

Principal Component Analysis of Morphostructural Indices of Noiler Chickens

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Abstract

Morphological architecture is central to description, characterization, classification and utility of a species. Six (6) morphological indices {compactness (CMP), massiveness (MAS), condition index (CID), stockiness (STK), long leggedness (LLG) and body index (BDI)} were used to describe and predict body weight of male (52) and female (62) Noiler chickens using stepwise regression analyses of morphological indices and principal component analysis (PCA) factor scores. Descriptive analysis revealed significant ($P < 0.05$) sexual dimorphism in favour of male in all morphological indices except ($P > 0.05$) in STK, BDI and LLG. Two PCs accounting for 89.11% and 89.16% of total variation were extracted for male and female chickens, respectively while CMP (male, 0.961; female, 0.953), CID (male, 0.889; female, 0.907) and MAS (male, 0.833; female, 0.820) had highest correlations with BWT in PC 1 of both sexes. Stepwise regression analysis indicated that CMP was the most important predicting morphological index accounting for 73.70%; and 78.10% prediction accuracy (R^2) of BWT of cocks and hens, respectively. Regression analysis of factor scores of PCs indicated that PC 1 of the two sexes yielded the best prediction models and explained 89.70% and 91.00% of total variation in BWT of male and female Noiler chickens, respectively. Sexual dimorphism is evident and application of PC factor score models is more reliable in predicting BWT of male and female Noiler chickens than interdependent morphological indices because of its orthogonality and higher prediction accuracy.

Keywords: Compactness, Factor score, Morphological architecture, Morphological indices, Sexual dimorphism.

1. Introduction

Chicken remains the most populous and consumed avian species in Nigeria. However, preponderance of available chicken genetic resources is composed of indigenous chickens characterized with slow growth rate, low egg production and high resistance to endemic poultry parasites and diseases compared to the exotic genotypes. These indigenous stocks evolved from random bred population that has never undergone genetic improvement, mostly concentrated in rural areas in the hands of small holders and perform multipurpose tasks to the owners.

Due to the poor performance of African indigenous chickens in respect of egg and meat production, efforts are being made to introduce some tropically-adapted genotypes [1] with superior performance in egg and meat outputs than local chickens. Among some found in Nigeria is Kuroiler breed of chicken developed in India for both meat and egg production [2, 3]. Likewise Sasso strain, another improved tropically-adapted germplasm developed in France and tested in Ghana [4]. Similarly, tropically-adapted breeds such as Noiler and FUNAB Alpha have also been developed in Nigeria.

Noiler chicken is a dual-purpose breed of chicken bred for egg and meat production. This breed has been well accepted among poultry farmers and well distributed in Nigeria. The acceptability of this new breed of chicken among small holder farmers in Nigeria was attested to in a recent study

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in five agro-ecological zones on farmers' preference for the newly developed tropically-adapted breeds of chicken [5]. These researchers showed that of the five newly developed breeds (Noiler, Kuroiler, Sasso, FUNAAB Alpha and Shika Brown) and Fulani ecotype chicken, Noiler chicken alongside Sasso and FUNAAB Alpha were the most preferred breeds in five agro-ecological zones in Nigeria. Of recent, Bamidele et al. [6] reported the breed to be fast growing, more suitable as a dual purpose bird, more adaptable to the environment than the foreign tropically-adapted breeds (Kuroiler and Sasso) and rated higher as the most efficient at converting feed to body weight with 50% reduction in feed conversion ratio compared to the indigenous Fulani chicken.

Multifactorial analysis of morphological traits have been used to characterize different breeds of livestock as they give idea of body conformation and are used to describe a population in a better way than conventional methods of grading and weighing [7]. These multivariate statistical techniques are invaluable in circumventing shortcomings of univariate and bivariate correlation analyses by simultaneous integration of many variables at a time and are also capable of explaining complex interrelationships existing among variables.

