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Factor analysis and body dimensions of the Japanese quail (*Coturnix Coturnix Japonica)*

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Abstract

Morphometric variation can be effectively measured within and between populations and used as a basis for characterization of different livestock types. The study was aimed at contributing to the characterization process of the Japanese quail (mottled brown and white) through quantitative assessment. Zoometrical data on body weight and 11 body measurement were taken on 747 mottled brown quail and 272 white quail from six different farms around Ibadan in the Southwest Nigeria. Descriptive statistics showed that average body weight of Japanese quail reared in Southwest Nigeria were 158.72±2.03, 157.24±1.31, 140.6 ±1.39, and 136.27±2.7g for mottled brown female, brown male, white female and white male, respectively. Sexual dimorphism was observed in all the traits with higher values recorded for the females. Significant correlation (P<0.001) was observed between body weight and body measurements. The best correlation was obtained between body weight and thigh length r = 0.76 and 0.70 for mottled brown quail and white respectively. Factor solution from the principal component analysis, with varimax rotation of the transformation matrix showed three factors were identified in each of the genetic group (total variance of first principal component = 27.86, 30.16, 31.88 and 38.85 for mottled brown male, mottled female, white male, white female quail, respectively). In the two strains of Japanese quail, PC1 had the largest share of the total variance and correlated highly with body weight, breast length, wing length, thigh length and shank length. The PC1 could be used to describe the generalised form of quail. PC2 was orthogonal to PC1 and loaded heavily on breast girth and neck length. Data was also subjected to linear and stepwise regression. More reliable prediction was obtained from stepwise regression, R^2 was highest with breast girth R^2=0.71 and breast length R^2=0.81 for brown and white quail, respectively. The weight of Japanese quail is linearly related to body measurements. The high, positive correlation between body weight and zoometric body measurements indicates that these easily measured parts can be used as criteria for assessment and selection of body weight.

Keywords: Japanese quail, linear measurement, body weight, characterization

Analyse factorielle et dimensions corporelles de la caille japonaise (*Coturnix Coturnix Japonica*)

Résumé

La variation morphométrique peut être efficacement mesurée au sein et entre les populations et utilisée comme base pour la caractérisation des différents types de bétail. L'étude visait à contribuer au processus de caractérisation de la caille japonaise (tachetée de brun et de blanc) par une évaluation quantitative. Des données zoométriques sur le poids corporel et 11 mesures corporelles ont été prises sur 747 cailles brunes tachetées et 272 cailles blanches de six fermes différentes autour d'Ibadan dans le sud-ouest du Nigéria. Les statistiques descriptives ont montré que le poids corporel moyen des cailles japonaises élevées dans le sud-ouest du Nigéria était de 158,72 ± 2,03, 157,24 ± 1,31, 140,6 ± 1,39 et 136,27 ± 2,7g pour la femelle brune tachetée, le mâle brun, la femelle blanche et le mâle blanc, respectivement. Un dimorphisme sexuel a été *observé dans tous les traits avec des valeurs plus élevées enregistrées pour les femelles. Une corrélation significative (P<0,001) a été observée entre le poids corporel et les mesures corporelles. La meilleure corrélation a été obtenue entre le poids corporel et la longueur des cuisses r = 0,76 et 0,70 pour la caille brune tachetée et la caille blanche respectivement. La solution factorielle de l'analyse en composantes principales, avec rotation varimax de la matrice de transformation, a montré que trois facteurs ont été identifiés dans chacun des groupes génétiques (variance totale de la première composante principale = 27,86, 30,16, 31,88 et 38,85 pour le mâle brun tacheté, la femelle tachetée, le blanc mâle, cailles blanches femelles, respectivement). Dans les deux souches de cailles japonaises, PC1 avait la plus grande part de la variance totale et était fortement corrélé avec le poids corporel, la longueur de la poitrine, la longueur des ailes, la longueur des cuisses et la longueur du jarret. Le PC1 pourrait être utilisé pour décrire la forme généralisée de la caille. PC2 était orthogonal à PC1 et fortement chargé sur la circonférence de la poitrine et la longueur du cou. Les données ont également été soumises à une régression linéaire et pas à pas. Une prédiction plus fiable a été obtenue à partir de la régression pas à pas, le R^2 était le plus élevé avec le tour de poitrine $R^2 = 0,71$ et la longueur de poitrine $R^2 = 0,81$ pour les cailles brunes et blanches, respectivement. Le poids de la caille japonaise est linéairement lié aux mensurations. La corrélation élevée et positive entre le poids corporel et les mensurations zoométriques indique que ces parties facilement mesurables peuvent être utilisées comme critères d'évaluation et de sélection du poids corporel.*

Mots-clés : Caille japonaise, mesure linéaire, poids corporel, caractérisation

Introduction

Since the 11th century, the Japanese quail (*Coturnix c. japonica*) has been known as a meat and egg producer, but has never been as popular as chicken because of the small body size (Cheng and Kimura, 1990). Despite their small body, these birds can be distinguished for their adaptability to breeding cages, prolificacy, rapid replacement of generations and high productivity (Cheng and Nichols, 1992; Minvielle *et al*., 1997). This genus was introduced into Nigeria to expand the poultry sub-sector and help supplement the domestic chicken production (Ani *et al.,* 2009).

