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Pigeon's Morphometric Traits Influence Body Weight and are Good Sources of Shared Variability

***Egena, S.S.A., Otu, B.O., Luka, I.A., Owotunse, M.G., Jibrin, K. and Halidu, F.**

Department of Animal Production, Federal University of Technology, P.M.B. 65, Minna, Niger State, Nigeria.

***Corresponding author:** acheneje.egena@futminna.edu.ng; phone number: 08033117407

Target audience: Pigeon farmers, Poultry breeders, Animal geneticists.

Abstract

To assess the sources of shared variability among body weight and selected morphometric traits of pigeons and find the factors impacting their body weight, six hundred pigeons were used in the study; body weight, body length, chest girth, wing span, and drumstick length were measured. Results showed that pigeons varied in their morphometric traits by location ($P < 0.01$). The correlation coefficient between the parameters was mostly significant ($P < 0.01$), positive, ranging from -0.059 to 0.998. The proportions of the total variance of the first two principal factors were high at all locations. The first two factors accounted for 99.85, 87.00, and 65.09 % of the total variability of the body weight of the pigeons in Gwagwalada, New Bussa, and Minna, respectively. Making up the largest share of the total variance, the first factor represented body weight. Chest girth dominated the first factor in Gwagwalada pigeons, while wing span dominated in New Bussa and Minna pigeons, respectively. Predictive regression equations (stepwise) relating live body weight to body measurements showed improvement with increasing use of independent variables up to 71.70, 70.60, and 36.40 % for Gwagwalada, New Bussa, and Minna pigeons, respectively. These results showed that chest girth (Gwagwalada), and wing span (New Bussa and Minna) of the pigeon influenced their body weight positively and hence, could be selected and used in improving the bird. Future studies should look into the use of the body parts in improving body weight in the pigeons at the various locations.

Keyword: Communality, correlation, factor analysis, pigeon, variance.

Description of Problem

Pigeons have multiple uses: for aesthetics, sports, as a carrier/messenger, and even as a source of meat (1). Being cosmopolitan, pigeons are found in literally every country (except the north and south poles), where they have adapted properly to life in rural, semi-urban, and urban environments in intimate contact with man (2). Historically, more than 800 varieties of the domesticated pigeon have been recognized, created by artificial and or natural selection (3; 4). The modern pigeon genotypes differ from each other in terms of behavioural, physiological, and morphological characteristics from their ancestors (5; 6). This is owing to selective breeding for different purposes, and this has led to pigeons with variegated plumage colours and patterns, crest types, flight displays, feathers, and vocalizations (1). Another area affected is the body weight and growth-related traits such as body length, shank length, wing span, drumstick length, and so on.

The connection between body weight and body dimensions is an effective tool in anticipating animal live body weight. This is fundamental because the live body weight is the culmination of the weights of all the parts of the animal. This means that variation in any of the body parts will likely influence the body weight; this positive or negative difference in weight is direction-dependent. Generally, body measurement traits rise as body weight increases reflecting a positive association between the traits. Such interrelationships assist breeders not just in breeding stock selection, but also in predicting body weight without having to slaughter the animal (7).

Univariate and bivariate analysis are the most common tools used in studies of body measurements and live weight. However, this is particularly restrictive in terms of growth as body features are both phenotypically and genotypically related. Rosario *et al.* (8), who reported on pigeon growth, say that the mechanisms involved are too complex to be explained one-sidedly. In their opinion, this is because growth traits are biologically linked due to pleiotropy and the linkage of genes. The multivariate analysis for growth traits considers not only their linear relationship but also their interdependence. Factor analysis is one of the methods of performing multivariate analysis. It is a means of extracting or finding a smaller number of factors (unobservable variables) that best explain most of the data variance while also making contextual sense.