Principal component analysis (PCA) is a mathematical model/procedure that transforms a number of uncorrelated variables into a smaller number of uncorrelated variables called principal components which are ordered so that the first few retain most of the variation present in the original variables[8]. PCA has been used as a tool in the assessment of the body shapes which could be of evolutionary significance as well as permit an understanding of the complex growth process going on in the body dimensions of an animal during growth period [9].

In Nigeria, this multivariate analysis technique has been extensively used to estimate body weight, describe shape, size, function, morphostructural dimensions, interrelatedness of body measurements and body weight and as a selection criterion for the improvement of body size in indigenous poultry species [1, 10, 11, 12, 13] and also in recently developed tropically-adapted chicken breeds [1]. Despite the quantum of empirical studies on PCA of the morphological parameters of the aforementioned breeds of

chickens, related studies on Noiler chicken are sparse or non-existent. Against this background, the present study was conducted to describe morpho-architecture and predict body weight of Noiler chickens using multiple regression models of morphological indices and principal component factor scores. The results of this study would provide additional information for better understanding of morphological characteristics and would also be applicable in characterization, genetic improvement and utilization of the breed.

2. Materials and methods

Study area and experimental birds

The study was conducted at the Poultry Unit of the Teaching and Research farm of Bowen University, Iwo, Osun State, Nigeria. The coordinate of the study area is Latitude $7^{\circ} 38' 6.97''$ N and Longitude $4^{\circ} 10' 53.62''$ E. The area enjoys double maxima of rainfall and the vegetation is a derived savanna characterized with tall grasses, deciduous shrubs and trees.

The experimental birds were sourced at day-old from Amo farm, a reputable poultry farm located at Awe, Oyo state, Nigeria and were reared intensively under standard poultry management conditions.

Data collection

At 15 week of age, data on body weight (BWT) and six morphological parameters: body girth (BGT), body length (BDL), wing length (WGL), shank length (SHL), shank diameter (SHD) and thigh length (THL) of one hundred and fourteen (114) (male, 52; female, 62) Noiler chickens were taken and records classified according to sex. The methodology and anatomical references for the measurements were as described by [14].

In addition, six (6) morphological indices: massiveness (MAS), stockiness (STK), body index (BDI), compactness (CMP), long leggedness (LLG) and condition index (CID) were estimated from morphometric parameters according to Yakubu et al. [14] and Oguntunji [15] as follows:

$$\text{MAS} = (\text{BWT}/\text{BDL}) \times 100$$

$$\text{STK} = (\text{BGT}/\text{BDL}) \times 100$$

$$\text{BDI} = (\text{BDL}/\text{BGT}) \times 100$$

$$\text{CMP} = (\text{BWT}/\text{BGT}) \times 100$$

$$\text{LLG} = (*\text{TLL}/\text{BDL}) \times 100$$

$$\text{CID} = (\text{BWT}/\text{WGL}) \times 100$$

*TLL: summation of SHL and THL

Statistical Analysis

The mean and standard deviation of morphological parameters and indices were generated from the pooled data. In addition, interdependent relationship (correlation, r) existing between the estimated indices were also generated while student t-test was used to investigate sexual dimorphism in morphometric parameters and indices.

Furthermore, the Principal Component Analysis (PCA) or factor analysis was employed to explain interrelatedness/relationship among the body weight and morphological indices. The PCA was performed with the following mathematical model [16]:

$$Y_{ij} = \sum_{k=1}^q a_{ik} c_{kj} + e_{ij}$$

Where:

Y_{ij} : The value of i^{th} observation in j^{th} measurement

q : The number of common factor

a_{ik} : The value of i^{th} observation in k^{th} common factor

c_{kj} : The regression coefficient of k^{th} common factor for predicting j^{th} measurement

e_{ij} : The value of i^{th} observation in j^{th} communality value

Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was estimated to determine the appropriateness of the factor model and value below five was rejected [7] while Bartlett's test of sphericity test (X^2) was performed to test if the correlation matrix is an identity matrix (i.e. each variable correlated with itself) used to test the validity of principal component analysis of the data set [17]. The varimax criterion of the orthogonal rotation was employed in the rotation to enhance the interpretability of the principal components [10].

