genetic architecture of the lambs. The implications of the positive relationships in the present study are that body weight could be estimated from body measurements, especially under village conditions where scales are not readily available. The association may also be useful as selection criterion, since positive correlations of traits suggest that the traits are under the same gene action (pleiotropy).

Path coefficients of explanatory variables

Path coefficients of the independent variables of male lambs are presented in Table 3. Path analysis permits the partitioning of correlation coefficient into component parts (Marjanovic-Jeromela *et al*., 2008). The first component is the path coefficient (beta weight) that measures the direct effect of the predictor variable on the response variable. The second component estimates the indirect effect of the predictor variable on the response variable through other predictor variables. Although the correlation coefficient between withers height and body weight in the present study was high (r = 0.85), its direct

Table 1: Descriptive statistics of body weight and body dimensions of Yankasa lambs

Trait	Female lambs (n= 55)			Male lambs (n= 37)		
	Mean	SD	CV	Mean	SD	CV
BW (kg)	15.28[a]	3.03	19.83	15.90[a]	2.27	14.28
WH (cm)	59.04[b]	8.63	14.62	62.62[a]	6.24	9.96
BL (cm)	56.06[a]	8.56	15.27	58.65[a]	7.06	12.04
HG (cm)	64.64[a]	10.60	16.40	65.54[a]	7.58	11.57
SW (cm)	13.90[a]	2.27	16.33	14.46[a]	1.59	11.00
HW (cm)	8.16[a]	0.99	12.13	8.17[a]	0.93	11.38
RW (cm)	12.21[a]	2.26	18.51	12.97[a]	1.76	13.57
RL (cm)	18.90[a]	2.83	14.97	19.03[a]	1.83	9.62

SD: Standard deviation; CV: Coefficient of variation.
Means along the same row bearing the same superscripts do not differ significantly (P>0.05)

Table 2: Phenotypic correlations among body weight and body measurements of Yankasa lambs according to sex*

Trait	BW	WH	BL	HG	SW	HW	RW	RL
BW		0.85	0.86	0.95	0.64	0.59	0.64	0.83
WH	0.87		0.83	0.86	0.77	0.49	0.54	0.85
BL	0.91	0.91		0.88	0.74	0.49	0.67	0.87
HG	0.94	0.92	0.92		0.68	0.53	0.68	0.88
SW	0.74	0.75	0.79	0.80		0.42	0.58	0.74
HW	0.64	0.67	0.66	0.70	0.63		0.43	0.53
RW	0.61	0.65	0.67	0.71	0.86	0.49		0.61
RL	0.84	0.90	0.87	0.90	0.71	0.68	0.64	

*Significant at P<0.01 for all correlation coefficients
Upper matrix: Male lambs
Lower matrix: Female lambs

Table 3: Direct and indirect effects of biometric traits on body weight of Yankasa male lambs

Trait	Correlation coefficient with body weight	Direct effect	Indirect effect							
			WH	BL	HG	SW	HW	RW	RL	Total
WH	0.85	0.14[ns]		0.09	0.70	-0.04	0.06	-0.01	-0.09	0.71
BL	0.86	0.10[ns]	0.12		0.71	-0.04	0.06	-0.01	-0.09	0.75
HG	0.95	0.81**	0.12	0.09		-0.03	0.06	-0.01	-0.09	0.14
SW	0.65	-0.05[ns]	0.11	0.07	0.55		0.05	-0.01	-0.07	0.70
HW	0.59	0.13*	0.07	0.05	0.43	-0.02		-0.01	-0.07	0.45
RW	0.64	-0.02[ns]	0.08	0.07	0.55	-0.03	0.06		-0.06	0.67
RL	0.83	-0.10[ns]	0.12	0.09	0.71	-0.04	0.07	-0.01		0.94

** Significant at P<0.01; * Significant at P<0.05; ns: non-significant effect on body weight was very low (path coefficient = 0.14) and non-significant (P>0.05) as indicated by the t-test. Its indirect effect was 0.71, realized mostly via heart girth. The direct effect of body length on body weight was equally non-significant (path coefficient = 0.10). Heart girth had the greatest direct effect (path coefficient = 0.81; P<0.05) on body weight. Its indirect effects were indeed low and non-significant. Shoulder width had a low, negative and non-significant influence on body weight (path coefficient = -0.05). This is an indication that the correlation between shoulder width and body weight was considerably due to the indirect effect of heart girth. Although the direct effect of head width on body weight was low (path coefficient = 0.13), it was significant. Rump width and rump length negatively impacted on body weight (path coefficient = -0.02 and -0.10, respectively). Their direct effects were also non-significant. It could be inferred, therefore, that heart girth and head width are valuable in the estimation of body weight of male lambs.

