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Use of Path Analysis to Investigate Association between Body Weight and Body Dimensions (Body Metric Traits) in Nigerian Locally Adapted Turkeys

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ABSTRACT

A regression model for estimate of body weight (BW) through body metric traits of Nigerian locally adapted turkeys using path analysis was developed. A total of 150 comprising 86 Lavender and 64 White plumages of both sexes were used. The body weight and five body metric traits which are the thigh length (TH), Keel length (KL), Shank length (SL), Breast girth (BG), Wing length (WL), Wing span (WS) and Body length (BL) were measured and analysed. Sex and genotype had significant effect on the body weight (Lavender: Male 565.26±36.79 g, Female 543.61±53.74 g; White: Male 629.06±46.21 g, Female 394.54±63.40 g) at 8 weeks of age. Pearson's correlations results between body weight and TH, KL, SL, BG, WL, WS as well as BL in both sexes indicated positive and highly correlation. However, Path analysis indicated that BL (path coefficient = 0.560; $p < 0.05$) only had positive and significant direct influence on the male body weights. In female turkeys, direct influence of other biometric traits was not significant on body weight. Also, KL (path coefficient = 0.497; $p < 0.05$) had the highest positive and significant direct influence on the body weight closely trailed by the BL (path coefficient = 0.391; $p < 0.01$). The KL via BL (R^2= 0.18) had the highest influence on the female body weight. The other biometric traits had non-significant direct influence. TH had the utmost input to the body weight of the male turkeys via BL (R^2= 0.065). Thus, selecting and improving BL for males; KL and BL for females will contribute positively to the BW of Nigerian locally adapted turkeys.

Keywords: Biometric traits, locally adapted turkey, Nigerian, path analysis

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INTRODUCTION

Assessing animals visually is a common individual method of judging traits (Abanikannda*,* Leigh, & Olutogun, 2002; Yakubu, 2010; Yakubu & Mohammed, 2012). Essentially, live body weight is mostly used to appraise body development and conformation features in animals such as turkeys (De Brito Ferreira, Ramos De Carvallo, Nogueria Baros, & De Assis Mello, 2000; Kuzelov, Taskov, Angelkova, Atanasova, & Mladnov, 2011). Association among body features provides valuable information on performance, productivity as well as carcass characteristics of animals. Hence, estimation of genetic parameters in animal genotyping programmes from quantitative determination of size and shapes of animals are necessary in order to improve selection for growth by identifying early and late maturing animals of different sizes (Yakubu & Mohammed, 2012).

In the past, morpho-biometric traits have been used to forecast body weight of animals in which different regression models have been used to exploit the correlation between these traits. These models have aided in ensuring on-farm measurement of body weight to be less tiresome as well as lessen risks related with the use of weighing scale particularly in animals with large body size.

A number of morpho-biometric traits are not only related with the response trait (i.e. body weight) but also among themselves (Sahu, 2013). Therefore, the extent of relationship between response trait and predictor traits determined by correlation analysis does not reflect definite strength of association. This is because other traits from predictor traits might have influenced on both response trait and any predictor trait. Since the predictor traits are not only interrelated with the response trait but also among themselves, there is a need therefore to establish the direct and indirect (via other traits due to interrelationship) effects of each predictor trait on the response trait (Sahu, 2013; Yakubu & Mohammed, 2012). Hence, path analysis which is a quantifiable method of evaluating the relative extent of causal effect of variables represented in a system of presumed causal interactions (Griesemer, 1991) can be adopted. Path analysis is a subset of Structural Equation Modelling and standardized partial regression analysis that involves a closed variables' system which are linearly related (Ullman, 1996). Partitioning of correlation coefficient into parts is permitted by path analysis (Topal & Esenbuga, 2001; Woods, Wynne, Ploeger, & Leonard, 2003). The first part is the path coefficient that measures the direct influence of the predictor trait on the response trait. The second part assesses the indirect influence of the predictor trait on the response trait through other predictor traits (Pfeiffer & Morris, 1994). Ahn (2002) explained path analysis model as an extension of multiple regression model that allowed determination of independent variables that affected mostly the response variable. Hence, it serves as complement method to regression analysis.