Description of the genetic diversity of indigenous animal populations is a prerequisite for providing needed information for the conservation of useful genotypes against future uncertainties in the face of daunting global challenges such as climate change, emerging diseases, population growth, and rising consumer demands (Kayang, 2010). Characterization of diversity has long been based on morphological traits mainly. Monitoring quantitative genetic variation may reveal variation more closely related to fitness and hence, it may yield more interesting information on the effect of genetic and environmental changes to genetic diversity (Lynch 1996; Storfer 1996; McKay and Latta 2002; Bekessy *et al*., 2003). In addition, quantitative genetic variation can be a useful tool to detect some human-induced impacts on genetic diversity that cannot be detected with molecular neutral variation (Carvajal-Rodríguez *et al*., 2005).

The genetic characterization of domestic animals is the first step towards sustainable management or conservation of a particular population. Improved methods and greater use of phenotypic characterization is essential to assign livestock populations to the appropriate breeds, and to overcome a lack of information regarding key adaptation traits of indigenous farm animal genetic resources (AnGR). Phenotypic comparison based on morphological characters can provide to some extent a reasonable representation of genetic difference among populations. There have been several studies on the ideal male-to-female ratio, hatching egg storage time, correlation between egg weight and fertility rate as well as data on egg hatchability (Bacon and Nestor, 1975; Narahari *et al*., 1988; Adkins-Regan, 1995; Hassan *et al*., 2003; Petek *et al*., 2003). Fertility duration (Sittman and Abplanalp, 1965; Reddish *et al*., 1996) have also been reported for egg-type quails, however there has been little documentation on the morphometric characterization of the Japanese quail in Nigeria. The present investigation therefore, aimed at examining the morphological variation of two strains of Japanese quail present in Nigeria, this could aid their proper management, conservation and improvement in breeding programmes.

Materials and methods

Experimental animals

A total of 1019 birds comprised of 747 mottled brown quail (385 females and 362 males), 272 white quail (88 females and 184 males) between six weeks and six months of age were randomly sampled from different farms aroudn **i**Ibadan, Oyo State.

Data collection

Body weight and 12 morphometric traits were recorded for each bird. The body weight (BW) was determined using a digital scale (5kg) with 0.05g sensitivity while the linear body measurements were taken with the use of a measuring tape calibrated in centimeter. The anatomical reference points were as described by Gueye *et al*. (1998) and Teguia *et al*. (2008).

Beak length (BKL) was measured as length from the tip of the beak until insertion of the beak into the skull; Beak width (BKW) was measured from the insertion of the beak in the skull and perpendicular until the end of the inferior mandible.

Head length (HL) was measured as the distance between the *pars nasalis pars* nasalis ossis frontalis and the mid-point of the *os occipitale*.

Head width (HW): Taken as distance between the two *pars orbitalis ossis frontalis.*

Breast Length (BRL): Taken as length of sternum or breast plate.

Breast Girth (BG): Taken as the circumference of the breast around the deepest region of the breast

Neck length (NL): This is the length of the *axial skeleton* from the first to the last *cervical vertebrae.*

Back length (BL): Measured as length from insertion of the neck into the body to the saddle.

Thigh length (THL): Length from shinbone—femur joint, to shinbone–tarsus joint.

Shank length (SL): Measured as the distance between the mid region of the *Genus* and that of the *Regio tarsalis.*

Wing length (WL): Wing length was as the distance from the *humerus-coracoid* junction to the distal tip of the phalange digits, using a measuring tape.

Wingspan (WS): Distance between the ends of the longest primaries with wings stretched. On the work table, maintain the joints of the wings as stretched as possible.

Statistcal analysis

Descriptive statistics of each variable; means, standard errors and coefficients of variation of body weight and linear body measurements were calculated using the 'proc means' procedure of SAS (2003) package.

Pearson's correlation coefficients were used to determine the degree of relationship among body parameters. From the correlation matrix, data were generated for the principal component factor analysis. Anti-image correlations, Kaiser-Meyer- Olkin measures of sampling adequacy and Bartlett's Test of Sphericity 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. 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 factor programme of SPSS (2011) statistical package was used for the principal component analysis.

Linear regression was fitted to the data to achieve the model for prediction of live body weights from body parameters. Stepwise multiple regression procedure was used to find the best linear combination of metric variables that best explains the live weight. This was performed for each strain. It also ranked the variables in order of importance. All variables utilized in the model were those that met 0.05 significance level for entry into the model. The following linear regression equation was used to predict body weight from linear measurements.

$Y = a + bx$

where Y = body weight or dependent variable, a = constant in the regression equation, b = regression coefficient and, x = various body measurements

Results

The descriptive statistics of body weight and biometric traits of the two genetic groups and sexes investigated are presented in Table 1.

The relationship among measured variables of brown quail for both male and female were as presented in Table 2, while those for white quails: male and female are presented in Table 3. The result of brown female quail presented in Table 2 showed that body weight had positive and significant ($P<0.001$) correlation with head length, beak width, back length, breast length, breast girth, wing length, wing span, thigh length and shank length. The highest correlation with body weight was thigh length (0.75). Correlations with head width (0.01) and there was no significant ($P>0.05$) correlation with beak length and negative correlation with neck length. For brown male, body weight on Table 3 had a positive and significant ($P<0.01$) correlation with all parameters measured. The highest correlation was thigh length (0.76).

