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ORIGINAL RESEARCH

Multivariate analysis of sexual size dimorphism in local turkeys (*Meleagris gallopavo*) in Nigeria

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Abstract Sexual size dimorphism is a key evolutionary feature that can lead to important biological insights. To improve methods of sexing live birds in the field, we assessed sexual size dimorphism in Nigerian local turkeys (*Meleagris gallopavo*) using multivariate techniques. Measurements were taken on 125 twenty-week-old birds reared under the intensive management system. The body parameters measured were body weight, body length, breast girth, thigh length, shank length, keel length, wing length and wing span. Univariate analysis revealed that toms (males) had significantly ($P<0.05$) higher mean values than hens (females) in all the measured traits. Positive phenotypic correlations between body weight and body measurements ranged from 0.445 to 0.821 in toms and 0.053–0.660 in hens, respectively. Three principal components (PC1, PC2 and PC3) were extracted in toms, each accounting for 63.70%, 19.42% and 5.72% of the total variance, respectively. However, four principal components (PC1, PC2, PC3 and PC4) were extracted in hens, which explained 54.03%, 15.29%, 11.68% and 6.95%, respectively of the generalised variance. A stepwise discriminant function analysis of the eight morphological traits indicated that body weight, body length, tail length and wing span were the most discriminating variables in separating the sexes. The single discriminant function obtained was able to correctly classify 100% of the birds into their source population. The results obtained from the present study could aid future management decisions, ecological studies and conservation of local turkeys in a developing economy.

Keywords Conservation · Discriminant analysis · Local turkeys · Principal components · Sexual dimorphism

Abbreviations

BW	Body weight
BG	Breast girth
BL	Body length
D	Discriminant function
KL	Keel length
PC	Principal component
SL	Shank length
TL	Thigh length
WL	Wing length
WS	Wing span

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Introduction

Sexual size dimorphism, a difference in body size between sexually mature males and females, is a fundamental

morphological characteristic of many animals. Sex identification is vital to the development of efficient breeding strategy and has important consequences for ecology, behaviour, physiology, population dynamics and evolution (Blanckenhorn 2005; Xirouchakis and Poulakakis 2008; Puebla-Olivares and Figueroa-Esquivel 2009). In most organisms, sexual dimorphism goes beyond the fundamental differentiation of reproductive organs to include dimorphisms in body size, shape, colour, as well as the presence of specific morphological structures in one sex (Fairbairn and Roff 2006). Usefulness of body measurements as predictors of sex increases with increasing sexual size dimorphism and with decrease in the variability within sexes (Fletcher and Hamer 2003). In organisms with determinate growth, sexual size dimorphism (SSD) occurs before maturity (Badyaev 2002; McKenzie et al. 2007) during the developmental process of growing apart, an ontogenetic perspective on the evolution of SSD. Cloaca examination, laparoscopy, analysis of steroid hormones and DNA analysis, which have been used for sex determination in birds, required trained researchers and specialised equipment, and are expensive and time-consuming (Palma et al. 2001). Therefore, being able to reliably distinguish sexes by measuring morphological traits in the field would be especially useful.

Local turkeys constitute about 1.05 million of the total poultry population in Nigeria being the smallest when compared to other poultry species like chicken (estimated at 160 million), guinea fowl (8.3 million) and ducks (1.7 million) (FAOSTAT, 2011). Characterization and conservation of local turkeys is important because they contain a reservoir of genetic variation which may be lost in the improved gene pool (Peters et al. 2002; Adebambo 2003). The rate at which wild species and domestic breeds and strains are disappearing is of global concern and an increasing number of these require human intervention to guarantee their survival (Kumaraswany and Udayakumar 2011; Drechsler et al. 2011). Morphological variation within a species can provide biologists with a wealth of information, which could be quite attractive and useful for screening overall genetic diversity of different livestock species (Toro and Caballero 2005; Yakubu et al. 2011).