Researchers (9; 10; 11a, b; 12), used independent factor scores derived from multivariate techniques in the body morphological data analysis of various animals. Pinto *et al.* (13), used it as a selection criterion to improve body weight. However, this has not been widely used in Nigerian pigeons, aside from the work of (14) who reported on body weight and morphometric features. The little reported work on pigeons in Nigeria has to do mostly with meat quality characteristics (15; 16), while (17) and (18) both examined the genetic parameters of domestic pigeons. This study was carried out therefore, as an attempt to expand the sparse body of knowledge about the use of multivariate analysis to assess growth-related traits in pigeons. The aim of this study, therefore, was to evaluate the sources of common variance in Nigerian pigeons to infer the best factors describing their body conformation.

Materials and Methods

Animals, their management, and geographical location of the study area

Records (600) were obtained from pigeons at three different random locations (Gwagwalada; N=200, Minna; N=200, New Bussa; N=200). Gwagwalada is one of the six Area Councils of the Federal Capital Territory of Nigeria at latitude 9° 04′ 35.00″ N and longitude 6° 59′ 7.44″ E; Minna, the capital of the state of Niger, lies at 9° 36′ 54.86″ N and longitude 6° 32′ 51.94″ E. New Bussa is the headquarters of Borgu Local Government Area of Niger State and is located at latitude 9° 52′ 59.99″ N and longitude 4° 30′ 59.99″ E.

Experimental Birds and Management

The birds were raised semi-intensively. They were allowed to go out in the morning, and were given additional food (maize, guinea corn grains) in the evening after their return.

Parameters measured

The following measurements were taken into account: Body Weight (BW) of individual pigeons measured with a sensitive hanging digital scale; Body Length (BL) measured as the length between the tip of the beak and the tip of the tail without feathers; Chest Girth (CG) measured as the chest circumference; Wing Span (WS) measured as the length between the tips of the right and left wings after both are fully extended, and Drumstick Length (DL) measured as the distance from the point of attachment of the thigh to the hock. BW, BL, CG, and WS were measured as described by (19). Body dimensions were all measured in cm.

Data analysis

The collected data were analyzed with the multivariate analysis method of (20), particularly factor analysis with the method of Principal Component Analysis (PCA). Previously, the data were standardized as described by (21). The multivariate technique involved the use of factor analysis of the BW and the original four body measurements of the pigeons. The Pearson correlation coefficient between BW and linear body measurements was estimated. The data were then subjected to factor analysis. The basic principle of factor analysis is to reduce the set of *p* variables to a set of *m* underlying dimensions. These underlying factors were derived from the correlations between the *p* variables and each factor is estimated as the weighted sum of the *p* variables (**22**). The $_i^{th}$ factor is thus.

$F_i = W_{i1}X_1 + W_{i2}X_2 + \ldots W_{ip}X_p$

The *p* variables can also be expressed as a linear combination of *m* factors.

$X_j = A_{1j}F_1 + A_{2j}F_2 + \ldots A_{mj}F_m + U_j$

Where U_j = variance that is unique to the variables (i.e., differences not explainable at all via the shared components).

The first factor in the result contained most of the original variance, while the following factors contained traits that showed a narrow variance that was not explained in the first factor. The following factors were mutually orthogonal to the previous ones, and therefore, contained fewer variations. The total variance of a variable is equal to one and can be written in the form of common variance “communalities” and unambiguous variance ″uniqueness”. Communality represents the portion of the variable variance that comes from all common factors. In contrast, uniqueness represents the portion of the variable variance that cannot be attributed to its correlation with other variables (23) *and is therefore attributed to that particular variable*.

The comparison of live weight and body measurements was carried out with the model

$\mathbf{Y_{ij}} = \mu + a_i + e_{ij}$

Where Y_{ij} = total observations (BW, BL, CG, WS, DL); μ = overall mean; a_i = location effect ($_I$ = 3); e_{ij} = random residual error. The mean comparison at $P < 0.05$, was performed using the Least Significant Difference (LSD).