Table 3 shows correlation coefficient for white female quail. It was observed that body weight has positive association and was significant ($P<0.001$) with head width, beak length, back length, breast length, wing length, wing span, thigh length, shank length, correlations with breast length breast girth was significant at ($P<0.05$). Highest correlation value was with thigh length (0.80).

For white male quail, it was observed that body weight had positive association and significant ($P<0.001$) correlation with all other body parameters measured except for beak width and neck length. Highest correlation was thigh length (0.64). Correlations with beak width was positive at $P<0.05$. Neck length was negatively correlated at ($P>0.05$).

The relationship between thigh length and other body parameters measured for brown female quail showed that there was a positive and significant ($P<0.001$) correlation with head length, body weight, beak width, back length, breast length, breast girth, wing length, wing span and shank length with correlation for value lowest being beak width (0.22) and highest value body weight (0.75). At ($P<0.01$) there was positive correlation with head width and there was negative correlation with beak length and neck length. Values for white female quails showed positive and significant ($P<0.001$) correlation with body weight (0.81), Beak length (0.70), back length (0.60), breast length (0.46), wing span (0.56), wing length (0.41) and shank length (0.59).

There was also significant ($P<0.01$) correlation with head length, head width, beak width, breast girth, while no correlation existed with neck length

Table 1: Means standard deviation, standard error and coefficient of variation of measured body parameters of mottled brown and white Japanese quail

Parameters	SEX	Brown				White			
		Mean	SD	SE	CV	Mean	SD	SE	CV
BDW	M	136.27	17.16	0.902	12.59	140.67	18.86	1.39	13.41
	F	157.24	25.74	1.31	16.37	158.72	19.09	2.03	12.02
	T	147.08	24.36	0.89	16.56	146.51	20.70	1.26	14.13
HL	M	3.68	0.45	0.023	12.21	3.55	0.27	0.02	7.78
	F	3.72	0.45	0.02	12.19	3.67	0.25	0.02	6.74
	T	3.71	0.453	0.01	12.18	3.59	0.27	0.01	7.61
HW	M	1.53	0.22	0.01	14.39	1.53	0.12	0.09	8.47
	F	1.52	0.172	0.01	11.40	1.56	0.14	0.02	10.03
	T	1.53	0.197	0.01	12.00	1.54	0.13	0.01	8.71
BKL	M	1.47	0.22	0.01	14.39	1.56	0.12	0.01	7.85
	F	1.56	0.82	0.04	52.82	1.64	0.17	0.01	10.03
	T	1.51	0.61	0.02	40.34	1.59	0.13	0.01	9.09
BKW	M	0.46	0.09	0.01	20.95	0.48	0.08	0.01	17.89
	F	0.54	0.26	0.01	47.40	0.52	0.11	0.01	22.22
	T	0.50	0.20	0.01	39.73	0.49	0.10	0.01	19.98
NL	M	4.74	0.63	0.03	13.36	4.75	0.81	0.05	16.96
	F	4.80	0.68	0.03	14.16	4.51	0.70	0.07	15.45
	T	4.77	0.66	0.02	13.80	4.47	0.78	0.04	16.68
BL	M	9.833	0.99	0.05	10.11	10.13	0.89	0.07	8.80
	F	10.19	0.89	0.05	8.76	10.55	1.10	0.12	10.42
	T	10.01	0.96	0.04	14.7	10.37	0.98	0.06	9.56
BRL	M	6.80	0.96	0.05	14.12	6.98	0.71	0.05	10.10
	F	6.92	0.86	0.04	12.46	7.41	1.44	0.15	19.47
	T	6.86	0.91	0.03	13.29	7.12	1.02	0.06	14.35
BRG	M	12.80	1.29	0.07	10.06	12.92	2.09	0.15	16.18
	F	13.01	1.21	0.06	9.27	13.04	1.75	0.19	13.42
	T	12.91	1.25	0.05	9.68	12.96	1.98	0.12	15.31
W L	M	15.19	1.02	0.05	6.68	14.36	2.15	0.16	14.95
	F	15.50	1.13	0.06	7.31	15.48	1.52	0.16	9.81
	T	15.35	1.01	0.04	7.09	14.72	2.03	0.12	13.80
WS	M	32.44	2.86	0.15	8.82	32.90	1.90	0.14	5.77
	F	33.39	1.94	0.10	5.82	34.53	1.76	0.19	5.09
	T	32.93	2.48	0.09	7.53	33.44	2.00	0.12	5.99
TL	M	5.43	0.45	0.02	8.31	5.62	0.54	0.03	9.63
	F	5.97	0.87	0.04	14.68	6.08	0.83	0.09	13.59
	T	5.71	0.75	0.02	13.18	5.76	0.68	0.04	11.81
SL	M	3.56	0.32	0.02	8.84	3.52	0.17	0.01	4.94
	F	3.62	0.36	0.02	10.0	3.62	0.22	0.02	5.96
	T	3.60	0.34	0.01	9.49	3.55	0.19	0.01	5.45

Male (M), Female (F), Total (T), Head Length (HL), Head Width (HW), Beak Length (BRL), Beak Width (BW), Neck Length (NL), Back Length (BL), Breast Length (BRL), Breast Girth (BRG), Wing Length (WL), Wing Span (WS), Thigh Length (TL), Shank Length (SL).