In addition, stepwise multiple regression analysis was conducted to predict BWT from morphological indices and principal component factor scores:

$$BWT = B_0 + B_1X_1 + \dots + B_nX_n \text{ (Equation 1)}$$

$$BWT = B_0 + B_1PC_1 + \dots + B_nPC_n \text{ (Equation 2)}$$

Where:

BWT = body weight

B_0 = the regression intercept

B_i = the i -th partial regression coefficient of the i -th morphological index/principal component

X_i or the i -th principal component (PC).

All data analyses were performed with SPSS [18].

3. Results and discussion

Descriptive analysis of morphometric parameters and indices

The result of body weight, morphometric parameters and indices of adult male and female Noiler chickens were presented in Table 1.

Table 1. Descriptive statistics of body weight, morphometric parameters and morphological indices of male and female Noiler chickens

Variable	Male (N=52)	Female (N=62)
Body weight (kg)	1.99±0.27 ^a	1.60±0.20 ^b
Body girth (cm)	42.42±3.15 ^a	38.98±2.30 ^b
Back length (cm)	32.97±2.40 ^a	29.94±2.25 ^b
Wing length (cm)	23.54±1.87 ^a	21.03±1.70 ^b
Shank length (cm)	8.86±0.61 ^a	7.86±0.47 ^b
Shank diameter (cm)	4.80±0.34 ^a	4.14±0.18 ^b
Thigh length (cm)	15.50±1.02 ^a	13.80±0.86 ^b
Massiveness	6.04±0.77 ^a	5.38±0.75 ^b
Stockiness	129.04±10.07 ^a	130.79±11.18 ^a
Body index	77.99±6.42 ^a	77.03±6.84 ^a
Compactness	4.68±0.46 ^a	4.12±0.50 ^b
Long leggedness	74.11±4.58 ^a	72.77±6.90 ^a
Condition index	8.48±1.18 ^a	7.66±1.08 ^b

^{ab} Means with different superscripts are significantly different at $P < 0.05$

The cocks were significantly ($P < 0.05$) superior to the hens in all measured morphometric parameters and indices except ($P > 0.05$) in STK, BDI and LLG. One major unique attribute of this breed of chicken is sexual dimorphism in body weight. The higher values reported for males in BWT and other body measurements is consistent with related studies on Nigerian local chickens [10, 19, 20]. Sexual dimorphism in body weight is a common phenomenon in poultry and males have been shown to have higher body weight than females. The genetic basis of sexual dimorphism is an intriguing problem of evolutionary genetics because dimorphic traits are limited to one sex [21]. John-Alder et al. [22] attributed proximate cause of sexual dimorphism to the factor that produces intersexual differences in growth hormone concentrations or trade-offs in allocating energy between growth and reproduction. Similarly, Semakula et al. [23] adduced heavier

body weight of cocks to the ability to secrete more sex hormone responsible for muscle development than hens. Oguntunji and Ayorinde [24] posited that higher BDL and BGT in males are indicative of meatiness; hence, higher body mass of males compared to the females. Nevertheless, scarcity of empirical reports on morphometric indices of

chickens did not permit critical comparison of the reported values on body indices.

Phenotypic correlations (r) among body weight and morphological indices

The matrix of Pearson’s coefficient of correlation (r) among body weight and morphometric indices of Noiler chickens were presented in Table 2.