However, the use of a multivariate analysis technique such as path analysis has not been exploited in revealing interrelationship between the body weight and body metric traits of turkeys in Nigeria. The present study therefore investigated the direct and indirect causal influences between body weight and body metric traits of Nigerian locally adapted turkey.

MATERIALS AND METHODS

Experimental Animals and Management

A total of 150 Lavender (male = 41, female =45) and White (male=31, female=33) plumages of locally adapted Nigerian turkeys raised intensively were used for this study. The birds were reared on deep litter in poultry farm house for the management. Water and feed were provided *ad-libitum* to all the turkeys. The turkeys were fed commercial feed from day old until the end of the experiment. This research was carried out at the Poultry Unit, Directorate of University Farm of the Federal University of Agriculture, Abeokuta, Nigeria. All the protocols for this research were approved by the Animal Care and Use Committee of the Federal University of Agriculture, Abeokuta, Nigeria.

Biometric Traits Measured

The traits measured include body weight (BW) and five body metric traits measured at 8 weeks. The body metric traits include: Body length (BL) as distance from the tip of the beak, through the body trunk to the tail; Body girth (BG) as circumference of the breast region; Wing length (WL) as length of the wing from the scapula joints to the last digit of the wing; Shank length (SL) as length of the tarso-metatarsus from the hock joint to the metatarsal pad; Keel length (KL) as length of the meta-sternum. Measurements were done using a tape rule except the body weight which was measured using a balance scale.

Statistical Analysis

Body weight and linear body dimensions averages were computed with their Pearson correlations. In order to have direct appraisal of values that reflect the relative importance of body dimension traits so as to explain variation in the body weight (Seker & Serin, 2004), Standardized partial regression coefficients called path coefficients (beta weights) were also computed.

The path coefficient from an independent variable (X) to a dependent variable (Y) (Mendes, Karabayir, & Pala, 2005) is stated below:

$$P_{yx_i} = \frac{b_i S_{xi}}{S_y}$$

Where:

P_{yxi} = path coefficient from X_i to Y (i= BL, BG, WL, SL, KL),

b_i = partial regression coefficient,

S_{Xi} = standard deviation of X_i,

S_Y = standard deviation of Y

The multiple linear regression model used is given below:

$$Y = \alpha + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + \varepsilon$$

Where:

Y = endogenous variable (body weight),
α = intercept,
b's = regression coefficients,
X's = exogenous variables (BL, BG, WL, SL, KL),
ε = residual error assumed to be normally distributed with null mean and unit variance.

T-test was adopted to verify significance of each path coefficient in the multiple linear regression model as stated by Sangun, Cankaya, Kayaalp and Alkar (2009):

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

Where:

$var(b_j)$ = the diagonal member of matrix $s^2 (X'X)^{-1}$,

s^2 = Residual mean square gotten from Analysis of variance

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 indirect effect of X_i via X_j on Y,
r_{XiXj} = correlation coefficient between i^{th} and j^{th} independent variables,
$P_{Y.Xj}$ = path coefficient that showed the direct effect of j-biometric traits on the body weight.

Path analysis was used to segregate Coefficient of determination (R^2) into its parts as follows:

$$R^2 = P^2_{Y.X1} + P^2_{Y.X2} + P^2_{Y.X3} + P^2_{Y.X4} + P^2_{Y.X5} + 2r_{X1X2}P_{Y.X1}P_{Y.X2} + 2r_{X1X3}P_{Y.X1}P_{Y.X3} + 2r_{X1X4}P_{Y.X1}P_{Y.X4} + 2r_{X1X5}P_{Y.X1}P_{Y.X5} + 2r_{X2X3}P_{Y.X2}P_{Y.X3} + 2r_{X2X4}P_{Y.X2}P_{Y.X4} + 2r_{X2X5}P_{Y.X2}P_{Y.X5} + 2r_{X3X4}P_{Y.X3}P_{Y.X4} + 2r_{X3X5}P_{Y.X3}P_{Y.X5} + 2r_{X4X5}P_{Y.X4}P_{Y.X5}$$

Where:

$P^2_{Y.X1}$ = direct effects of biometric traits (BL, BG, WL, SL, KL) contributing to the body weight;

$2r_{XiXj}P_{Y.Xi}P_{Y.Xj}$ = combined effects of biometric traits (BL, BG, WL, SL, KL) contributing to the body weight.

