Determining the morphological structure of indigenous chickens using multivariate principal component analysis of body measurements

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Abstract

The study was conducted to predict body weight from linear body measurements of indigenous non-descript chickens using principal component analysis (PCA). Linear body measurements for body weight (BW), body length (BoL), back length (BaL), neck length (NL), breast circumference (BrC), shank length (ShL), shank circumference (ShC), and toe length (TL) were taken from 360 indigenous non-descript hens. Phenotypic correlations among linear body measurements were all positive and significant (P <0.01). Body weight and BrC had the strongest correlation (P <0.01) coefficient of 0.71. Two principal components were extracted with a total variance of 63.9%. Principal component one (PC1) had the largest share of BrC (0.84), BW (0.83), and BoL (0.76) and ShC (0.62) in the order. Then principal component two (PC2) had high loadings in the order of TL (0.85), ShL (0.79), and BoL (0.62). The principal components based on a linear regression model could be a preferable tool to predict body weight of indigenous chickens raised under extensive production system. In conclusion, linear traits such as BrC, BoL and ShC could be useful tools to estimate body weight of chickens.

Keywords: body length, body weight, breast circumference, non-descript chickens, shank circumference
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Introduction

Indigenous chickens are the commonly kept livestock in a multipurpose and communal production system (Mtileni *et al*., 2012). They provide income, eggs and nutritious meat particularly for resource-limited farmers. Keeping indigenous chickens is preferred instead of other livestock because they are easy to slaughter and are consumed once off with no need for refrigeration (Ncobela & Chimonyo, 2015). As such, they play a central role in alleviating hunger and malnutrition to the whole household. For sustainable use of indigenous chicken genetic resources, breed characterization is crucial. This characterization contributes importantly to the clarification of the contributions that indigenous chickens have to the resource-limited households, which is unquantified.

The impact of climatic changes and geographic conditions has resulted in a variation of physical characteristics for local populations of indigenous chickens (Okpeku *et al*., 2011), which may give rise to breed variation of phenotypic attributes. Before characterizing different breeds of indigenous chickens, it is relevant to morphologically identify within the breed variations, as a first step in understanding their matching ability to the environment. Phenotypic characterisation of indigenous chickens facilitates matching of desirable and beneficial traits with the conducive environments so that they can function efficiently in terms of growth and reproduction performance. Quantitative measurement of the conformation of indigenous chickens, whose production and productivity is low, is also crucial when designing schemes for conservation of genetic resources, chicken improvement and sustainability (Ogah, 2011).

Body weight and conformation, which are amongst the traits of economic value, are important for animals raised for meat production and breeding practices, respectively (Okpeku *et al*., 2011). Use of quantitative traits to predict body weight in scavenging indigenous chickens has been given little attention (Yakubu & Ayoade, 2009). Use of linear body measurements to predict body weight motivates farmers to keep records for breeding and production purposes using an easy, adoptable and cheap method. It also assists in selecting for increased in body weight using correlated linear traits (Besbes, 2009).

The linear body measurements are regarded as multivariate since conformation traits are interdependent (Yakubu & Ayoade, 2009). Principal component is the common statistical tool used to measure and visualize genetic distance and relatedness between or within populations. Okpeku *et al*. (2011) defined principal component analysis (PCA) as a multivariate technique, which is used when morphological variables depend on each other. The study was conducted to predict body weight from linear body measurements of non-descript chickens using principal component analysis. It was hypothesized that breast circumference is the best predictor of body weight

Materials and Methods

The study was conducted in six local district municipalities located in KwaZulu-Natal, with their altitude ranging from 80 to 1900 m above sea level. Annual rainfall in these areas range from 600 mm in the drier valley to over 1400 mm near the coast. The districts were as follows: UThungulu district, located at 28.6192°S, 31.5370°E;UMkhanyakude district, located at 27.2719°S, 32.537°E; UGu district, located at 30.6218°S, 30.2513°E, UMgungundlovu district, located at 29.5101° S, 30.3436°E; UThukela district, located at 28.6783°S, 29.6035°E; and Amajuba district, located at 27.8036°S, 30.0665°E. The ethical committee of the University of Zululand approved the use and care of chickens (UZREC 171110-030 PGM 2014/124).