Results

Body weight and growth-related traits

The mean values, standard deviations, and the coefficient of variability for the live BW and the body dimensions of the pigeons depending on location are shown in Table 1. In Gwagwalada, the average body weight was 332.20 g, in New Bussa 338.90 g, while it was 359.33 g in Minna. Values for the other parameters Gwagwalada vs. New Bussa vs. Minna were: 19.70, 20.71, 22.05 cm (BL); 20.84, 20.26, 20.11 cm (CG), 27.80, 27.54, 28.74 cm (WS), and 5.81, 6.16, 6.13 cm (DL), respectively. The highest CV was observed for BW at all the locations (11.29, 14.32, and 19.59 %); the least CV was recorded for WS (Gwagwalada and Minna) and CG for New Bussa pigeons. The live BWs and body measurements differed ($P < 0.001$) depending on the location. Body weight and length were better in Minna pigeons (359.33; 22.05), while Gwagwalada pigeons had the least values for the traits (332.20; 19.70). Minna pigeons also had wider wing span (28,74), while those from New Bussa had the least value for wing span (27.54). Pigeons from Minna had similar drumstick length with those from New Bussa (6.13; 6.16, respectively), with those from Gwagwalada having the least value (5.81). Gwagwalada pigeons were however, better in chest girth (20.84), with those from New Bussa and Minna having the least values (20.26; 20.11, respectively).

Correlation between BW and growth related traits of pigeons

The correlation coefficients between the interdependent variables of the pigeons are shown in Table 2a and 2b, respectively. Correlation coefficients were predominantly positive and significant ($P < 0.01$) between live BW and body dimensions, except for correlations between BW and BL, BW and CG, BW and WS, and BW and DL (Gwagwalada) which were negative but significant ($P < 0.01$): It was also observed that the correlation between CG and DL, and WS and DL was positive but not significant ($P > 0.05$).

Table 1 Mean, Standard Deviation (SD), and Coefficients of Variation (CV%) for live BW and body dimensions of pigeons

	Gwagwalada			New Bussa			Minna		
Parameter	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
BW (g)	332.20^c	37.50	11.29	338.90^b	48.51	14.32	359.33^a	70.40	19.59
BL (cm)	19.70^c	0.89	4.47	20.71^b	1.99	9.59	22.05^a	2.13	9.64
CG (cm)	20.84^a	12.70	4.67	20.26^b	1.34	6.62	20.11^b	2.07	10.27
WS (cm)	27.80^b	1.03	3.72	27.54^c	2.71	9.83	28.74^a	1.76	6.11
DL (cm)	5.81^b	0.46	7.86	6.16^a	0.50	8.16	6.13^a	1.13	18.38

^{abc} = means with different superscripts in the same row differ significantly, ***$p < 0.001$; BW = body weight, BL = body length, CG = chest girth, WS = wing span, DL = drumstick length.

Table 2b Correlation coefficients between live body weight and body dimensions of pigeons in Minna

	BW (g)	BL (cm)	CG (cm)	WS (cm)	DL (cm)
BW (g)	1				
BL (cm)	0.304**	1			
CG (cm)	0.438**	0.480**	1		
WS (cm)	0.535**	0.307**	0.361**	1	
DL (cm)	0.143**	0.196**	0.085ns	0.059ns	1

BW = body weight, BL = body length, CG = chest girth, WS = wing span, DL = drumstick length, **p <0.01.

Table 2a Correlation coefficients between live body weight and body dimensions of pigeons in Gwagwalada and New Bussa

	BW (g)	BL (cm)	CG (cm)	WS (cm)	DL (cm)
BW (g)	1	0.722**	0.743**	0.706**	0.402**
BL (cm)	-0.374**	1	0.818**	0.602**	0.710**
CG (cm)	-0.351**	0.998**	1	0.672**	0.723**
WS (cm)	-0.368**	0.997**	0.996**	1	0.407**
DL (cm)	-0.395**	0.998**	0.998**	0.996**	1