Table 2: Correlation coefficients of Body Parameter in Female and Male Mottled brown quail

Body weight and linear parameters female and male mottled brown quail													
	HL	BDW	HDW	BKL	BKW	NL	BL	BRL	BRG	WL	WS	TL	**SL**
HL		0.40***	0.27***	-0.01^{ns}	0.14*	0.05^{ns}	0.49***	0.16*	0.23***	0.17**	0.26***	0.45***	0.36***
BDW	0.34***		0.18**	0.034^{ns}	0.23***	-0.06^{ns}	0.42***	0.45***	0.38***	0.43***	0.47***	0.75***	0.45***
HDW	0.28***	0.27***		-0.04^{ns}	0.09^{ns}	0.12**	0.22***	0.13**	0.16**	0.09	0.13**	0.15**	0.16**
BKL	-0.00^{ns}	0.20***	0.19**		0.07^{ns}	-0.02^{ns}	0.05***	0.07^{ns}	0.11*	0.08^{ns}	0.01^{ns}	-0.01^{ns}	0.00^{ns}
BKW	0.06 ^{ns}	0.19**	0.01^{ns}	0.35		-0.01^{ns}	0.30***	-0.02^{ns}	0.16*	-0.06^{ns}	-0.06^{ns}	0.22***	0.12*
NL	0.08 ^{ns}	0.10^{ns}	0.14**	0.08	-0.01 ^{ns}		0.11*	0.04^{ns}	0.30***	0.16**	0.95 ^{ns}	0.55 ^{ns}	0.72 ^{ns}
BL	0.29***	0.28***	0.12***	0.06***	0.24**	0.14**		0.11*	0.42***	0.25***	0.10*	0.42***	0.24***
BRL	0.23***	0.66***	0.28***	0.29^{ns}	0.09 ^{ns}	0.05^{ns}	0.18**		0.13**	0.15**	0.31***	0.33***	0.44***
BRG	0.07^{ns}	0.32***	0.07^{ns}	0.00 ^{ns}	0.06 ^{ns}	0.42***	0.29***	0.18**		0.46***	0.05^{ns}	0.33***	0.15***
WL	0.17**	0.25***	0.13*	0.11*	0.01 ^{ns}	0.14 **	0.22***	0.20**	0.34***		0.55***	0.27***	0.22***
WS	0.30***	0.25***	0.16***	-0.02 ^{ns}	-0.09 ^{ns}	0.03 ^{ns}	0.09^{ns}	0.28***	-0.023^{ns}	0.35***		0.34***	0.34***
TL	0.21***	0.76***	0.19***	0.08 ^{ns}	0.10 ^{ns}	0.19**	0.22***	0.48***	0.33***	0.24***	0.17***		0.38***
SL	0.37***	0.43***	0.30***	0.04 ^{ns}	-0.04 ^{ns}	-0.11*	0.11*	0.49***	0.03^{ns}	0.15**	0.26**	0.30***	

*** = P<0.001, ** = P<0.01, *= P<0.05, ns= not significant Head Length (HL), Head Width (HW), Beak Length (BRL), Beak Width (BW), Neck Length (NL), Back Length (BL), Breast Length (BRL), Breast Girth (BRG), Wing Length (WL), Wing Span (WS), Thigh Length (TL), Shank Length (SL).

Table 3: Correlation among Body Parameter of Female and Male White Quail

body weight and linear parameters female and male **white** quail													
	HL	BDW	HW	BKL	BKW	NL	BL	BRL	BRG	WL	WS	TL	**SL**
HL		0.40**	0.23*	0.39**	0.27*	-0.25*	0.46***	0.17 ^{ns}	0.07 ^{ns}	0.10 ^{ns}	0.26*	0.38**	0.30**
BDW	0.54***		0.45***	0.74***	0.34*	-0.05^{ns}	0.65***	0.54***	0.35**	0.56***	0.67***	0.81***	0.61***
HW	0.35***	0.43***		0.35**	0.34**	-0.02^{ns}	0.17***	0.40**	0.16 ^{ns}	0.17 ^{ns}	0.32**	0.36**	0.38**
BKL	0.26**	0.50***	0.30***		0.29**	-0.07^{ns}	0.51***	0.47***	0.36**	0.44***	0.52***	0.70***	0.50***
BKW	0.20**	0.20***	0.08 ^{ns}	0.09 ^{ns}		-0.07 ^{ns}	0.16 ^{ns}	0.42***	0.11 ^{ns}	0.05 ^{ns}	0.18 ^{ns}	0.34**	0.22*
NL	-0.17*	-0.07 ^{ns}	-0.00 ^{ns}	0.09 ^{ns}	-0.12 ^{ns}		-0.02 ^{ns}	0.10 ^{ns}	0.58***	0.36**	0.06 ^{ns}	0.02 ^{ns}	0.06 ^{ns}
BL	0.28***	0.67***	0.43***	0.45***	0.15*	0.06***		0.20 ^{ns}	0.42***	0.44***	0.34**	0.60***	0.40***
BRL	0.22**	0.30***	0.22**	0.20**	-0.04^{ns}	0.39***	0.36***		0.21 ^{ns}	0.35**	0.42***	0.46***	0.36**
BRG	0.12*	0.36***	0.14*	0.31***	-0.12 ^{ns}	0.56***	0.28**	0.48***		0.52***	0.18 ^{ns}	0.31**	0.23**
WL	0.24**	0.42***	0.15*	0.27**	0.02 ^{ns}	0.28***	0.23**	0.36***	0.72***		0.75***	0.41***	0.39**
WS	0.29***	0.56***	0.24*	0.28***	0.07 ^{ns}	0.10 ^{ns}	0.31***	0.28***	0.50***	0.68***		0.56***	0.47***
TL	0.30***	0.64***	0.27**	0.45***	0.02 ^{ns}	0.19**	0.52***	0.28***	0.41***	0.42***	0.34***		0.59***
SL	0.26**	0.30***	0.14 ^{ns}	0.09 ^{ns}	0.08 ^{ns}	0.07 ^{ns}	0.21**	0.32***	0.34**	0.27**	0.30***	0.24**	