Previous efforts on the characterization of Nigerian local turkeys had centred on univariate analysis (Ilori et al. 2010), whereas the current trend in the phenotypic differentiation of various livestock species involves the use of multivariate approaches (Mc Cracken et al. 2000; Robertson et al. 2008; Yakubu et al. 2009; Yakubu and Akinyemi 2010; Yakubu and Okunsebor 2011). Therefore, the present investigation was undertaken to evaluate sexual size dimorphism in local turkeys using multivariate principal component and discriminant analyses. The information obtained could aid in ecological studies, conservation, selection and better management of Nigerian local turkeys.

Materials and methods

Location of the study

The study was carried out at the Poultry Breeding Unit of the University Teaching and Research Farm, University of Agriculture, Abeokuta, Nigeria with latitude 7°10′ N and longitude 3°2′ E. The area has a tropical climate with a mean annual rainfall of about 1,037 mm. The mean monthly ambient temperature ranges from 28°C in December to 36°C in February with a yearly average of 34°C. Relative humidity ranges from 60% in January to 94% in August with a yearly average of about 82%. The vegetation represents an interphase between the tropical rainforest and the derived savannah.

Experimental birds and management

One hundred and twenty five, clinically normal, 20-week-old local turkeys comprising 61 males (toms) and 64 females (hens) generated through artificial insemination were randomly selected for the study. The experimental birds were raised intensively. They were fed starter mash containing 26.7% crude protein (CP) and 2,860 kcal metabolizable energy (ME)/Kg from day old to 6 weeks of age, followed by grower mash of 24% CP and 2,851.1 kcal/ME/Kg from weeks 7 to 13 and finisher mash containing 19.7% CP and 2,900 kcal/ME/Kg from 14 to 20 weeks of age, respectively. Feed and clean water were provided ad libitum. Vaccinations against Newcastle, gumboro and fowl pox diseases were carried out, while prophylactic antibiotics and anticoccidial drugs were appropriately administered. Other routine management practices were also carried out. All birds were subjected to similar treatment throughout the study period.

Traits measured

Body weight (BW) (in grams) and seven linear body measurements (in centimeter) namely body length (BL), wing length (WL), wing span (WS), shank length (SL), thigh length (TL), breast girth (BG) and keel length (KL) were measured on each adult turkey. BL was measured as the distance between the base of the neck and the cauda (tail without feathers). WL was taken as the distance between the tip of the phalanges and the coracoids–humerus joint. WS was measured as the distance between the left wing tip to the right wing tip across the back of the turkey. SL was measured as the distance between the end of the thigh and the tarsus. TL was taken as the distance between the hock joint and the pelvic joint. BG was measured as the circumference of the breast around the deepest region of the breast while KL was measured as the distance between the anterior and posterior ends of keel. BW was taken using a balance of

0.05 g sensitivity, while linear body measurements were measured using a measuring tape. All measurements were taken in duplicates by the same person in order to avoid between-individual variations.

Statistical analysis

The morphological traits were subjected to analysis of variance to determine sex effect using the MEAN procedure of SPSS (2010). Means were separated using the two-tailed two-sample *t* test of the same statistical package. Pearson's correlation coefficients (*r*) between all the parameters measured were estimated for each sex. Multivariate techniques (principal component and discriminant analyses) were also employed in distinguishing the sexes. According to Everitt et al. (2001), principal component (PC) analysis is a method for transforming the variables in a multivariate dataset into new variables, which are uncorrelated with each other and accounted for decreasing proportions of the total variance of the original variables. In the PC analysis of the present study done separately for each sex, cumulative proportion of variance criterion was employed in determining the number of factors to extract. The varimax criterion of the orthogonal rotation method was employed in the rotation of the factor matrix to enhance the interpretability of the factor analysis. Canonical discriminant analysis, also a multivariate technique, was used to identify the combination of variables that best separate the two sexes. The relative importance of the morphological variables in discriminating the two populations was assessed using Wilk's Lambda and F-to-remove statistic. Collinearity among the variables used in the discriminant model was evaluated using the tolerance statistic. For sex identification, the unstandardized discriminant function procedure of the canonical discriminant analysis was employed. The ability of this function to identify toms (adult male turkeys) and hens (adult female turkeys) was indicated as the percentage of individuals correctly classified from the sample that generated the function. Accuracy of the classification was evaluated using split-sample validation (cross-validation). The proportion of individuals correctly re-allocated is taken as a measure of the morphological distinctness of the population.

