BODY WEIGHT PREDICTION AND PHENOTYPIC CORRELATION WITH LINEAR BODY MEASUREMENTS IN TWO STRAINS OF JAPANESE QUIAL

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ABSTRACT
The study was conducted to predict and correlate body weight with linear body measurements (LBMs) using 80 unsexed F_1 progeny produced by 24 Panda White and Cinnamon Brown strains of Japanese quail. Data on body weight and LBMs (body width, BW; shank length, SL; body length, BL; wing length, WL; thigh length, TL; keel length, KL and body girth, BG) were taken on individual quails at weekly intervals from 3 to 6 weeks of age. Stepwise multiple regression and Pearson's Product Moment correlation analyses were performed. Accuracy of body weight prediction was generally low based on the coefficients of determination (R^2) which ranged from 15 to 45% in all ages for both strains. The R^2 values decreased in Panda White strain and increased in Cinnamon Brown strain at 3 and 6 weeks of age, respectively. Thigh length was the best single predictor of body weight (R^2 = 26%) at 3 weeks in Panda White strain. Wing length and BL partially predicted body weight most accurately (R^2= 45%) at 6 weeks of age in Cinnamon Brown quails. Significant ($P<0.05$) positive correlation coefficients (r) existed between body weight and TL (r =0.50) in Cinnamon Brown and KL (r =0.47) in Panda White both at 4 weeks; SL (r =0.39) in Panda White at 5 weeks and BL (r = 0.43), WL (r =0.48) and TL (r =0.40) in Cinnamon Brown and BL (r =0.48) in Panda White each at 6 weeks of age. Correlation coefficients of other traits were either positive or negative but non-significant ($P>0.05$). Body weight can best be predicted at younger age with TL in Panda White and at older age with both WL and BL in Cinnamon Brown quails. Genetic improvement of body weight can be realised as correlated responses by indirect selection of some LBMs at 4 weeks of age in both Cinnamon Brown and Panda White strains of Japanese quail.

Keywords: Japanese Quails, Panda White, Cinnamon Brown, Prediction, Phenotypic correlation.

INTRODUCTION
Quails are small poultry species known for their production of both meat and egg (Baumgartner, 1993). They have advantages over other poultry species in fast growth, early sexual maturity, high rate of egg production, short generation interval and short incubation period (Owen and Amakiri, 2010; Reddish *et al*., 2003). These favourable attributes could make quail production a viable option in ameliorating shortage of protein among the populace in developing countries. The most studied aspect of quail production is nutrition, particularly of Japanese egg-type (Bawa, 2006; Dafwang, 2006). Genetic studies on quail production must be given prior attention for improvement of their meat and egg traits. Recent works have focused on improvement through selection (Khaldari *et al*., 2010) and genetic parameter estimation (Luciano *et al*., 2013; Momoh *et al*., 2014), but a few have concentrated on body weight prediction and linear relationship between body weight and morphometric or conformation traits (Gambo *et al*., 2014) also called linear body measurements.

Measurement of body weight of animals is essential in determining their market price. However, this task is not only onerous, owning to the fact that quails are small birds and not easily amenable to experimental conditions, but also almost impossible in most rural farms due to absence of weighing scales and inability of illiterate farmers to read scales. Moreover, the use of scales in assessment of body weight of animals has not been found most accurate. This is because weight of an animal includes feed in its gut. Linear body traits are, however, not biased by the level of gut fill, and therefore expected to give more accurate estimate of the weight of the animal. In the absence of weighing scales, body weight can be predicted from the linear body measurements, and this has been reported in cattle (Mbap and Bawa, 2001), sheep (Udoh *et al*., 2012), goats (Salako and Ngere, 2002) and poultry species other than quails (Olowofeso, 2009). Information on prediction of body weight from linear body measurements of quails is scare in available literature, and where such exists, different strains of Japanese quails have been emphasized.

Furthermore, phenotypic correlation between body weight and linear body measurements should be established to determine appropriate breeding programmes that will result in genetic improvement of growth traits of these birds. Linear body measurements allow comparisons of growth in different parts of the body (Abdullah *et al*., 2003), and have been used as predictors of live weight and carcass composition (Oke *et al*., 2004) of animals.

They serve as criteria for indirect selection and improvement of body weight. The prediction of body weight and phenotypic correlation between body weight and linear body measurements in different strains of Japanese quail will be useful in evaluating genetic differences among strains for the purpose of selection in desired line of improvement. The objectives of this study were to predict body weight of Panda White and Cinnamon Brown strains of Japanese quail using linear body measurements and to study the phenotypic correlation between these traits of the quails.