Correlation matrix of Gwagwalada below the diagonal; New Bussa above the diagonal; *BW = body weight, BL = body length, CG = chest girth, WS = wing span, DL = drumstick length, **p <0.01.*

Factor analysis of pigeons from the three locations

Table 3 shows the results of the factor analysis of pigeons from the three locations. Two common factors (varimax rotated independent factors) were identified in all the birds, corresponding to 99.85, 87.00, and 65.09 % of the total variance of the five variables in pigeons (Gwagwalada, New Bussa, and Minna, respectively). This left 0.15, 13.00, and 34.91 % for the unique factors, respectively. The first factor (PC1; ′general size′) was characterized by high positive loadings on all body traits except BW (Gwagwalada), and DL (New Bussa and Minna), respectively. The first factor, general size, accounted for 83.33, 72.48 and 45.22 % of the variance in the pigeons evaluated in Gwagwalada, New Bussa, and Minna, respectively. The coefficient associated with CG dominated the first factor in Gwagwalada pigeons, while WS and DL dominated the first factor in New Bussa and Minna pigeons, respectively. The second factors (PC2) were characterized predominantly by positive loadings on all body traits of the pigeons (New Bussa and Minna), and predominantly negative loadings in pigeons sampled in Gwagwalada. The variance of each trait was divided into a common part, which is shared with some or all of the other traits, and a uniqueness portion characteristic only to that particular trait and is not shared with other traits. The variation in the traits was caused by 65.09 to 99.85 % of the common determinants of the pigeon′s morphometric traits, while 0.15 to 34.91 % of the variance was due to distinctive factors of each trait. In Gwagwalada pigeons, the communality for the traits was in the range of 0.00 (BW) to 0.003 (WS), 0.065 (DL) to 0.183 (WS) for New Bussa pigeons and 0.095 (DL) to 0.471 (BL) for Minna pigeons.

Table 3 Explained variations associated with rotated factor analysis with Kaiser normalization, communalities, and unique factors for the pigeons

Trait	Common factor		Communality	Unique factor
	Gwagwalada			
BW (g)	-0.189	0.982	1.000	0.00
BL (cm)	0.981	-0.192	0.998	0.002
CG (cm)	0.985	-0.168	0.999	0.001
WS (cm)	0.981	-0.186	0.997	0.003
DL (cm)	0.976	-0.214	0.999	0.001
Variance	4.166	0.826	4.992	
% of total variance	83.33	16.52	99.85	
Description	General size	CG		
	New Bussa			
BW (g)	0.883	0.288	0.863	0.137
BL (cm)	0.574	0.723	0.851	0.149
CG (cm)	0.630	0.697	0.883	0.117
WS (cm)	0.877	0.218	0.817	0.183
DL (cm)	0.151	0.955	0.935	0.065
Variance	3.624	0.726	4.350	
% of total variance	72.48	14.52	87.00	
Description	General size	WS		
	Minna			
BW (g)	0.787	0.052	0.622	0.378
BL (cm)	0.610	0.396	0.529	0.471
CG (cm)	0.752	0.130	0.583	0.417
WS (cm)	0.780	-0.087	0.616	0.384
DL (cm)	0.022	0.951	0.905	0.095
Variance	2.261	0.994	3.255	
% of total variance	45.22	19.87	65.09	
Description	General size	WS		

BW = body weight, BL = body length, CG = chest girth, WS = wing span, DL = drumstick length.

Predictive equations explaining the relationship between BW, and growth-related traits

Predictive equations were generated to explain the relationship between BW and body measurements (Table 4a-c). The equations were all significant ($p<0.01$) and showed an improvement (based on increasing coefficient of determination; R^2, and decreasing standard error; SE values) with increasing use of the independent variables (predictors). The results of the predictive equations indicated that BW could accurately be predicted from body measurements, especially when the independent variables are combined. The best predictive equations were chosen based on their coefficient of determination (R^2) values and standard errors, which were found to be best when the four variables were used simultaneously in the equation model.