Results

Descriptive statistics of the morphological traits of toms and hens are presented in Table 1. Sex differences were observed in all the body parameters with toms having significantly ($P<0.05$) higher values than hens.

Pairwise correlations of body weight and linear body measurements are presented in Table 2. Positive and highly significant ($P<0.01$) correlation coefficients were observed in toms with values ranging from 0.072 to 0.924. In hens, however, the coefficients ranged from 0.016 to 0.745.

Kaiser–Meyer–Olkin measure of sampling adequacy (0.874 and 0.755 for toms and hens, respectively) and the significance of the Bartlett's Test of Sphericity indicate the appropriateness of the principal component analysis (Table 3). While three PCs were extracted for toms, four were obtained for their hen counterparts. In toms, PC1 had its loadings for BW, KL, BG and TL, accounting for 63.70% of the total variance. WS, SL and WL were more associated with PC2, which explained 19.42% of the variance, while PC3 had its loading for BL, which contributed 5.70% to the total variance. PC1 was characterised by BW, KL, BG and TL, explaining 54.03% of the total variation in hens, while PC2, which accounted for 15.29% of the variation, was more correlated with WS and SL. 11.68% of the variation was explained by PC3 which was singly determined by WL, while BL was the sole variable associated with PC4 accounting for 6.95% of the total variation

Table 1 Descriptive statistics of morphological traits in toms and hens

Traits	Toms (n=61) means+S.E.M	S.D	C.V	Hens (n=64) means+S.E.M	S.D	C.V
BW	3,242.3±35.97a	280.93	8.66	2,244.5±18.61b	148.84	6.63
BL	39.69±0.23a	1.80	4.54	34.37±0.16b	1.29	3.75
BG	56.19±0.28a	2.20	3.91	48.54±0.21b	1.70	3.50
TL	19.39±0.11a	0.88	4.54	17.05±0.07b	0.56	3.28
SL	13.12±0.09a	0.70	5.34	11.28±0.05b	0.39	3.46
KL	13.60±0.08a	0.66	4.85	11.68±0.06b	0.45	3.85
WL	33.91±0.23a	1.79	5.28	29.23±0.13b	1.01	3.45
WS	72.56±0.39a	3.02	4.16	62.07±0.20b	1.56	2.51

Means in the same row bearing different letters are significantly different ($P<0.05$)

S.E standard error, *S.D* standard deviation, *C.V* coefficient of variation, *BW* body weight, *BL* body length, *BG* breast girth, *TL* thigh length, *SL* shank length, *KL* keel length, *WL* wing length, *WS* wing span

Table 2 Phenotypic correlation of morphological traits of toms (upper diagonal) and hens (lower diagonal)

Traits	BW	BL	BG	TL	SL	KL	WL	WS
BW	–	0.510**	0.821**	0.764**	0.445**	0.767**	0.663**	0.533**
BL	0.29*	–	0.545**	0.475**	0.144^{ns}	0.609**	0.176^{ns}	0.072^{ns}
BG	0.596**	0.329**	–	0.771**	0.540**	0.797**	0.681**	0.564**
TL	0.604**	0.346**	0.722**	–	0.537**	0.659**	0.692**	0.660**
SL	0.203^{ns}	0.313*	0.505**	0.578**	–	0.317*	0.749**	0.816**
KL	0.660**	0.131^{ns}	0.619**	0.746**	0.522**	–	0.446**	0.309*
WL	0.053^{ns}	−0.016^{ns}	0.046^{ns}	0.340**	0.454**	0.202^{ns}	–	0.924**
WS	0.573**	0.402**	0.745**	0.738**	0.645**	0.606**	0.359**	–

BW body weight, *BL* body length, *BG* breast girth, *TL* thigh length, *SL* shank length, *KL* keel length, *WL* wing length, *WS* wing span, *ns* non-significant