*** = P<0.001, ** = P<0.01, *= P0.05, ns= not significant Head Length (HL), Head Width (HW), Beak Length (BRL), Beak Width (BW), Neck Length (NL), Back Length (BL), Breast Length (BRL), Breast Girth (BRG), Wing Length (WL), Wing Span (WS), Thigh Length (TL), Shank Length (SL)

Table 4 and 5 showed the linear regression and coefficient of determination R^2 for predicting body weight at different ages in the brown and white Japanese quail. Result presented in Table 4 indicates that all parameters measured were significant in the prediction of body weight ($P<0.001$) except for neck length which was not significant for female brown. Result showed that for both sexes, breast length, breast girth, back length and thigh length will be more reliable for predicting body weight. The values of these parameters include 0.42, 0.40, 0.42, 0.57 and 0.50, 0.47, 0.51, 0.57 for males and females respectively. Other parameters will not be reliable for predicting as they contributed little judging by their R^2 values. Result presented in Table 6 indicates predicted values from simple linear model equation for male and female white quail.

Table 4: Regression of body Parameters on body weight in mottled Brown quail.

	Male mottled Brown quail				Female mottled Brown quail			
Variable	Regression Equation	R^2	SE	Prob	Regression Equation	R^2	SE	Prob
HL	Y= 88.37+13.02X	0.12	1.90	***	Y= 72.54+22.55X	0.16	2.68	***
HW	Y= 103.87+21.12X	0.07	3.94	***	Y= 115.60+27.43X	0.31	7.48	***
BKL	Y= 112.50+16.17Xl	0.03	4.07	***	Y= 155.53+1.10X	0.0012	1.60	ns
BKW	Y= 121.031+32.84X	0.03	9.14	***	Y= 144.40+23.65X	0.05	4.96	***
NL	Y= 123.031+2.72X	0.01	1.42	Ns	Y= 169.13-2.47X	0.004	1.92	ns
BL	Y= 87.32+4.98X	0.08	0.87	***	Y= 31.75+12.32X	0.18	1.33	***
BRL	Y= 56.59+11.70X	0.42	0.71	***	Y= 63.46+13.56X	0.20	1.36	***
BRG	Y= 80.84+4.33X	0.10	0.66	***	Y= 50.05+8.23X	0.14	1.00	***
WL	Y= 72.55+4.19X	0.11	0.86	***	Y= 5.86+9.76X	0.18	1.05	***
WS	Y= 87.40+1.50X	0.14	0.30	***	Y= -50.80+6.23X	0.22	0.59	***
TL	Y= -2073+28.88X	0.57	1.30	***	Y= 24.61+22.X	0.57	0.98	***
SL	Y= 52.64+23.44X	0.18	2.59	***	Y=40.72+32.10X	0.20	3.23	***

*** = P<0.001, ** = P<0.01, *= P0.05, ns= not significant Head Length (HL), Head Width (HW), Beak Length (BRL), Beak Width (BW), Neck Length (NL), Back Length (BL), Breast Length (BRL), Breast Girth (BRG), Wing Length (WL), Wing Span (WS), Thigh Length (TL), Shank Length (SL)

Body weight had a significant ($P<0.001$) linear relationship with all body measurements for both sexes except with neck length for both sexes. Prediction of body weight will be most reliable with breast length, breast girth and back length. The R^2 value for male suggest that the breast length contributed 42 and 50% respectively, breast girth contributed 0.40 and 0.47 while back length had a higher contribution of 0.54 and 0.56 for both male and female respectively. Thigh length had the highest R^2 of 0.57 for both sexes. Conversely, the values obtained for neck length (0.005), beak width (0.03), head width (0.18) will not be reliable in predicting body weight.