Discussion

Mean values for the BW of pigeons observed in the study were higher than those reported for pigeons in Ilorin, Kebbi, and Osun,

Table 4a Predictive multiple regression (stepwise) equations relating live body weight to body dimensions in the pigeons (Gwagwalada)

Step	Independent variable (predictor)	Intercept	Regression coefficient	SE	R^2
1.	BL (cm)	-0.039	-0.026	1.02	0.140**
2.	BL (cm)	-0.051	-0.400	0.95	0.259**
	CG (cm)		0.395		
3.	BL (cm)	-0.049	-0.370	0.95	0.262**
	CG (cm)		0.416		
	WS (cm)		-0.062		
4.	BL(cm)	-0.014	-0.072	0.58	0.717**
	CG (cm)		0.761		
	WS (cm)		0.033		
	DL (cm)		-0.331		

BW = body weight, BL = body length, CG = chest girth, WS = wing span, DL = drumstick length, SE = standard error; R^2 = coefficient of determination, **p <0.01.

Table 4b Predictive multiple regression (stepwise) equations relating live body weight to body dimensions in the pigeons (New Bussa)

Step	Independent variable (predictor)	Intercept	Regression coefficient	SE	R^2
1.	BL (cm)	-0.061	0.650	0.74	0.522**
2.	BL (cm)	-0.071	0.310	0.68	0.592**
	CG (cm)		0.362		
3.	BL (cm)	-0.061	0.262	0.63	0.658**
	CG (cm)		0.213		
	WS (cm)		0.316		
4.	BL (cm)	-0.064	0.380	0.58	0.706**
	CG (cm)		0.354		
	WS (cm)		0.261		
	DL (cm)		-0.282		

BW = body weight, BL = body length, CG = chest girth, WS = wing span, DL = drumstick length, SE = standard error; R^2 = coefficient of determination, **p <0.01.

Table 4c Predictive multiple regression (stepwise) equations relating live body weight to body dimensions in the pigeons (Minna)

Step	Independent variable (predictor)	Intercept	Regression coefficient	SE	R^2
1.	BL (cm)	0.012	0.306	0.96	0.092**
2.	BL (cm)	0.011	0.123	0.90	0.203**
	CG (cm)		0.383		
3.	BL (cm)	0.008	0.048	0.81	0.357**
	CG (cm)		0.264		
	WS (cm)		0.428		
4.	BL (cm)	0.008	0.030	0.81	0.364**
	CG (cm)		0.265		
	WS (cm)		0.427		
	DL (cm)		0.090		

BW = body weight, BL = body length, CG = chest girth, WS = wing span, DL = drumstick length, SE = standard error; R^2 = coefficient of determination, **p <0.01.

Nigeria by (14). However, while they reported longer BL, the pigeons they examined had smaller CG and WL values; the DL values of both studies were similar. Observed differences in some of the parameters may be due to the period of sampling, breed effect, management regimes, and consumer's preference for meatier birds. Besides, the current study was carried out during the rainy season with fewer environmental stressors. Pigeons are raised semi-intensively mainly in Nigeria where the study was carried out. Birds are therefore exposed to additional feeding in the form of grains (maize, sorghum, maize bran). The BW of the birds compared favourably with those reported for Turkish Alabadem pigeons (1). However, the BL, WS, and CG values were lower than those reported for Bangladeshi Jalali pigeons (24), Turkish Scandaroon pigeons (25), and pigeons found in Northern Ghana (26). Other reports of body weights of male and female pigeons include 304.10 and 257.50 g (27); 344.95 and 338.41 g (28); 356-344 g (29); 484-474 g (29); 328-432 g and 314-425 g (30; 31; 32). Canova (33) and Bolla (34) reported high live weights between 679.50-736.10 g and 450-700 g, respectively. The National Research Council (35) reported pigeon weight in the range of 500-1400 g. Kendeigh (36) cited Bergmann's rule which suggested location to be a major player in the size of animals; as a rule, small animals are more likely to be found in warmer areas and larger ones in cooler areas. This is because size affects the energy metabolism or relationships between an endotherm and its environment. Location effect was observed in the BW and body measurements, with Minna pigeons predominating, except in CG. A similar location effect was also observed by (26) in a study carried out in Ghana. BW had the best variation (CV of 11.29, 14.32, 19.59 %; Gwagwalada vs. New Bussa vs. Minna), while WS and CG had the lowest variation (CV of 3.72, 6.62, 6.11 %; Gwagwalada vs. New Bussa vs. Minna). The high variance observed for BW makes it a candidate trait of choice for selection and subsequent improvement. DL in Minna pigeons was also so favoured because of the great variation. Parvez *et al.* (37) also observed variation in quantitative traits when assessing phenotypic traits of different pigeon breeds in Northern Bangladesh.