*$P<0.05$; **$P<0.01$

When all the eight morphological traits were entered stepwise in the discriminant analysis, body weight, wing span, body length and thigh length were found as the most discriminating variables in separating the sexes based on significant F values (Table 4). There was a drop in Wilk's Lambda to 0.108 with a significant difference between the sexes ($F=269.223$; $P<0.001$). In order to predict each sex, the unstandardized discriminant model below derived from the four most discriminating variables was employed:

$$\text{Discriminant Function (D)} = -25.541 + 0.003\text{BW} + 0.300\text{BL} - 0.786\text{TL} + 0.324\text{WS}$$

The discriminant function (D) was able to classify correctly 100% of the birds (Table 5). Cross-validation with the split-sample method equally indicated 100% overall success rate.

Discussion

Morphological relationships change with overall body size, and body size often varies among populations (McCoy et al. 2006). Body weight is a trait of utmost importance in livestock breeding. The present finding is in consonance with that of Herendy (2008) who reported sex difference in the live body weight of mature turkeys. Toelle et al. (1990) observed sex differences in the genetic parameters of live, carcass and skeletal data of turkeys 16 weeks of age. In a related study in ducks, Yakubu (2011) reported comparative advantage of males over females in most morphological traits examined. The apparent sexual size dimorphism of the birds could be attributed to the usual between-sex differential hormonal effects on growth. This is consistent with the findings of earlier workers (Zaky and Amin 2007; Teguia et al. 2008; Cox et al. 2009; Cox and Calsbeek 2010; Adeleke et al. 2011). Body size is a central character of organisms, and we expect selection to act on body size in manner which optimises fitness within the

Table 3 Eigenvalues and share of total variance along with factor loadings after varimax rotation and communalities for comparing the morphological traits of toms and hens

Traits	PC1	Tom PC2	PC3	Comm.	PC1	PC2	Hen PC3	PC4	Comm.
BW	0.863	0.328	0.159	0.878	0.937	−0.027	0.014	0.200	0.919
KL	0.859	0.098	0.332	0.858	0.777	0.437	0.089	−0.120	0.817
BG	0.793	0.410	0.274	0.872	0.632	0.613	−0.183	0.166	0.837
TL	0.701	0.502	0.212	0.789	0.693	0.512	0.219	0.170	0.819
WS	0.288	0.927	−0.074	0.948	0.566	0.593	0.226	0.292	0.809
SL	0.124	0.915	0.164	0.880	0.125	0.867	0.320	0.151	0.893
WL	0.461	0.835	−0.051	0.912	0.065	0.198	0.963	−0.300	0.972
BL	0.403	−0.001	0.899	0.971	0.132	0.176	−0.029	0.960	0.970
Eigenvalue	5.096	1.554	0.458		4.323	1.223	0.934	0.556	
Percentage variance	63.70	19.42	5.72		54.03	15.29	11.68	6.95	

For toms, Kaiser–Meyer–Olkin measure of sampling adequacy=0.847; Bartlett's test of sphericity (chi-square=460.335; $P<0.001$); Determinant=0.0001. For hens, Kaiser–Meyer–Olkin measure of sampling adequacy=0.755; Bartlett's Test of Sphericity (chi-square=296.556; $P<0.001$); Determinant=0.007

PC principal component, *Comm.* communality, *BW* body weight, *WL* wing length, *WS* wing span, *SL* shank length, *TL* thigh length, *BL* body length, *BG* breast girth, *KL* keel length

Table 4 Morphological traits selected by stepwise discriminant analysis to separate toms and hens

Variable	Wilk's lambda	F-to-remove	P level	Tolerance
BW	0.165	18.002	<0.001	0.450
WS	0.134	44.738	<0.001	0.508
BL	0.120	20.182	<0.001	0.737
TL	0.108	13.418	<0.001	0.340

BW body weight, *WS* wing span, *BL* body length, *TL* thigh length

constraints imposed by phylogeny, ontogeny and physiology. Ontogenic differences between sexes is thought to be one of the underlying causes of sexual size dimorphism and it manifests when expression of the same alleles, on average, moves one sex towards, and the other sex away from its phenotypic optimum (Rice and Chippindale 2001). In most sexually dimorphic species, males appear bigger in size and more conspicuous compared to their female counterparts. Apart from the fact that it must appeal to as many females as possible, it is equally expected to evolve morphological features that will make it compete with other males for females in the flock. The successful male becomes dominant in the flock, thus having a higher chance of transferring its genes to its progeny. Kaliontzopoulu et al. (2007) suggested sexual, fecundity and natural selection as the three major forces differentially acting on males and females of a population.