Table 2. Phenotypic correlations of body weight and morphometric indices of male (above diagonal) and female (under diagonal) Noiler chickens

	BWT	MAS	STK	BDI	CMP	LLG	CID
Correlation BWT		0.855	0.316	-0.347	0.859	0.108	0.839
MAS	0.851		0.638	-0.647	0.794	0.508	0.757
STK	0.103	0.479		-0.992	0.042	0.698	0.261
BDI	-0.119	-0.487	-0.995		-0.060	-0.680	-0.285
CMP	0.884	0.793	-0.149	0.137		0.114	0.779
LLG	0.145	0.583	0.695	-0.689	0.187		0.097
CID	0.803	0.645	0.065	0.057	0.763	0.006	

The correlation coefficients for the two sexes were similar and ranged from -0.992 (BDI/STK) to 0.859 (BWT/CMP) and -0.995 (BDI/STK) to 0.884 (BWT/CMP) for cocks and hens, respectively. The BWT of both male and female Noiler chickens had strongest and significant (P<0.05) relationships with CMP (male, 0.859; female, 0.884) chronologically followed by MAS (male, 0.855; female 0.851) and CID (male, 0.839; female, 0.800). Due to the scarcity of related studies involving correlation of morphological indices with BWT, comparison of the result is impossible. However, since BGT and BDL is integral part of CMP and MAS respectively, correlation values from related studies corroborated significant strong relationship (r > 0.80) of BGT and BDL with BWT in chickens [10], turkey [2011], Muscovy ducks [25] and Nigerian indigenous guinea fowl [26].

The reported strongest relationship between BWT and CMP is suggestive that selection of Noiler birds with high CMP cum BGT could result in simultaneous selection for noiler chickens with higher body weight. Commenting on relationship among variables, Yakubu et al. [10] submitted that the strong relationship between body weight and body measurements may be useful as selection criterion since positive correlations suggested that that the trait are under the same gene action (pleiotropy).

Principal component analysis

Tables 3 and 4 showed that Bartlett’s test of sphericity for male (688.455) and female (829.004) chickens, respectively were highly significant (P<0.001); thus, indicating that the original correlation matrix is an identity matrix used to test the validity of PCA of the data set [17].

The Kaise-Meiyer-Olkin (KMO) measure of sampling adequacy of male (0.696) and female (0.695) chickens indicated that the common factor model was appropriate as KMO values were above the threshold value of 0.50 [7]. The range of communality values for male (0.706 – 0.973) and female (0.723 – 0.979) chickens were high and indicated the appropriateness of the morphological indices for factor analysis.

Two principal components each were extracted for the two sexes and the total variation explained for the cocks (Table 3) and hens (Table 4) were 89.11% and 89.16%, respectively. The first and second PC of the cocks explained 47.86% and 41.25%, respectively while 47.78% and 41.38% of total variation was explained by the first and second PC of the female, respectively. Similar morphological indices had highest positive loadings in the PCs of the two sexes.

Table 3. Eigen vectors, rotated components and communalities of body weight and morphological indices of male Noiler chickens

Morphological index	PC1	PC2	Communality	KMO	Chi square (X^2)
Body weight	0.95	0.16	0.92	0.696	688.455 (P<0.001)
Massiveness	0.82	0.55	0.97		
Stockiness	0.14	0.96	0.95		
Body index	-0.17	-0.96	0.94		
Compactness	0.95	-0.05	0.91		
Long leggedness	0.04	0.84	0.71		
Condition index	0.91	0.12	0.84		
Variance explained (%)	47.86	41.25			
Cumulative variance explained (%)	47.86	89.11			

The variables with highest loadings in PCs 1 of the two sexes in descending order were CMP (male, 0.953; female, 0.961), BWT (male, 0.947; female, 0.954), CID (male, 0.907; female, 0.889) and MAS (male, 0.820; female, 0.833), while their PCs 2 were characterized with high positive loadings for STK (male, 0.964; female, 0.974), LLG (male, 0.839; female, 0.836) and moderate value for MAS (male, 0.547; female, 0.533).

Table 4. Rotated component matrix scores and communalities of body weight and morphological indices of female Noiler chickens

Morphological index	PC1	PC2	Communality	KMO	Chi square (X^2)
Body weight	0.95	0.17	0.92	0.695	829.004 (P<0.001)
Massiveness	0.83	0.53	0.98		
Stockiness	-0.04	0.97	0.95		
Body index	0.02	-0.97	0.94		
Compactness	0.96	-0.07	0.93		
Long leggedness	0.16	0.84	0.72		
Condition index	0.87	-0.08	0.80		
Variance explained (%)	47.78	41.38			
Cumulative variance explained (%)	47.78	89.16			

It is noteworthy that the high and moderate correlations of MAS with PC₁ and PC₂ of male and female Noiler chickens, respectively was graphically demonstrated in Figure 1.