Two experiments were conducted in the study. The first experiment was based on a survey and the second experiment was morphological measurements. In the first experiment, a snowball sampling procedure was used to identify households that own indigenous chickens within each district area. Agricultural advisors, traditional leaders and key informants of the districts also aided in selecting households. A total of 360 households, 60 in each district area, were used in the study. Indigenous chicken farmers were individually interviewed using structured questionnaire in their respective homesteads. Local enumerators from the respective districts were used to make farmers comfortable in engaging and disclose legitimate and reliable data in their own language. Questionnaires were translated into Zulu vernacular language to improve the quality of the data captured. The questionnaires captured chicken breeds, management practices, flock sizes, housing availability, feeding systems, health measures, role of chickens and challenges to chicken production. All farmers answered all questions asked. All farmers selected were willing to partake in the study.

In the second experiment, three hundred and sixty indigenous chicken farmers who participated in the first experiment participated in present experiment. A grand total of 560 indigenous non-descript hens.The selected hens had to show signs of sexual maturity such as being receptive to courtship behaviour. The selected hens were those that already laying eggs. To facilitate catching of chickens, they were called using cluck-cluck noise and offered maize and were caught using a hook for measurement. No observed harm in whatsoever way was caused during catching and handling of chickens. Chickens used were non-descripts but those predominantly dark and brown in colour were prioritized because were common in most of the households. Farmers associated dark brown coloured breed to Ovambo chickens.

Body weight (BW), back length (BaL), body length (BoL), neck length (NL), breast circumference (BrC), shank length (ShL), shank circumference (ShC), toe length (TL) were measured on each bird. The methods by Ajayi *et al.* (2012) was used as a point of anatomical reference. Body measurements were taken using a flexible measuring tape (in centimeters) and body weight was measured using a ± 5kg calibrated weighing scale. Back length was measured as the distance below the neck region to the cauda (tail without feathers). Body length was measured as a length taken between the tip of the rostrum maxillare (beak) and that of the cauda (tail, without feathers). Neck length was measured as the distance below the head to the beginning of back length. Breast circumference was measured as the circumference of the breast around the deepest region of the breast. Shank length was measured from the hock joint to the metatarsus. Shank circumference was measured as the diameter of the metatarsus just below the spur. Toe length was measured as the average length of toes. All measurements were taken by the one person to avoid between-individual variations.

Data on socio-economic status (frequencies), means, standard errors of body weight and linear body measurements were obtained using the statistical package for social science SPSS 20 (2010). Reasons for rearing indigenous chickens were ranked by calculating indices, given for each reason divided by the sum of for all reasons.

Pearson coefficient of correlation among body weight and linear body measurements was estimated, and the principal factor analysis was obtained from the correlation matrix. Principal component analysis was applied to linear body measurements. The linear body measurements were, combined and formed unrelated components.

The interpretation of principal components was improved by varimax rotation. The appropriateness of the principal component analysis was tested using communalities.

Bartlett's Test of Sphericity was conducted to determine the appropriateness of the common factor model in analyzing body weight. Models for predicting body weight from (a) body measurements and (b) from principal components were obtained using the stepwise multiple regression procedure.

$BW= a+B_iX_i+\ldots.B_kX_k$ (a)

$BW=a+B_iCP_i +B_kPC_k$ (b)

where BW is the body weight, a is the regression intercept, B_i is the *ith* partial regression coefficient of the *ith* linear body measurement, and X_i or the *ith* principal component (PC). Models with a higher coefficient of determination (R^2) were considered better than models with low (R^2).