Generally, the correlation between BW and the four variables in the pigeons was mostly high and positive. This agrees with previous reports on the pigeon (37; 26; 24; 14). This means that improving one of the traits (especially where the correlation is positive and significant) is likely to have a positive effect on BW as well. This could also indicate a case of a positive pleiotropic effect, in which the same gene sets control BW and the accessed traits. Maciejowski and Zieba (38) postulated that some linear body parts could serve as indicators of body weight gain in poultry. According to Mohiuddin (39), such positive phenotypic correlations could translate into positive genetic correlations, and therefore, selection for one trait will invariably lead to improvement in the other trait because of the correlated response. The observed negative phenotypic correlation values between BW and body measurements in the pigeons in Gwagwalada is an indication that the BW values of the pigeons do not necessarily depend on location or origin; a negative correlation was also reported by Abubakar *et al.* (14) in their study.

BW in Gwagwalada pigeons had the highest communality with no uniqueness associated with it. The factors that contributed most to the general body size (PC1) of the pigeons sampled in Gwagwalada, New Bussa, and Minna were CG and WS, respectively. This means that the BW is positively associated with these body parts. As these body parts increase in size due to selection and genetic improvement, an increase in BW is envisaged. Being positive, the other variables also contributed in their little ways to the BW of the pigeons. While the factor loads in the second component (PC2) were negative in Gwagwalada pigeons (and consequently limited the BW), DL loaded the most in New Bussa and Minna pigeons. Mercieca *et al.* (40) used this procedure to split variables contributing to racing pigeons′ flight speed into four components. The high proportion of the unique variance in pigeons in New Bussa and Minna means that the traits contributing to the uniqueness had certain characteristic functional needs that could add up to the general body size.

Raji *et al.* (41) believed that the most accurate results in BW prediction are those achieved by using numerous parameters as independent variables at the same time. This was confirmed in the current study. Regressing BW on BL, CG, WS, and DL showed that when BL was used alone, it accounted for only 14.00, 52.20 and 9.20 %, respectively of the total BW variability in Gwagwalada, New Bussa, and Minna pigeons. With the inclusion of the other variables, the percentage of the total variance gradually increased, eventually reaching 71.70, 70.60, and 36.40 %, respectively when all the four variables were used in the analysis. This is a clear indication that BW could be predicted with reasonable accuracy from all four variables, rather than when using only the individual variables.

Conclusion and Application

In summary, factor analysis was able to examine the interdependence of the variables (BW, BL. CG, WS, and DL) by analyzing them together rather than individually. Equally, BW could be best predicted with great accuracy from the body measurements of pigeons which, when combined, accounted for most of the variance affecting BW in the birds. The final regression equations generated for estimating live BW from the original body measurements are:

Gwagwalada: BW (g) = -0.014 - 0.072BL + 0.761CG + 0.033WS - 0.331DL

New Bussa: BW (g) = -0.064 + 0.380BL + 0.354CG + 0.261WS - 0.282DL

Minna: BW (g) = 0.008 + 0.030BL + 0.265CG + 0.427WS + 0.090DL

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