Since sexual size dimorphism is simply a difference in size between the sexes, selection which acts to change body size in each of the sexes will also affect sexual size dimorphism (Lande 1980). Loison et al. (1999) observed that dimorphism increased with body weight and attributed this relationship to the positive association between level of polygyny and weight, while Georgiadis (1985) reported that

Table 5 Classification results for the discriminant analysis

Predicted group membership				
	Sex	1.00	2.00	Total
Original count	1	61	0	61
	2	0	64	64
%	1	100.0	0.0	100.0
	2	0.0	100.0	100.0
Cross-validated count	1	61	0	61
	2	0	64	64
%	1	100.0	0.0	100.0
	2	0.0	100.0	100.0

Species 1.00=toms (male turkeys); 2.00=hens (female turkeys). A total of 100% of the original grouped cases correctly classified. A total of 100% of cross-validated grouped cases correctly classified

males of sexually dimorphic species attain a mature weight that is greater than that of females by growing slightly faster than females and, more importantly, by continuing to grow after the female growth has stopped. Sexual size dimorphism may also be related to the reduced nutritional requirements of the female during the breeding season. This, in turn, will affect trade-offs in investments into growth versus reproduction. Additionally, sex differences in growth strategies can promote divergent responses of males and females to environmental pertubations and therefore lead to phenotypic plasticity in the expression of sexual size dimorphism (LeBlanc et al. 2001; Blondel et al. 2002).

Positive and high correlation coefficients of morphological traits observed in males compared to their female counterpart is an indication that the morphological architecture of the two populations differs. Varying correlation coefficients between male and female birds had been reported previously (Yakubu and Akinyemi 2010; Yakubu 2011). This might be exploited in developing criterion for the selection of superior birds.

The observed difference between the toms and hens with respect to the total variance explained especially by the first PC lends more credence to the possible existence of sexual dimorphism in Nigerian local turkeys. This corroborates the submission of McCoy et al. (2006) that if the first PC is not shared, then the patterns of morphological variation are fundamentally different. In related studies, Mc Cracken et al. (2000) and Santiago-Alarcon and Parker (2007) justified the use of PCs in separating sexes.

The four discriminating variables obtained can easily be taken in the field to separate the sexes of Nigerian local turkeys. The reduction in the number of variables required to distinguish between toms and hens saves time and energy, and this could aid in ecology, conservation, selection and breeding practices. The discriminant function obtained correctly classified the birds. This could be used to individually calculate the probability of being male or female in the field since positive D scores indicate toms and negative D scores indicate hens. This further justifies the use of discriminant models in classifying birds as reported by earlier workers (Mc Cracken et al. 2000; Robertson et al. 2008; Yakubu 2011). Sexual dimorphism is important because it allows the assessment of sex effect on dispersal patterns, heritability differences in morphology, molt intensity and chronology, feeding behaviour, migration patterns, sex ratios and predation risk (Bourgeois et al. 2007). The present findings in Nigerian local turkeys provide useful insights into the development or function of SSD as a general phenomenon in evolutionary biology. However, there is need for more experimental studies involving the use of other conventional and non-conventional parameters in addition to increase in sample size to help clarify causes and consequences of sex differences.

Conclusion

The univariate analysis revealed that sexual size dimorphism existed in Nigerian local turkeys with higher mean values recorded for toms in all the eight morphometric traits investigated. This was consolidated by the differential number of and varying loadings on the principal components. BW, BL, TL and WS were found as the most discriminating variables to separate the sexes. The present information could be exploited in animal ecology, population dynamics and conservation of local turkeys.

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