Tables 6 and 7 reveal the stepwise regression equation for prediction of body weight using other body parameters measured. The models were highly significant ($P<0.001$). R^2 coefficient ranges from 0.58 in thigh length to shank length (0.71), beak width, and breast girth. In mottled brown male quail thigh length was the first step recorded with 0.58 R^2 while the last step, step six was shank length with 0.72R^2. For mottled brown female, thigh length was also the first step observed with 0.57R^2 while the last step entered was back length as the eighth step with 0.71R^2. For female white quail, five variables can be reliably used in predicting body weight, which

Table 5: Regression of body Parameters on body weight in White Quail

	Male white quail				Female white quail			
Variable	Regression Equation	R^2	SE	Prob	Regression Equation	R^2	SE	Prob
HL	Y= 9.07+37.11X	0.29	4.26	***	Y= 45.24+30.90X	0.161	7.60	***
HW	Y= 43.78+63.44X	0.18	9.7	***	Y= 61.64+62.08X	0.21	13.00	***
BKL	Y= 19.51+77.86Xl	0.25	9.8	***	Y= 17.20+85.83X	0.55	8.32	***
BKW	Y=118.83+45.81X	0.03	16.04	**	Y= 129.26+56.61X	0.12	16.72	***
NL	Y=148.64-1.67X	0.005	8.34	Ns	Y= 168.06-1.41X	0.002	2.95	***
BL	Y= 6.92+13.19X	0.39	1.22	***	Y= 39.09+11.33X	0.42	1.42	***
BRL	Y= 84.37+8.06X	0.09	1.89	***	Y= 106.02+7.11X	0.28	1.20	***
BRG	Y= 97.57+3.33X	0.13	0.62	***	Y=109.09+3.80X	0.12	1.10	***
WL	Y= 87.91+3.67X	0.17	0.59	***	Y= 49.27+7.07X	0.32	1.12	***
WS	Y= -44.06+5.61X	0.31	0.60	***	Y= -94.16+7.32X	0.45	0.18	***
TL	Y= 15.07+22.36X	0.41	01.98	***	Y= 45.02+18.70X	0.65	1.46	***
SL	Y=26.24+32.49X	0.09	7.65	***	Y= -38.58+54.48X	0.37	7.52	***

*** = P<0.001, ** = P<0.01, *= P0.05, ns= not significant Head Length (HL), Head Width (HW), Beak Length (BRL), Beak Width (BW), Neck Length (NL), Back Length (BL), Breast Length (BRL), Breast Girth (BRG), Wing Length (WL), Wing Span (WS), Thigh Length (TL), Shank Length (SL)

are thigh length, wing span, breast length, back length and beak length with range of 0.65 to 0.77 R^2 for thigh length and breast length respectively. Although beak length and breast length had higher R^2 they were significant ($P<0.01$) and ($P<0.05$) respectively.

The principal components of morphometric variables in the studied quails are presented in Tables 8 and 9. The anti – image correlations computed showed that partial correlations were

Table 6: Table Stepwise Regression of body parameters of mottled brown quail

Parameters	Sex	Intercept	SE	R^2	Probability
Thigh	M	20.006	1.29	0.578	***
	F	14.770	1.033	0.570	***
WL	M	-	-	-	-
	F	3.010	0.917	0.625	***
BRL	M	5.585	0.638	0.685	***
	F	6.015	0.920	0.663	***
BW	M	16.48	5.089	0.711	**
	F	10.813	3.03	0.679	***
NL	M	-	-	-	-
	F	-4.620	1.137	0.688	**
WS	M	-	-	-	-
	F	2.023	0.507	0.695	**
BRG	M	1.007	0.402	0.715	*
	F	2.307	0.917	0.704	**
BL	M	-	-	-	-
	F	2.192	0.974	0.708	*
HL	M	4.384	1.18	0.715	**
	F	-	-	-	-
SL	M	4.098	1.886	0.719	*
	F	-	-	-	-

*** = P<0.001, ** = P<0.01, *= P0.05, ns= not significant Head Length (HL), Head Width (HW), Beak Length (BRL), Beak Width (BW), Neck Length (NL), Back Length (BL), Breast Length (BRL), Breast Girth (BRG), Wing Length (WL), Wing Span (WS), Thigh Length (TL), Shank Length (SL), R^2 = Co-efficient of multiple determination

Table 7: Stepwise Regression of body parameters of White Quail

Parameters	Sex	Intercept	SE	R^2	Probability
TL	M	10.892	1.760	0.412	***
	F	23.022	8.364	0.654	***
HL	M	15.849	3.044	0.546	***
	F	-	-	-	-
WS	M	2.904	0.436	0.765	***
	F	2.62791	0.668	0.723	***
BL	M	5.580	1.034	0.695	***
	F	4.2689	1.081	0.663	***
NL	M	-3.556	0.978	0.714	**
	F	-	-	-	-
BKL	M	17.435	7.218	0.723	*
	F	23.022	8.364	0.792	**
BRL	M	-	-	-	-
	F	1.8897	0.767	0.8064	*

*** = P<0.001, ** = P<0.01, *= P0.05, ns= not significant Head Length (HL), Head Width (HW), Beak Length (BRL), Beak Width (BW), Neck Length (NL), Back Length (BL), Breast Length (BRL), Breast Girth (BRG), Wing Length (WL), Wing Span (WS), Thigh Length (TL), Shank Length (SL), R^2 = Co-efficient of multiple determination

low, indicating that true factors existed in the data of both sexes of the two quail breeds. This was supported by Kaiser-Meyer- Olkin measure of sampling adequacy studied from the diagonal of partial the body measurements caused by the underlying factor.