In female lambs (Table 4), the highest direct positive contribution to body weight was equally made by heart girth; and was followed by body length (path coefficient = 0.87 and 0.30, respectively; P<0.01). The direct effects of withers height, shoulder width, head width, rump width and rump length on body weight were however, non-significant.

The use of path analysis to explain the relationship between morphological traits and body weight of goats had been reported (Yakubu and Mohammed, 2009). However, these authors observed that body length had the highest direct impact on body weight, closely followed by chest girth and shoulder width. In a related study, Wu *et al.* (2008) showed the relationship between body weight and body dimensions of rabbits using path analysis. The results revealed how the independent variables influenced the dependent variable (body weight) directly (chest girth, body length and ear length) and indirectly (ear width). According to them, wrong conclusion and wrong selection could arise if decision is based on phenotypic correlation alone. Mendes *et al.* (2005) also used path analysis to quantify the association between body weight and body measures of American Bronze Turkeys.

Coefficients of determination and establishment of preliminary regression equations

The direct and combined effects of body dimensions on the variation of body weight of Yankasa lambs are presented in Table 5. In males, heart girth had the highest direct contribution to the variation in body weight (R^2 = 0.656). The sum of determination coefficients of any independent variable and interaction of two independent variables in the present study was: $\sum d$= 0.924. According to path analysis principle, the sum of determination coefficients plus the determination coefficient of error is 1 (Wu *et al.*, 2008). In this case, the determination coefficient of error was 1-$\sum d$= 0.076. The preliminary multiple regression equation for male lambs was:

$$\mathbf{Y= -3.867 + 0.052WH + 0.033BL+ 0.243HG - 0.070SW+ 0.319HW - 0.030RW -0.127RL}$$

Similarly, the direct contribution of heart girth to body weight of female lambs was the highest (R^2 = 0.757). Combined effects of heart girth and body length were the highest among the variable pairs (R^2 = 0.480). The sum of determination coefficients in this case was 0.907 while the determination coefficient of error was 0.093. The preliminary linear model for female lambs was:

$$\mathbf{Y = -1.548 – 0.016WH + 0.105BL + 0.249HG + 0.089SW – 0.183HW – 0.221RW – 0.062RL}$$

Table 4: Direct and indirect effects of biometric traits on body weight of Yankasa female lambs

Trait	Correlation coefficient with body weight	Direct effect	Indirect effect							
			WH	BL	HG	SW	HW	RW	RL	Total
WH	0.87	-0.05^{ns}		0.27	0.80	0.05	-0.04	-0.11	-0.05	0.92
BL	0.91	0.30*	-0.05		0.80	0.06	-0.04	-0.11	-0.05	0.61
HG	0.94	0.87**	-0.05	0.28		0.06	-0.04	-0.12	-0.05	0.08
SW	0.74	0.07^{ns}	-0.04	0.24	0.70		-0.04	-0.15	-0.04	0.67
HW	0.64	-0.06^{ns}	-0.03	0.20	0.61	0.04		-0.08	-0.03	0.67
RW	0.61	-0.17^{ns}	-0.03	0.20	0.62	0.06	-0.03		-0.04	0.78
RL	0.84	-0.06^{ns}	-0.05	0.26	0.78	0.05	-0.04	-0.10		0.90

** Significant at P<0.01; * Significant at P<0.05; ns: non-significant

Table 5: Direct and combined effects of the independent variables contributing to the variation of body weight of Yankasa lambs