The reported total variance explained by the PCs of Noiler cocks (89.11%) and hens (89.16%) in this study were comparable with the range 87.84% to 90.60% and 83.14% documented for three genetic groups of Nigerian local chickens ([10] and intensively-reared Nigerian local chickens [19], respectively but were higher than similar pooled total variance explained reported for indigenous chickens [13, 20], Muscovy ducks [24, 25], guinea fowl [26] and turkey [11].

It is worth emphasizing the reported similarity in the loading variables and proportions of contribution of variables characterizing the two PCs of the two sexes. Survey of literature reported differences in variable loadings and their proportions in the PCs of male and female poultry species [13, 24, 25]. The observed contrasting trend in the present study might be attributed to

the fact that the referenced populations originated from unselected random bred populations; hence, disparities in morphological architecture of males and females. Conversely, the signature effect of intense selection Noiler strain underwent in the course of its development in order to ensure uniformity in growth, performance and phenotypic attributes could be the principal underlying genetic factor responsible for similarity in morphological architecture of male and female; hence, similarity in variable loadings of morphological indices in the PCs of the two sexes. The PC 1 of the two sexes could be described as general body size because of high loadings of BWT, CMP, MAS and CID. The highest correlation of CMP with BWT in PC 1 of the two sexes could be adduced to the fact that both BWT and BGT (an integral of CMP) were environmentally-sensitive and BGT has been indicated as an indicator of meatiness in poultry [1, 11, 24]. Conversely, the lower correlation of MAS and CID with BWT compared with CMP

might be attributed to the fact that they were environmentally-independent and skeletal-frame-related indices made up of bones on which muscles and visceral (which were environmentally-sensitive) were attached [24].

The highest correlation of CMP with BWT in PC 1 of cocks and hens is plausible and is suggestive that irrespective of sex, selection of Noiler chicken with promising higher adult BWT can be predicted and selected for at an early age. Since correlation of CID and MAS were also higher in the PC 1 of cocks and hens, the trend of result indicates further that alternatively, data on CID (WGL an integral of CID) and MAS (BDL an integral of MAS) could also be used in predicting and selecting Noiler chicken with promising adult BWT in lieu of data on CMP cum BGT.

There is no lucid explanation for the trend of variables characterizing PC 2. However, a critical

look at the variables with high loadings in PC 2 of the two sexes is suggestive that BDL is the second major factor. This submission is hinged on the fact that the three morphological indices with high (STK and LLG) and moderate (MAS) loadings were BDL-related morphological indices. This possibly points to the fact that BDL is the second most important morphological indices of male and female Noiler chickens.

Though MAS was pictorially captured between component plots 1 and 2 (Figure 1); however, its high and moderate loading with PC 1 and 2, respectively of the two sexes was corroborated with its closeness to CMP and CID (variables with high loadings in component plot 1) than STK and LLG (variables with high loadings in component plot 2) it had moderate correlation with.