MATERIALS AND METHODS

Experimental site

The research was conducted in the poultry unit of the Teaching and Research Farm, Michael Okpara University of Agriculture, Umudike, Nigeria. The University is located on Latitude $05^0$29´ North of Equator and Longitude $07^0$33´East of Greenwich Meridian. It is approximately 122 m above sea level within the rainforest zone of South-Eastern Nigeria (Nwaogwugwu *et al*., 2009). Maximum ambient temperature of the area ranges from 27 ^{0}C to 36 ^{0}C during the hot period of the year (November - April), minimum ambient temperature ranges from 20^{0}C to 26^{0}C during the cold rainy season (May - September) while relative humidity ranges from 57 % to 91 % (Nwaogwugwu *et al*., 2009). The climate is described as hot humid tropics.

Experimental quails and their management

Twenty-four (24) base population of Panda White and Cinnamon Brown strains of quails of breeding age, each consisting of 12 parents were obtained from the Teaching and Research farm of the University for the breeding experiment. The quails were managed in small cages constructed on deep littler pens, measuring 2.65 x 1.67m^2. They were fed layer mash and provided cool, clean water *ad libitum*. The feed contained 2500kcal/kg metabolisable energy (ME) and 16.5% crude protein (CP) *ad libitum*. Vitamin and minerals were given as supplements. The quails were exposed to 17 hours of light per day. They were mated by pure crossing in the ratio of 1 cock to 5 hens per strain to produce fertile eggs. Fertile eggs from each strain were collected, identified differently and hatched artificially in 4 consecutive batches at weekly intervals. A total of eighty (80) F_1 chicks, with 40 per strain were produced. These were identified and brooded separately according to their hatch and strain. Brooding lasted for 2 weeks and was done artificially. Chicks were fed starter mash (2800kcal/kg ME and 20% CP) for 0-3 weeks and grower mash (2550kcal/kg ME and 15% CP) for 3-6 weeks and provided quality water *ad libitum*. Birds were vaccinated against Newcastle disease with Newcastle disease vaccine at day -old intraocularly and at 2 weeks with Newcastle disease vaccine lasota through drinking water.

Data collection and measurement of traits

Data on body weight and linear body measurements were collected on individual quails at weekly intervals. Body weight was measured in grammes (g) with OHAUS sensitive weighing scale (Cs 5,000) with sensitivity of 2.0 g. Linear body measurements were read in centimetres (cm) using a tape. The measurements were described as follows: shank length (SL), measured as the length of the leg from the hock joint to the tarso-metatarsus pad; body length (BL), measured as the length of the body from the base of the comb to the base of the tail around the orapigial gland; wing length (WL), measured as the length of the wing from the scapular joint to the last digit of the wing; thigh length (TL), measured as the distance between the hock joint and end of ball and socket joint; body width (BW), measured as the circumference of the widest part of the body; keel length (KL), measured as the length of breast bone from the V-joint to the end of the sternum and body girth (BG), measured as the circumference of the breast around the deepest region.

Statistical Analyses

Stepwise multiple linear regression was performed with the linear model:

$$\mathbf{Y = a + b_1x_1 + \ldots + b_kx_k + e,}$$

where Y is the body weight, a, constant, $b_1 \ldots b_k$, partial regression coefficients, $x_1 \ldots x_k$, linear body measurements and e, error. The regression coefficient (b) derived from the linear model was computed by formula:

$$\mathbf{b} = \sum \mathbf{xy} - \sum \mathbf{x} \sum \mathbf{y}/\boldsymbol{n} \div [\sum \mathbf{x^2} - (\sum \mathbf{x})^2],$$

where x and y are linear body measurements and body weight, respectively and n, number of observation.

Pearson's product moment correlation was also carried out to determine the association between body weight and each of the linear body measurements. The coefficient of correlation (r) obtained from the analysis was computed using the formula:

$$\mathbf{r} = \sum \mathbf{xy} - \sum \mathbf{x} \sum \mathbf{y}/\boldsymbol{n} \div \sqrt{[\sum \mathbf{x^2} - (\sum \mathbf{x})^2] - [\sum \mathbf{y^2} - (\sum \mathbf{y})^2]}.$$

Data were analysed using IBM SPSS Statistics (2011) software.