Trait	Components of Coefficient of determination (R^2)	
	Male lambs	Female lambs
Direct effects		
$P^2_{Y.X1}$	0.020	0.003
$P^2_{Y.X2}$	0.010	0.090
$P^2_{Y.X3}$	0.656	0.757
$P^2_{Y.X4}$	0.003	0.005
$P^2_{Y.X5}$	0.017	0.004
$P^2_{Y.X6}$	0.000	0.029
$P^2_{Y.X7}$	0.010	0.004
Combined effects		
X1 (WH) and X2 (BL)	0.023	-0.027
X1 (WH) and X3 (HG)	0.195	-0.080
X1 (WH) and X4 (SW)	-0.011	-0.005
X1 (WH) and X5 (HW)	0.018	0.004
X1 (WH) and X6 (RW)	-0.003	0.011
X1 (WH) and X7 (RL)	-0.024	0.005
X2 (BL) and X3 (HG)	0.143	0.480
X2 (BL) and X4 (SW)	-0.007	0.033
X2 (BL) and X5 (HW)	0.013	-0.024
X2 (BL) and X6 (RW)	-0.003	-0.068
X2 (BL) and X7 (RL)	-0.017	-0.031
X3 (HG) and X4 (SW)	-0.055	0.097
X3 (HG) and X5 (HW)	0.112	-0.073
X3 (HG) and X6 (RW)	-0.022	-0.210
X3 (HG) and X7 (RL)	-0.143	-0.094
X4 (SW) and X5 (HW)	-0.005	-0.005
X4 (SW) and X6 (RW)	0.001	-0.020
X4 (SW) and X7 (RL)	0.007	-0.006
X5 (HW) and X6 (RW)	-0.002	0.010
X5 (HW) and X7 (RL)	-0.014	0.005
X6 (RW) and X7 (RL)	0.002	0.013
Sum total	**0.924**	**0.907**

Deletion of less significant variables in the estimation of body weight

The path coefficients of withers height, body length, shoulder width, rump width and rump length in males were statistically non-significant, as revealed by the t-test. This is an indication that these variables were less significant in the estimation of body weight, as they were realized considerably via heart girth. Thus, they were expunged from the regression model to obtain a much more simplified equation. In female lambs, however, withers height, shoulder width, head width, rump width and rump length were removed. The removal, especially of withers height from the two models could be attributed to the fact that height is due to growth of bones, whose function of increase in weight is probably not proportionate to increase in general body weight (Thiruvenkadan, 2005). Similarly, Anderson (1999) reported that height at withers has limited value as an indicator of weight, and negligible value as an indicator of type and function.

Establishment of optimum regression models

After the deletion of five of the predictor variables (WH, BL, SW, RW and RL), the path coefficients for heart girth and head width in male lambs were calculated again (path coefficient = 0.89 and 0.12 for HG and HW, respectively; $P<0.01$). The direct effects of heart girth and head width in contributing to the variation in body weight were: R^2 = 0.792 and 0.014 for HG and HW, respectively. The combined effect gave R^2 value of 0.113. The optimum multiple regression model for male lambs was:

$$\mathbf{Y = -3.925 + 0.265HG + 0.302HW}$$

The sum of determination coefficient for the model was 0.919 while the determination coefficient of error was 0.081.

In female lambs, the path coefficients of heart girth and body length were recalculated, and were found to be equally highly significant (path coefficient = 0.70 and 0.26 for HG and BL, respectively; $P<0.01$). The direct effects of heart girth and body length accounted for 0.490 and 0.068 of the variation in the body weight; while their combined effect explained 0.335 of the observed variation. The optimum linear model for female lambs was:

$$\mathbf{Y = -2.840 + 0.200HG + 0.092BL.}$$

The R^2 value was 0.893 while the determination coefficient of error was 0.107.

The present findings in Yankasa lambs are consistent with earlier reports on the use of body measurements such as heart girth, body length and head width for weight estimation. According to Jawasreh and Khasawney (2007), heart girth was found as a trait of utmost importance in the prediction of body weight from body measurements of sheep. This could be as a result of the fact that the muscle and a little of fat along with bone structure contribute to the formation of heart girth. This is buttressed by the study of Thiruvenkadan (2005) who reported that the higher association of body weight with chest girth was possibly due to a relatively large contribution to weight by chest girth consisting of bones, muscles and viscera. Similarly, Kunene *et al*. (2009) submitted that heart girth was the single most important variable to estimate the live weight of Zulu young sheep with milk set of teeth. The importance of heart girth was also accentuated by Sowande and Sobola (2008) who reported that heart girth together with head length and width of hindquarters were better in predicting live weight of West African Dwarf sheep in the fitted multiple linear regression models. In a related study in goat kids, Vargas *et al*. (2007) reported that body weight could be predicted from body traits such as heart girth, body length and head width.