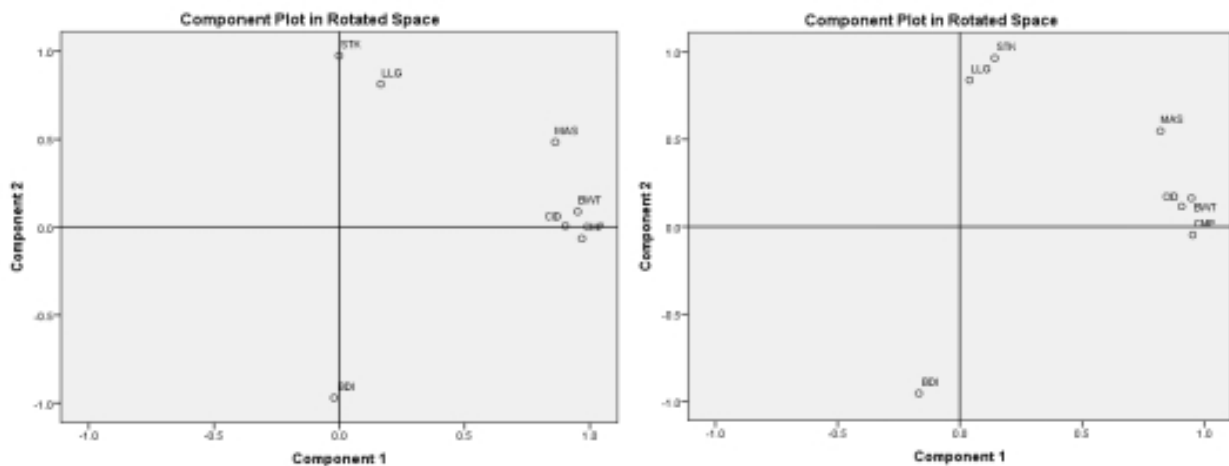


Figure 1. Component plot of body weight and morphological indices of male (left) and female (right) Noiler chickens

Predictive linear regression models

The result of stepwise regression analysis of morphological indices (Table 5) indicated that CMP alone accounted for 73.70% of the total variation of BWT of cocks. The prediction accuracy (R^2) increased to 81.80% when MAS was added in model 2 while highest proportion of variance explained (85.10%) was obtained when CID was included in model 3. In addition, prediction of BWT of cocks using factor score of PC 1 explained 89.70% of total variability of body weight of cocks while inclusion of PC 2 slightly improved the accuracy of prediction to 92.30%.

Similarly for the female Noiler chicken (Table 4), CMP contributed highest proportion (78.10%) of variation in BWT, while inclusion of MAS and

CID slightly increased variance explained to 84.20% and 87.30% in model 2 and 3, respectively. Furthermore, the application of PCs as predictor of BWT of female Noiler chicken revealed that PC1 alone accounted for 91.00% of total variability while PC 2 had negligible contribution of 1.20% to 92.20% prediction accuracy of BWT.

Ours is the first cohort study to report application of morphological indices and their PC factor scores to predict body weight of Noiler chickens through stepwise regression analysis; hence, scarcity of empirical reports for comparison. Body weight is an important economic trait in farm animals and high premium is attached to it by livestock farmers. This might not be unconnected

with the fact that this metric trait contributes significantly to the profit margin of livestock farmers, most especially in livestock enterprise where the main target is market weight or dressed meat [15]. Most livestock studies described the size, shape and functions of animals and also predicted this quantitative trait from linear body measurements; however, combination of different linear measurements in form of indices may be more useful to describe the type and function of animal [27]. Commenting on superiority of indices

over zoometric measurements, Alderson [28] considered indices as a superior option for assessment of weight because it incorporates measures of desirable conformation, namely length and balance. It is expected to provide tested empirical alternative to the limited use of single measurements for the assessment of type, weight and functions as well as enhanced the ability of breeders to select potential breeding stock [29].

Table 5. Stepwise multiple regression of bodyweight on morphological indices and principal component factor scores of male and female Noiler chickens

Sex	Variable	Prediction model	R ²	S.E.
Male	CMP	BWT= -0.3777+ 0.859CMP	73.70	0.14
	CMP, MAS	BWT= -0.35+ 0.487CMP+ 0.468MAS	81.80	0.12
	CMP, MAS, CID	BWT=0.30+0.338CMP+0.353MAS+ 0.468CID	85.10	0.11
		Principal components as predictors		
	PC ₁	BWT=0.257+0.947PC ₁	89.70	0.88
	PC ₂	BWT= 1.99+0.947PC ₁ +0.163PC ₂	92.30	0.77
Female	CMP	BWT= 0.131+0.884CMP	78.10	1.00
	CMP, MAS	BWT= 0.70+0.563CMP+0.404MAS	84.20	0.83
	CMP, MAS, CID	BWT=0.027+0.378CMP+0.375MAS+ 0.273CID	87.30	0.08
		Principal components as predictors		
	PC ₁	BWT= 1.603+0.954PC ₁	91.00	0.06
	PC ₂	BWT=1.603+0.954PC ₁ +0.108PC ₂	92.20	0.06