Results

Socio-economic status is displayed in Table 1. The majority of famers who owned chickens were female. Most of the farmers had no basic education. Chicken flock sizes ranged from 2 to 80 per household. Ovambo breed was among indigenous chickens kept by farmers in each household. The majority of farmers provided housing for their chickens using rusted corrugated irons, old planks and nets. Most of the farmers barely receive veterinary service. Nearly all farms used chickens mainly for meat consumption. Indigenous chickens were predominately reared under extensive production systems. Most of the farmers supplemented their chickens using rejected maize and kitchen waste. Three out of four farmers offered water to their chicken using plastic dishes and trays. About two-third of farmers prioritized theft as the major challenge to chicken production with index of 0.74. Almost all (98 %) farmers do not keep records and practice indiscriminate breeding. Virtually all (99.9 %) farmers had no knowledge on conservation of animal genetic resources.

Correlation of body weight and linear body measurements of indigenous chickens is presented in Table 2. All traits were positively correlated among each other. The ShL had a higher (P <0.01) correlation with TL. There was a higher correlation (P <0.01) between TL against ShC, BaL and BW. The ShC (r = 0.60) and BoL (r = 0.61) had high correlations (P <0.01) with BW. The BaL was highly correlated (P <0.01) with ShL (r = 0.52) and BW (r = 0.52). The NL also exhibited a high correlation (r = 0.49) with BoL. The BW has a strongest correlation (r = 0.71) with BrC (P <0.05)

Eigen-values, percentage of total variance along with the rotated component matrix and communalities of body measurements of indigenous chickens are presented in Table 3. The coefficients show the relative contribution of each trait to a particular principal component. Communalities represent the estimate of variance in each variable represented by components. The percentage of total variance is used to determine the accountability of total component on what is represented by linear body measurements. The Eigen-values represent the amount of variance out of the total variance explained by each of the component. Two principal components were extracted with Eigen-values of 4.08 and 1.03 for principal component 1 and principal component 2, respectively. Principal component 1 (PC1) and 2 (PC2) accounted for 51.1% and 12.9 % of total variance, respectively. Principal component 1 had high loadings on BrC (0.84), body weight (0.83), BL (0.76) and ShC (0.62). Principal component 2 had high loadings on TL (0.85), ShL (0.79) and BL (0.62).

Figure 1 shows the projections on principal components (PC) of the factors and associations for body measurements after a Varimax transformation. The dispersion of plots indicates the variation of principal component factors and associations of body weight. The PC2 had high loading of ShL and TL. On other hand, the PC1 had high loading of BrC, BW and BoL.

Table 1 Socio economic status of farmers who keep indigenous chickens

Socioeconomic status	Percentage
Famers who were females	70
Farmers with no basic education	65
Farmers who conserve indigenous chickens	1
Chicken used for meat consumption	80
Farmers who practice extensive production system	90
Chicken housing	92
Supplementary feeding	96
Water provision	75
Farmers who keep indigenous chickens	100
Farmers who keep Ovambo chicken breed	100
Chicken flock range	2-80*
Farmers who do not receive veterinary service	83
Farmers experiencing theft as a major challenge	64
Farmers who keep records	2
Indiscriminate breeding practice	98
Famers who are aware of inbreeding	52

* Absolute value

Table 2 Correlation coefficients of body weights and linear body measurements of indigenous chickens

Traits	BW	BaL	BoL	NL	BrC	ShL	ShC	TL
BW								
BaL	0.52**							
BoL	0.61**	0.44**						
NL	0.49**	0.38**	0.49**					
BrC	0.71**	0.32**	0.49**	0.39**				
ShL	0.48**	0.52**	0.42**	0.43**	0.32**			
ShC	0.60**	0.33**	0.42**	0.46**	0.47**	0.43**		
TL	0.39**	0.39**	0.21**	0.36**	0.23**	0.54**	0.39**	-

**$p<0.01$

Abbreviation: Shank length (ShL), Toe length (TL), Shank circumference (Shc), Body length (BoL), Back length (BaL), Neck length (NL), Body weight (BW) and Breast circumference (BrC)