This was found to be sufficiently high for all the morphometric traits in brown (0.71 and 0.74 for female and male animals) and white (0.72 and 0.79) quail, respectively. The overall significance of the correlation matrices tested with Bartlett's Test of Sphericity for the body dimensions of the brown quail (chi-square = 1288.14 versus 1473.81 for female and male animals; P<0.01) and for white quail (chi-square = 845.87 versus 530.82; 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 0.530–0.849 in brown quail and 0.505–084 in white quail, respectively. These further lend credence to the appropriateness of the factor analysis while estimates of the residual correlation matrix were low enough.

After varimax rotation of the component matrix in brown quail, three factors were extracted for each sex, and these accounted for 30.16 (females) and 27.86% (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 brown quail, body weight (0.84), back length (0.63), thigh length (0.77) and shank length (0.62) were more associated with the first PC, the second PC had its loadings (correlation between component and variable) for beak width (0.64) while in the third PC neck length (0.64) and breast girth (0.69) were more associated , respectively. In their male counterparts, PC1 had its loadings for body weight (0.84), head length (0.63), thigh length (0.73) and back length (0.63) while PC2 was

Table 8: Eigenvalues and share of total variance along with factor loadings after rotation and communalities of the biometric traits of mottled brown Japanese quail

Male	PC1	PC2	PC3	Communalities
Body Weight	0.843	-0.19	0.132	0.849
Head Length	0.523	-0.245	-0.151	0.596
Head Width	0.472	-0.188	0.28	0.530
Beak Length	0.287	0.190	0.652	0.808
Beak Width	0.203	0.357	0.667	0.753
Neck Length	0.203	0.247	0.667	0.676
Back Length	0.459	0.329	0.001	0.696
Breast Length	0.743	0.198	0.213	0.713
Breast Girth	0.436	0.633	-0.321	0.720
Wing Length	0.475	0.162	-0.337	0.469
Wing Span	0.428	-0.382	-0.342	0.555
Thigh Length	0.728	-0.96	-0.002	0.763
Shank length	0.579	0.622	0.018	0.618
Eigen Value	3.622	1.597	1.413	
% Variance	27.862	12.285	10.866	
Female				
Body Weight	0.845	-0.126	-0.167	0.777
Head Length	0.627	0.175	-0.199	0.528
Head Width	0.341	0.243	0.026	0.456.
Beak length	0.73	0.054	0.135	0.553
Beak Width	0.259	0.646	-0.405	0.594
Neck Length	0.135	0.338	0.646	0.630
Breast Length	0.514	-0.387	-0.068	0.627
Back Length	0.631	0.474	-0.064	0.419
Breast Girth	0.563	0.397	0.445	0.703
Wing Length	0.576	-0.225	0.570	0.734
Wing Span	0.570	-0.558	0.169	0.666
Thigh Length	0.769	-0.010	-0.264	0.667
Shank Length	0.617	-0.236	-0.214	0.498
Eigen Value	3.921	1.470	1.342	
% Variance	30.160	11.311	10.327	

PC – principal Component

related to shank length (0.62) and breast girth (0.63) and also PC3 had its loading for beak width (0.63) and beak length (0.65).

However, in white quail, measurements most highly correlated with PC1 were body weight, back length, breast length, wing length and thigh length (this explained 38% of the generalized variance of females), and could be termed “body size factor”. PC2 was primarily determined by neck length (0.85), breast girth (0.65) and shank length (0.65) which accounted for 14.2% of the variation. In their male counterparts PC1

Table 9: Eigenvalues and share of total variance along with factor loadings after rotation and communalities of the biometric traits of white Japanese quail

Male	PC1	PC2	PC3	Communalities
Body Weight	0.763	0.413	-0.180	0.791
Head Length	0.478	0.555	0.092	0.595
Head Width	0.460	0.366	-0.309	0.476
Beak Length	0.557	0.181	-0.361	0.475
Beak Width	0.126	0.527	0.475	0.612
Neck Length	0.324	-0.725	0.091	0.718
Back Length	0.416	0.114	-0.271	0.607
Breast Length	0.594	-0.243	0.187	0.544
Breast Girth	0.758	-0.489	0.096	0.829
Wing Length	0.767	-0.250	0.145	0.800
Wing Span	0.731	0.025	0.088	0.680
Thigh Length	0.597	-0.168	-0.242	0.452
Shank length	0.333	0.183	0.736	0.714
Eigen Value	4.145	1.884	1.247	
% Variance	31.882	14.490	9.594	
Female				
Body Weight	0.900	-0.145	-0.075	0.842
Head Length	0.466	-0.491	-0.184	0.505
Head Width	0.543	-0.252	0.333	0.552
Beak length	0.779	-0.167	-0.108	0.649
Beak Width	0.421	-3.44	0.550	0.632
Neck Length	0.130	0.855	0.230	0.809
Back Length	0.689	0.076	-0.232	0.618
Breast length	0.712	0.092	0.323	0.639
Breast Girth	0.529	0.636	0.074	0.781
Wing Length	0.710	0.451	-0.204	0.860
Wing Span	0.735	0.007	-0.208	0.805
Thigh Length	0.710	-0.130	0.0293	0.646
Shank Length	0.343	-0.084	0.552	0.757
Eigen Value	5.051	1.849	1.156	
% Variance	38.854	14.222	7.993	

PC – principal Component

had its loading for body weight (0.76), breast girth (0.76), and wing length (0.73) (this could be explained by 31.88 of the total variance). PC2 was solely related to neck length (0.72) which accounted for 14.90% of the variation and PC3 had its loading for shank length (0.74).