The biometric traits were vetted for multicollinearity problems using variance inflation factors (VIF) and tolerance (T) values. All analyses were done in SPSS (2001).

RESULTS

Effect of Interaction between Sex and Genotypes on Body Weight and Biometric Traits of Nigerian Locally Adapted Turkeys

The least square means of the biometric traits studied in the Nigerian locally adapted turkey is shown in Table 1. Genotypes had significant ($P < 0.05$) effect on all traits. The White male turkey was significantly ($p <$

0.05) heavier and had longer biometric traits dimension than its female counterpart, but when compared with the Lavender male and female genotypes, the traits did not differ significantly ($p > 0.05$).

Table 1
Interaction effect of sex and genotype on body weight (g) and biometric (cm) traits of the locally adapted Nigerian turkeys (LSM ± S.E)

	Lavender		White	
Traits	Male	Female	Male	Female
Body weight	565.26±36.79[ab]	543.61±53.74[ab]	629.06±46.21[a]	394.54±63.40[b]
Thigh length	9.65±0.26[ab]	9.93±0.42[ab]	10.53±0.40[a]	8.79±0.61[b]
Keel length	11.70±0.33[ab]	12.02±0.51[a]	12.76±0.47[a]	10.16±0.76[b]
Shank length	6.96±0.20[ab]	6.92±0.29[ab]	7.61±0.29[a]	6.10±0.47[b]
Breast girth	19.67±0.50[ab]	19.98±0.83[a]	21.50±0.77[a]	17.25±1.15[b]
Wing length	10.47±0.30[ab]	10.76±0.45[ab]	11.77±0.45[a]	9.35±0.71[b]
Wing span	23.19±0.64[ab]	23.52±1.01[ab]	25.07±0.95[a]	20.75±1.75[b]
Body length	18.53±0.63[ab]	19.50±1.07[ab]	20.72±0.98[a]	16.88±1.66[b]

Means in the same row bearing different superscript differ significantly (P<0.05)

Pearson Correlation of the Body Weight and Biometric Traits

Correlations between body weight (BW) and the biometric traits are shown in Table 2. There is high, positive and significant ($p < 0.05$) correlations between the BW and biometric traits. In male turkey, the correlation coefficients values ranged from 0.73 – 0.96, while in female turkey, a range of 0.84 – 0.96 was obtained. The highest

Table 2
Pearson correlation coefficients (with their significant level) of the body weight and body linear dimensions

	BW	TL	KL	SL	BG	WL	WS	BL
BW		0.76***	0.76***	0.73***	0.75***	0.77***	0.76***	0.80***
TL	0.89***		0.94***	0.94***	0.94***	0.92***	0.93***	0.92***
KL	0.93***	0.96***		0.94***	0.93***	0.92***	0.93***	0.92***
SL	0.86***	0.90***	0.92***		0.93***	0.90***	0.91***	0.91***
BG	0.91***	0.93***	0.96***	0.89***		0.92***	0.93***	0.91***
WL	0.84***	0.90***	0.91***	0.87***	0.91***		0.96***	0.92***
WS	0.87***	0.91***	0.92***	0.88***	0.92***	0.95***		0.92***
BL	0.92***	0.92***	0.95***	0.89***	0.92***	0.88***	0.91***	

***: p<0.001; Male: Lower diagonal; Female: Upper diagonal association with body weight in the male turkeys was with body length (r = 0.80, $p < 0.05$), while the association between BW and keel length (KL) was the strongest association recorded for the female turkey (r = 0.93, $p < 0.05$). The significant ($p < 0.05$) correlation between the biometric traits measured were all high. On the overall, correlation between wing length and wing span (WS) (r = 0.96, $p < 0.05$) for male birds and the strongest association in female birds was with keel length having a 96% correlation (r = 0.96, $p < 0.05$) with thigh length (TL) and breast girth (BG).