The reported highest contribution of explained variance of CMP in model 1 of the two sexes implies that this morphological index is the most important in predicting BWT. This result is consistent with a recent report of Oguntunji [15] on prediction of BWT of adult indigenous Muscovy ducks using regression tree analysis. Similarly, the BGT an integral component of CMP has been widely used as a predictor of BWT in poultry [1, 11].

The reported highest contribution of PC factor scores 1 of the two sexes in predicting body weight were indicative that the models were appropriate and morphological indices with high loadings under them were more important in predicting BWT and should be given special consideration while PCs 2 had negligible contributions. Preponderance contribution of PC 1 to the prediction of BWT is consistent with previous reports in poultry [1, 10, 12].

The orthogonality of the factor scores lends credence to their superiority and reliability in

predicting BWT better than interdependent variables/indices since variables/indices with high loading in one PC are not included in the others. Contrary to the unstable prediction accuracy (R²) generated in multiple regression models with inclusion of additional morphometric indices in models 2 and 3 of male and female Noiler chickens, the proportion of variance explained by their respective factor score 1 was stable with marginal increase in prediction accuracy with inclusion of factor score 2; thus, confirming reliability and superiority of regression models emanating from factor scores over models generated from explanatory morphological indices. In addition, it is noteworthy that the variance of BWT explained by factor scores 1 of male (89.70%) and female (91.90%) Noiler chickens were higher than the cumulative variation explained (male, 85.10%; female, 87.30%) by the stepwise regression models of morphological indices. This further confirms superiority of stepwise regression-based factor

score models over variable and or index-based models.

Multiple regression analysis is one of the statistical tools most commonly used to predict dependent trait from independent variables in biological sciences. It has been used extensively in livestock studies for prediction of body weight of animals [1, 10, 19] and for interpretation of complex relationships between body weight and zoometric measurements. Nevertheless, its biological interpretation may be misleading because of the number of predicted variables included in the model [19]. In addition, presence of collinearity complicates interpretation as a function of its influence on the magnitude of regression weights of the potential inflation of their standard errors, thereby negatively influencing statistical significance tests of these coefficients [30]. Pimmental et al. [31] corroborated these submissions that multicollinearity induces numerical instability into the estimate and has dire consequences on their precision. In spite of the aforementioned shortcomings of multiple regression analysis and allied statistical tools such as descriptive and bivariate correlation analysis, application of multifactorial statistical techniques such as PCA could be of invaluable solution. It has been reported that orthogonal variables gave a better and more dependable estimation of body weight than the use of original independent variables [12]. This is a major advantage of factor score over interdependent variables because it circumvents multicollinearity which may occur when two or more variables are used as predictors in multiple regression coefficients as unreliable predictors [32].

4. Conclusions

This study demonstrated sexual dimorphism in morphometric parameters and indices of male and female Noiler chickens. Synthesis of strong relationship of CMP cum BGT with BWT of male and female Noiler chickens as exemplified in highest coefficient of correlation, highest correlation with BWT in PC 1, highest regression coefficient and prediction accuracy as the only predictor of BWT in stepwise regression analysis are suggestive that this morphological index is a good predictor of BWT. This implies further that both sexes can be selected for at early age with

similar variable. Similarities in proportion of total variance explained and in variables characterizing the extracted PCs of the two sexes are indicative of similarity in morphological architecture and are also suggestive that similar genetic approach could be employed for the selection and genetic improvement of male and female Noiler chickens.

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