CONCLUSION

Path analysis revealed that heart girth had the largest direct effect on body weight. Its separate combination with head width and body length of male and female Yankasa lambs respectively, also accounted for the highest contribution to the variation in body weight. However, the direct effect of withers height, body length (males only), shoulder width, head width (females only), rump width and rump length on body weight in both sexes were non-significant as they were realized considerably through heart girth. Thus, these variables were expunged from the final models. The optimum regression equations included heart girth and head width, and heart girth and body length in male and female lambs, respectively. These two equations could serve as useful practical tools for livestock farmers, researchers and rural development workers for weight estimation in the field and for selection purposes.

REFERENCES

Al-TARAYRAY, J. A. – TABBAA, M. J. 1999. Some factors affecting body weight and dimensions and its adjustment factors for Awassi lambs in Jordan. *Dirasat Agric. Sci.,* vol. 26, 1999, p. 45-55.

ANDERSON, G. L. H. 1999. The development of a system of linear measurements to provide an assessment of type and function of beef cattle. *Animal Genetic Resources Information*, vol. 25, 1999, p. 45-55.

AZIZ, M. A. – SHARABY, M. A. 1993. Collinearity as a problem in predicting body weight from body dimensions of Najdi sheep in Saudi Arabia. *Small Rumin. Res*., vol. 12, 1993, p. 117-124.

ECONOMIDES, S. 1983. Intensive sheep production in the near east. *FAO Animal Health and Production*, vol. 40, 1983, p. 17.

GILL, J. L. 1986. Outliers and influence in multiple regression. *J. Anim. Breed. Genet.,* vol. 103, 1986, p. 161-175.

JAWASREY, K. I. Z. – KHASAWNEY, A. Z. 2007. Studies of some economic characteristics on Awassi Lambs in Jordan. *Egyptian J. of Sheep and Goat Sci*., vol. 2, 2007, p. 101-110.

JEONGHOON, A. 2002. Beyond single equation regression analysis: Path analysis and multi-stage regression analysis. *American Journal of Pharmaceutical Education*, vol. 66, 2002, p. 37-42.

KESKIN, A. – KOR, A. – KARACA, S. – Mirtagioglu, H. 2005. A study of relationships between milk yield and some udder traits by using of path analysis in Akkeci goats. *J. Anim. Vet. Adv.*, vol. 4, 2005, p. 547-550.

KUNENE, N. W. – NESAMVUNI, A. E. – NSAHLAI, I. V. 2009. Determination of prediction equations for estimating body weight of Zulu (Nguni) sheep. *Small Ruminant Research*, vol. 84, 2009, p. 41-46.

LENER, L. M. – DONALD, H. P. 1996. *Modern development in animal breeding*. Academic Press, London, 1996, 295 pp.

MARJANOVIC-JEROMELA, A. – MARINKOVIC, R. – MIJIC, A. – ZDUNIC, Z. – IVANOVSKA, S. – JANKULOVSKA, M**.** 2007. Correlation and path analysis of quantitative traits in winter rapeseed (*Brasssica napus L.*). *Agriculturae Conspectus Scientificus*, vol. 73, 2007, p. 13-18.

MENDES, M. – KARABAYIR, A. – PALA, A. 2005. Path analysis of the relationship between various body measures and live weight of American Bronze turkeys under three different lighting programs. *Tarim Bilimleri Dergisi*, vol. 11, 2005, p. 184-188.

PIMENTEL, E. C. G. – QUEIROZ, S. A. – CARVALHEIRO, R. – FRIES, L. A. 2007. Use of ridge regression for prediction of early growth performance in crossbred calves. *Genet. Mol. Biol*., vol. 30, 2007, p. 536-544.