RESULTS

Prediction of body weight from linear body measurements

At 3, 4, 5 and 6 weeks of age (Table 1), the regression coefficients between body weight and each of the linear body measurements in the regression equations and their corresponding R^2 values were -0.82 and 0.26%; 0.32 and 0.22%; 0.62 and 0.15% and 0.56 and 0.23% for TL, KL, SL and BL, respectively in Panda White quails. The corrsponding values in Cinnamon Brown quails were -0.27 and 0.20%;1.99 and 0.25%; -1.11 and 0.17% and 0.58 and 0.22%, BL, TL, BG and WL, respectively. For model 2 at week 6 of Cinnamon Brown strain, the partial regression coefficients between body weight and each of WL and BL and its corresponding R^2 values were 0.63, 0.62 and 45%, respectively. The intercepts of all the equations were positive, ranging from 27.72 to 60.33 for Panda White and 24.65 to 67. 29 for Cinnamon Brown strains. The regression analyses were either significant (P<0.05) or highly signicant (P<0.01).

Table 1: Stepwise Regression for Predicting Body Weight from Linear Body Measurements of Panda White Cinnamon Brown Strains of Japanese Quail *(Coturnix coturnix Japonica)*

Age (weeks)	Model	Strain							
		Panda White				Cinnamon Brown			
		Regressionequation	R^2	Se	Sig.	Regressionequation	R^2	Se	Sig.
3	1	BWT = 27.72-0.82TL	0.26	0.53	**	BWT = 27.03-0.27BL	0.20	0.53	*
4	1	BWT=29.14+0.32KL	0.22	0.76	*	BWT =24.65+l.99TL	0.25	0.47	**
5	1	BWT= 50.53+0.62SL	0.15	0.66	*	BWT= 51.03-1.1 1BG	0.17	1.04	*
6	1	BWT = 60.33-0.56BL	0.23	2.53	*	BWT =67.29+0.58WL	0.22	0.86	*
	2					BWT = 54.82+0.63WL + 0.62BL	0.45	0.74	**

* = significant (P<0.05), ** = highly significant (P<0.05)
R^2 = Coefficient of determination; Se = standard error of estimate
BWT = Body weight; BG= body girth; BL = body Length; WL Wing length; TL = thigh Length; SL = Shank Length

Phenotypic correlation between body weight and linear body measurements

Phenotypic correlation coefficients between body weight and linear body measurements in Panda White strain of Japanese quail is presented in Table 2. Whereas BL, KL, WL and TL negatively correlated with body weight with only TL being highly significant (P<0.01), BG, BW and SL positively correlated with body weight at 3 weeks old. Body weight correlated negatively with BG and SL; positively with BL, KL, BW, WL, and TL at 4 weeks old; negatively with KL and BW and positively with the rest of the linear body measurements at both 5 and 6 weeks of age. Significant (P<0.05) positive correlation coefficients were obtained between body weight and KL (r =0.47), SL (r =0.39) and BL (r =0.48) only at 4, 5 and 6 weeks of age respectively. The negative correlation between body weight and TL was highly significant (P<0.01).

Table 2: Phenotypic correlation coefficients between body weight and linear body measurements in Panda White strain of Japanese quail (*Coturnix coturnix japonica*)

	Age (weeks)			
LBMs	3	4	5	6
BL	-0.45**	0.04	-0.25	0.43*
BG	-0.05	0.08	-0.41*	0.24
KL	-0.20	0.31	-0.33	0.26
BW	-0.23	0.22	-0.10	0.19
WL	-0.07	0.34	-0.19	0.48*
TL	-0.21	0.50**	-0.16	0.40*
SL	-0.12	-0.44*	-0.13	0.31

* = Significant (P<0.05), ** = Highly signifcant (P<0.01)
LBMs = Linear body measurements; BL = Body lenght; BG = Body girth; KL = Keel le; BW = Body width, WL =Wing length

Phenotypic correlation coefficients between body weight and linear body measurements in Cinnamon Brown strain of Japanese quail is presented in Table 3. Body weight correlated negatively with all the linear traits at 3 and 5 weeks and positively at 6 weeks of age. At 4 weeks, body weight correlated negatively with all the linear body measurements except with SL. Highly significant (P<.01) negative and positive correlation coefficients were obtained between body weight and each of BL (r =0.45) and TL (r =0.50) at 3 and 4 weeks of age, respectively. Correlation coefficient between body weight and WL (r =0.48) was positive and significant (P<.05) at 6 weeks old. Correlation coefficients between body weight and BL (r =0.43) and TL (r =0.40) were also positive and significant (P<0.05) at 6 weeks of age.