Table 3 Eigenvalues and percentage of total variance along with the rotated component matrix and communalities of body measurements for indigenous chickens

Traits	Indigenous chickens		Communality
	PC1	PC2	
Body Weight	0.83	0.33	0.79
Back Length	0.37	0.62	0.53
Body Length	0.76	0.21	0.62
Breast circumference	0.84	0.00	0.72
Neck Length	0.56	0.42	0.49
Shank Length	0.29	0.79	0.71
Shank Circumference	0.62	0.38	0.53
Toe Length	0.00	0.85	0.73
Eigenvalues	4.08	1.03	
% of total Variance	51.05	12.89	
Cumulative %	51.05	63.94	

PC1 (1st principal component), PC2 (2nd principal component)

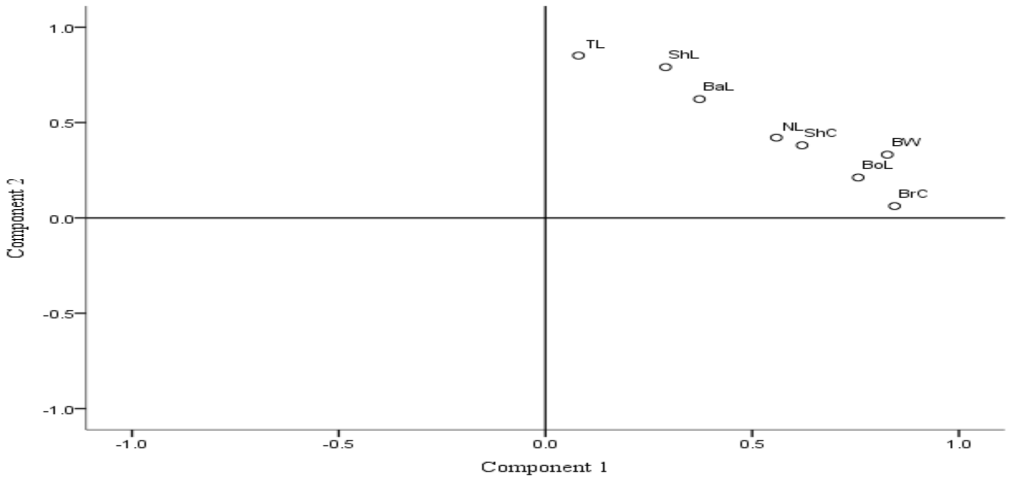

Figure 1 Projections on principal components (PC) of the factors and associations of body measurements after

Varimax transformation in indigenous chickens.
Breast circumference (BrC), body weight (BW), body length (BoL), shank circumference (ShC), neck length (NL), back length (BaL), Shank length (ShL), toe length (TL)

Table 4 shows the interdependent original body dimensions and their independent component factor scores. Using stepwise multiple regression, BrC accounted for 49.7% of the variation in BW. Back length increased the proportion of the explained variance to 59.3%. The accuracy of the model was improved (R^2 = 65.3%) by adding ShC. The ShC and BoL also improved (R^2 = 67.9%) the model. The model was further improved (R^2 = 68.5%) by inclusion of the TL. The use of PC 1 as a single predictor (R^2 = 68.4%) explained the total variability in BW. The combination of PC1 and PC 2 gave a considerable improvement (R^2 = 79.4%) in the amount of variance. The best prediction equation after inclusion of component scores was:
BW = 0.461PC1 + 0.185PC2 + 1.824

Table 4 Stepwise multiple regression of body weight on original body measurements and factor score in indigenous chickens