ROCHAS, A. – MCKIMON, D. – WILSON, R. T. 1991. Physical description and productivity of Landim goats and sheep in Mozambique. *Tropical Agriculture*, vol. 68, 1991, p. 207-214.

SAHANA, G. – GUPTA, S.C. - Nivsarkar, A.E. 2001. Garole: The prolific sheep of India. *Animal Genetic Resources Information*, vol. 28, 2001, p. 19-25

SANGUN, L. – CANKAYA, S. – KAYAALP, G. T. – AKAR, M. 2009. The use of factor analysis scores in multiple regression model for estimation of body weight from some body measurements in Lizard fish. *Journal of Animal and Veterinary Advances*, vol. 8, 2009, p. 47-50.

SEKER, H. – SERIN, Y. 2004. Explanation of the relationships between seed yield and some morphological traits in smooth Bromegrass (*Bromus inermis* Leyss) by path analysis. *Europian J. Agron*., vol. 21, 2004, p. 1-6.

SOWANDE, O. S. – SOBOLA, O. S. 2008. Body measurements of West African Dwarf sheep as parameters for estimation of live weight. *Tropical Animal Health and Production,* vol. 40, 2008, p. 433-439.

SPSS, 2001. Statistical Package for the Social Sciences. SPSS Inc., 444 Michigan Avenue, Chicago, IL60611, 2001.

THIRUVENKADAN, A. K. 2005. Determination of best-fitted regression model for estimation of body weight in Kanni Adu kids under farmer's management system. *Livestock Research for Rural Development*, vol. 17, 2005, http://www.cipav.org.co/lrrd/lrrd17/7/thir17085.htm

TOPAL, M. – MACIT, M. 2004. Prediction of body weight from body measurements in Morkaraman sheep. *J. Appl. Anim. Res.*, vol. 25, 2004, p. 97-100.

TOPAL, M. – ESENBUGA, N. 2001. A study of direct and indirect effects of some factors on weaning weight of Awassi lambs. *Turk. J. Vet. Anim. Sci*., vol. 25, 2001, p. 377-382.

ULLMAN. J. B. 1996. Structural equation modeling (In: Using Multivariate Statistics, Third Edition, B.G. Tabachnick and L.S. Fidell, Eds.). HarperCollins College Publishers, New York, NY. pp. 709-819.

VARGAS, S. – LARBI, A. – SANCHEZ, M. 2007. Analysis of size and conformation of native Creole goat breeds and crossbreds used in smallholder agrosilvopastoral systems in Puebla, Mexico. *Tropical Animal Health and Production*, vol. 39, 2007, p. 279-286.

WILSON, R. T. – DURKIN, J. W. 1984. Age at permanent incisor eruption in indigenous goats and sheep in semi-arid Africa. *Livest. Prod. Sci.,* vol.11, 1984, p. 451 – 455.

WU ZHAN-FU – MA XU-PING – TIAN SHU-FEI – WU SHU-QIN – LI CUN-XIN – GUAN LI-HUI – LI WEN-HAI – WANG HAI-YUN, 2008. Path analysis on weight, body dimension and ear type of Saibei rabbits. *Proceedings 9th World Rabbit Congress, Verona, Italy*, June 10-13, 2008, p. 261-264.

YAKUBU, A. 2003. Phenotypic variation in the body measurements of Uda sheep. Unpublished MSc. Thesis, University of Ibadan, Ibadan, Nigeria, pp. 64.

YAKUBU, A. – ABDULLAH, A. R. – ARI, M. M. – OGAH, D. M. 2005. Studies on live weight and linear body measurements of West African Dwarf sheep in North Central Nigeria. *Production Agriculture and Technology,* vol. 1, 2005, p. 37-145.

YAKUBU, A. 2009. Fixing collinearity instability in the estimation of body weight from morpho-biometrical traits of West African Dwarf goats. *Trakia J. Sci.,* vol. 7, 2009, p. 61-66

YAKUBU, A**.** 2009. Principal component analysis of the conformation traits of Yankasa sheep. *World Applied Sciences Journal* (In press).

YAKUBU, A. – MOHAMMED, G. L. 2009. Relationships between morphometric traits and body weight of Red Sokoto goats. *African Journal of Biotechnology* (In press).