Table 3: Phenotypic correlation coeeficients between body weight and linear body measurements in Cinnamon Brown strain of Japanese quail (*Coturnix coturnix japonica*)

	Age (weeks)			
LBMs	**3**	**4**	**5**	**6**
BL	-0.11	0.07	0.32	0.48*
BG	0.31	-0.26	0.35	0.10
KL	-0.22	0.47*	-0.03	-0.27
BW	0.29	0.16	-0.70	-0.24
WL	-0.17	0.14	0.14	0.35
TL	-0.51**	0.05	0.02	0.12
SL	0.27	-0.17	0.39*	0.08

* = Significant (P<0.05), ** = Highly signifcant (P<0.01)
LBMs = Linear body measurements; BL = Body lenght; BG = Body girth; KL = Keel length; BW = Body width, WL = Wing length

DISCUSSION

The positive regression coefficients obtained between body weight and each of keel length, shank length and body length in Panda White (4-6 weeks) and thigh length, wing length (singly) and wing length and body length (partially) in Cinnamon Brown (4 and 6 weeks) strains revealed that body weight increased by a unit increase in these traits. It is possible to predict body weight with these traits in quails. This is in agreement with the observation made by Sanda *et al*. (2014) that accurate prediction of body weight from linear body measurement will be obtained when positive relationship exists between them.

Similarly, the negative regression coefficients obtained at week 3 between body weight and each of thigh length in Panda White and body length and body girth in Cinnamon Brown quails revealed that body weight decreased with unit increase in these traits. This result suggests that body weight can be improved by selecting for improved body, keel and shank lengths in Panda White and thigh, wing and body lengths in Cinnamon Brown quails. This can practically be realised by including these linear traits in a selection index for body weight improvement in quails. This result lends credence to the findings of Fayeye *et al*. (2014) who reported that body length, in addition to comb length can be used to predict body weight in chicken.

The low values of coefficient of determination (R^2) in both Panda White and Cinnamon Brown quails indicated that other unknown factors may have contributed much more in body weight increase. However, the highest positive regression coefficients of 0.63 and 0.62 and R^2 value of 45% obtained at 6 weeks of aqge from partial contribution of wing length and body length to body weight increase in Cinnamon Brown quails revealed that these traits constituted highest predictors of body weight in this strain. The result of this research also collaborated with the findings of Gambo *et al*. (2014) who reported shank length (R^2 =84%), wing length (63%), body girth (R^2 =63) and body length (R^2 = 36%) as predictors of body weight in quails. The decrease in R^2 with age in Panda White quails confirms the findings of Oni *et al.* (2011) that prediction of body weight using linear body measurements should be carried out within the younger age groups of animals since prediction equation reported by Oni *et al.* (1998) would not hold over all ages. However, the R^2 values which increased with age in Cinnamon Brown contradicted these findings, and thus confirm the fact that strain is capable of affecting the performance of animals (Shim *et al*., 2012).

Changes from negative correlation coefficients at 3 weeks to positive at subsequent ages for most of the body, keel, wing and thigh lengths in Panda White quails (Table 2) indicate that age influences relationship between body weight and linear body measurements of animals. This affirms the findings of Hagos *et al*. (2016). Improvement of body weight by indirect selection for these linear body measurements will thus be possible where positive relationship between these traits exists. The positive correlation between body weight and most of the linear body measurements at 4 to 6 weeks of age is an indication that improvement of body weight should be done at older age in Panda White. Any of these linear traits, particularly keel, shank and body lengths which had highest significant positive correlation coefficients at 4, 5 and 6 weeks of age in Panda White quails should therefore be included in selection index as opined by Ojo (2010) to achieve body weight improvement resulting from correlated responses (Adeleke *et al*., 2011; Momoh *et al*., 2014).

Negative and positive correlation coefficients between body weight and linear body measurements of Cinnamon Brown quails (Table 3) occured alternatively with age, different from the pattern in Panda white (Table 2). This may be attributed to strain effect, indicating that the two strains of quails used in the present study actually come from different genetic boackground. The observation further suggests that selection for improved body weight using linear body measurements, especicialy body length, wing length and thigh lenght will be effective at 4 and 6 weeks of age in Cinnamon Brown quails where positive correlations occured. However, faster Genetic progress can be made by using thigh length as basis for indirect selection for body weight since the correlation between body weight and thigh length was highly significant and had highest positive coefficient.

ACKNOWLEDGMENT

We sincerely acknowledge Professor E. N. Nwachukwu of the Department of Animal Breeding and Physiology, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria for providing us his quails used as parent stock in this research.

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