Discussion

The estimates of correlation in the present study are comparable to those reported by earlier workers (Gueye *et al*., 1998; Yang *et al*., 2006). The strong relationship existing between body weight and body measurements may be useful as selection criterion~~,~~ since positive correlations of traits suggest that the traits are under the same gene action. Correlation coefficients of thigh length and other parameters such as shank length, wing length, back length, breast length, breast girth, and wing span indicate that an improvement in thigh length could lead to an improvement in the other parameter

High, positive and significant (P<0.001) correlations were observed for most of the variables tested. The high and positive correlations reported in this study implies that there exists a strong linear relationship between body weight and shank length, body girth, wing length, thigh length and back length. A similar result was reported by Ojo *et al*. (2014). This result also corroborates the reports of Yahaya *et al*., (2012), and Alabi *et al.* (2012) that high positive correlation exist between body weight and linear body measurements in broilers and naked neck/venda chickens of South Africa.

Generally, in the two quail population, PC1 had the largest share of the total variance and correlated highly with breast, body weight, thigh length, wing length, wing span and breast length. PC1 could be described as the generalized size factor. In a principal component analysis of body measurements of broilers, Yakubu *et al*. (2009b) reported that PC1 had high positive loadings on body weight, breast circumference and thigh length of Arbor Acre and termed PC1 "form factor". Mendes (2011) reported that PC1 had the highest correlation with shank length, breast circumference and body weight of Ross 308 broilers. Yakubu *et al*. (2009a) reported that the first principal component accounted for the largest variance in the morphological traits of three Nigerian chicken genotypes. Ogah *et al*. (2009) presented data that showed PC1 accounting for the largest variance in the body measurements of ducks with high positive loadings on body width, bill width, shank length, body length, head length and neck length. Pinto *et al*. (2006) used PCA to analyze performance and carcass traits measured in a population of *Gallus gallus*. The authors reported five first principal components explaining 93.30% of the total variation and the first component explained 66.00% which is much higher than the result obtained in this present study.

The use of PC1 as a single predictor in this present study, explained 27.86 and 31.88% for brown and white male while 30.16 and 38.54% total variance was explained for brown and white female quails, respectively. The first component was referred to as the generalized weight factor because the largest Eigen vectors were associated with bodyweight at 35 and 42 days of age. According to Mendes (2011), the first principal component provides an adequate summary of the data in most cases.

The variation in factor loading in male and female observed here may indicate differences in association of each measurement with bone which varies with sexes (Salako, 2006). There is a clear indication of weakness of the parameter measured in explaining the total variation in the body measurement of the Japanese quail which could be due to selection.

Highest R^2 was observed in thigh length (0.65) for mottled brown and white female quail while the highest in white male quail was in breast length (0.53). It was observed that back length breast length, breast girth generally had high and significant R^2. The result of R^2 for thigh length and breast girth obtained from this work is higher than the R^2 (0.15 and 0.37) for Japanese quail at eight weeks reported by Ojo *et al*. (2014). They also observed lower R^2 (0.09) for wing length at eight weeks compared to what was observed in this work 0.18, 017, 0.32 and 0.59 for brown female, brown male, white female and white male quail respectively. The subsequent improvement of R^2 values indicates a better reliability in prediction of live weight using any one of the other body parameters with R^2 values above 60%. For R^2 values below 50% there is need for the use of two or more body indices for body weight estimation.

The R^2 range obtained (0.58 to 0.72 and 0.41 to 0.81) for mottled brown and white were higher and closer compared with the wide range (0.16 to 0.95) obtained by Oni *et al.* (2001a). The R^2 value obtained in this work was also similar to the R^2 range obtained from the cock equations (0.66 to 0.82) by Jesuyon and Salako. (2013). It signified that the stepwise model fits the cock better than hen data (Oni et al., 2001b). The R^2 of 0.98 that was obtained by Essien and Adeyemi (1999) from the predictive equations of body weight on age in Lohmann brown and Annak broilers was similar to that obtained (R^2 = 0.79) from the regression of body weight on for white quail in this study. The R^2 of 0.347 to 0.575 obtained from stepwise regressions by Okon *et al*. (1997) were intermediate between that of the cocks and the hens in this study.

Conclusion

The study showed that body weight in Japanese quail is linearly related to body measurements, especially with thigh length, back length and breast length. The prediction of body weight from these measurements is possible. The high, positive and outstanding correlation between body weight and zoometric body measurements indicates that these easily measured parts can be used as criteria for assessment and selection of body weight. The study indicated that sexual dimorphism occur in quail birds. The present information could aid their management, conservation and future selection and breeding programmes.

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