Path Coefficient of the Biometric Traits

The path coefficients of the biometric traits are shown in Table 3. In male turkey, the results revealed that body length (BL) had the highest direct influence on BW (path coefficient = 0.560; $p<0.05$). The direct effects of the other biometric traits (TL, KL, BG, WS, shank length, body length (BL) and wing length) were not significant ($p > 0.05$). The non-significant variables except wing length were realized indirectly through body length. In female turkey (Table 4), the highest direct contribution to BW was made by KL (path coefficient = 0.497; $p < 0.05$) and closely followed by BL. The direct effect of the other variables were not significant ($p > 0.05$).

Relative Contribution of the Linear Body Dimensions to Body Weight

Table 5 shows direct and combined influences of biometric traits on the BW difference. In female turkeys, the highest single contributor to the BW difference was KL (R^2 = 24.69%), this was followed closely by BL (R^2 = 15.30). Among the interaction of the variable pairs for male turkeys, the combination of thigh length and body length was the highest (R^2 = 6.50). The sum of

Table 3
Direct and indirect influences of biometric traits (with their significant level) on body weight of male locally adapted Nigerian turkeys

Variables	Correlation with body weight	Direct Effect	Total indirect effect	Indirect effect						
				TL	KL	SL	BG	WL	WS	BL
TL	0.763***	0.127^{ns}	0.636		0.061	-0.106	-0.006	0.170	0.000	0.517
KL	0.759***	0.065^{ns}	0.694	0.119		-0.106	-0.006	0.169	0.000	0.517
SL	0.735***	-0.113^{ns}	0.847	0.119	0.060		-0.006	0.166	0.000	0.507
BG	0.746***	-0.006^{ns}	0.752	0.119	0.060	-0.105		0.169	0.000	0.509
WL	0.766***	0.184^{ns}	0.581	0.117	0.059	-0.102	-0.006		0.000	0.512
WS	0.763***	0.0004^{ns}	0.762	0.118	0.060	-0.103	-0.006	0.176		0.517
BL	0.797***	0.560***	0.015	0.117	0.060	-0.102	-0.006	-0.054	0.000	

***: $p<0.0001$; **: $p<0.01$; *: $p<0.05$; ^{ns}: $p>0.05$; TL: Thigh Length; KL: Keel Length; SL: Shank Length; BG: Breast Girth; WL: Wing Length; WS: Wing Span; BL: Body Length

Table 4
Direct and indirect influences of biometric traits (with their significant level) on body weight of female of the locally adapted Nigerian turkeys

Variables	Correlation with body weight	Direct Effect	Total indirect effect	Indirect effect						
				TL	KL	SL	BG	WL	WS	BL
TL	0.893***	-0.097^ns	0.990		0.478	-0.008	0.234	-0.207	0.133	0.360
KL	0.929***	0.497*	0.432	-0.094		-0.008	0.241	-0.211	0.134	0.370
SL	0.863***	-0.008^ns	0.872	-0.087	0.459		0.223	-0.201	0.128	0.349
BG	0.912***	0.251^ns	0.662	-0.091	0.476	-0.007		-0.211	0.134	0.361
WL	0.841***	-0.231^ns	1.072	-0.087	0.454	-0.007	0.229		0.139	0.346
WS	0.873***	0.146^ns	0.728	-0.088	0.456	-0.007	0.230	-0.220		0.357
BL	0.925***	0.391**	0.684	-0.089	0.470	-0.008	0.231	-0.054	0.133	

***: p<0.0001; **: p<0.01; *: p<0.05; ^ns: p>0.05; TL: Thigh Length; KL: Keel Length; SL: Shank Length; BG: Breast Girth; WL: Wing Length; WS: Wing Span; BL: Body Length

Table 5
Relative contribution of the body metric traits to body weight of the locally adapted Nigerian turkeys

Variable	Partial co-efficient of determination (R^2)	
	Male	Female
Thigh Length	0.02	0.00944
Keel Length	0.00	0.24686
Shank Length	0.01	0.00007
Breast Girth	0.00	0.06296
Wing Length	0.03	0.05349
Wing Span	0.00	0.02126
Body Length	0.31	0.15296
Combined effects		
TL via KL	0.008	-0.05
TL via SL	-0.013	0.00
TL via BG	-0.001	-0.02
TL via WL	0.022	0.02
TL via WS	0.000	-0.01
TL via BL	0.065	-0.03
KL via SL	-0.01	0.00
KL via BG	0.00	0.12
KL via WL	0.01	-0.10
KL via WS	0.00	0.07
KL via BL	0.03	0.18
SL via BG	0.00	0.00
SL via WL	-0.02	0.00

Table 5 *(continue)*

Variable	Partial co-efficient of determination (R^2)	
	Male	Female
SL via WS	0.00	0.00
SL via BL	-0.06	0.00
BG via WL	0.00	-0.05
BG via WS	0.00	0.03
BG via BL	0.00	0.09
WL via WS	0.00	-0.03
WL via BL	0.09	-0.08
WS via BL	0.00	0.05
Total Contribution	64.50	89.10
Residuals	35.50	10.90
Sum Total	100.00	100.00

R^2 was 64.50%, while the determination co-efficient for error was 35.50%. For females, keel length had the highest direct contribution (R^2 = 24.69%) to body weight, this was closely followed by body length (15.30%).

In male turkeys, BL had highest direct contribution to the BW variation (R^2 = 2%). The combined influences of TL and KL were the highest among the variable pairs (R^2 = 31.0%). The sum of R^2 of the independent and interaction of the dependent pairs in the present study for the male turkeys was 64.50%.

DISCUSSION

The morphological differences obtained in this study can be mainly attributed to genetic differences and sexual dimorphism. The differences between the White genotype sexes might be due to variation in rates and strategies of growth as well as metabolic rates. Sexual dimorphism normally results in sex differential hormonal action leading to differential growth rates (Baéza, Williams, Guémené, & Duclos, 2001) in White genotype sexes. BW could be estimated from biometric traits as revealed by positive and strong association between BW and biometric traits. Wolanski, Renema, Robinson, Carney and Fanchert (2006) reported that in the absence of weighing scale, component parts of animal could be used to evaluate animal growth. Hence, biometric traits improvement will invariably result in a resultant improvement in the BW of the locally adapted turkey genotypes. High positive correlation between the traits suggests that they are under the same gene action (Yakubu, 2010).

In the direct effects (path coefficient), only BL of male indigenous turkey was significant while the other body measurements did not meet the significance threshold. The total value of the indirect for BL was small implying that the correlation between BW and BL was largely due to direct influence. The larger indirect effect observed for the other traits implies that their correlation with BW was realized more indirectly than directly, this is evident from the non-significant effect of their direct effect on body weight. Thus, BL was the only important and useful predictor with predicting body weight in the locally adapted male turkey genotypes. For the female turkey however, KL and BL had significant direct effect on BW. The total value of indirect effect for most of the traits was larger than their direct effects. The large indirect effect obtained indicates that a high percentage of the significant correlation observed between BW and the traits was primarily indirect than direct. Since only KL and BL had significant direct effects on BW, it means they could be used in the estimation of BW in female locally adapted Nigerian turkeys. Thus, selecting and improving BL for males, KL and BL in female turkey will impact positively on the BW of the locally adapted turkey genotypes.

CONCLUSION

In accordance with the result of this study, there were both sex and genotype differences in the morphometric traits of the locally adapted turkey genotypes studied. Pearson's correlations values shown that BW had definite and great association with TL, KL, SL, BG, WL, WS and BL. Path analysis however indicated that BL only had positive and significant direct effect while the TH, KL, WL, WS had positive but non-significant direct effect on the male body weights while the KL had the highest positive and significant direct effect on the female BW followed by the BL with other traits having non-significant direct effect. Thus, the highest contribution to the BW of the male turkeys was by TL via BL while in the female turkeys the KL via BL had the highest contribution.

Therefore, the BW of locally adapted Lavender and White turkey genotypes could be appraised with a high grade of precision using prediction indices like BL for males, KL and BL for females. Also, selection of locally adapted turkeys could be done using biometric traits in order to increase meat production.

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