Model	Predictors	Models	R^2 (%)	SE
Original body measurements as predictors				
1	BrC	BW=0.10BrC-1.46	49.7	0.40
2	BrC, BaL	BW=0.085BrC+0.049BaL-2.222	59.3	0.36
3	BrC, BaL, ShC	BW=0.069BrC+ 0.041BaL+0.207ShC-2.434	65.3	0.33
4	BrC, Bal, ShC, BoL	BW=0.060BrC+0.032BaL+0.180ShC+0.021BoL-2.683	67.9	0.32
5	BrC, Bal, ShC, BoL, TL	0.060BrC+0.028BaL+0.161ShC+0.022BoL+0.043TL-2.760	68.5	0.32
Principal components as predictors				
1	PC1	BW = 0.461PC1+1.824	68.4	0.31
2	PC2	BW = 0.461PC1+0.185PC2+1.824	79.4	0.25

Body weight (BW) and Breast circumference (BrC), Back length (BaL), Body length (BoL), Shank circumference (ShC), Toe length (TL), PC1 (1st principal component), PC2 (2nd principal component)

Discussion

Adult females are liable for most of homestead related activities (Guèye, 2003). The findings that the majority of respondents who owned chickens were females indicate a potential to use chickens for women empowerment (McAinsh *et al.*, 2004). The findings that the purpose of keeping chickens is for meat consumption is in line with the report of Mtileni *at al*. (2012). The KwaZulu-Natal province is categorised as most undernourished province in South Africa, which explains why famers consider consuming chicken instead of selling. Indigenous chickens are commonly kept in an extensive production system with little, if any, or no supplementary feeding (Mtileni *et al*., 2012). These are ubiquitous, implying that they have the potential to alleviate dietary protein shortages. The majority of famers practised uncontrolled breeding system, yet were aware of inbreeding and its undesired consequences. This reveals how less farmers value indigenous chickens in comparison with other livestock such as cattle. On other hand, record keeping is difficult to employ due to several challenges such as uncontrolled mixture of chickens, which results into loss of genetic diversity.

Understanding relationship between BW and linear body measure is pertinent as part of selection criterion for breeding. The positive correlation among morphological traits assert that these traits are interrelated and indicate high predictability among variables. The positive relationship between BW and all of body measurements implies that BW can be predicted from linear body measurements. Similar findings were reported by Udeh & Ogbu (2011) who highlighted that an increase in linear body measurements will result to increase in BW. Highest and positive correlation between BW and BrC reported in present study is similar to the findings by Ajayi e*t al*. (2012) who cited correlation coefficient of 0.914 between BrC and BW. High and positive correlation between BW and BrC suggest that BrC could be a dependable predictor of BW. The correlation is attributed to a large deposit of muscles and bones in the breast region of indigenous chickens (Ajayi *et al*., 2012). Breast circumference could be used as a reliable estimator of BW in chickens. The weakest correlation between BW and TL is in line with the report by Egena *et al*. (2014) who indicated that TL had the lowest correlation coefficient with body weight. Selection for increased in TL is ideal for fast-growing birds instead of small framed indigenous chicken such as Ovambo. Nonetheless, indigenous chickens scavenge distant areas searching for feed. Therefore, selection for an increased in TL would be beneficial for indigenous chickens.

The communalities obtained in the present study coincide with the findings elsewhere (Yakubu *et al*. 2009; Udeh & Ogbu, 2011; Egena *et al*., 2014). The PC approach reduced eight explanatory variables into two components that gave a better description of body size and shape. Principal Component 1 has largely been associated with size and PC2 associated with body shape (Yakubu *et al*., 2009). These PCs could be useful in evaluating animals for breeding and selection purposes (Ajayi *et al*., 2012), and they can be used as selection criteria for improving body weight of indigenous chickens (Egena *et al.*, 2014). The findings that PC1 had high loadings of BoL, BrC and ShC and PC2 had high loading of ShL, TL and BaL are concordant to those reported by Ajayi *et al*. (2012). The lowest contribution of ShL to PC1 indicates its weakness in explaining the total variation in body measurements of indigenous chickens. Egena *et al.* (2014) indicated that ShL is a non-economical trait, suggesting that it is can be a negligible factor when explaining the total variation in body measurements.The variability of body measurements reported in the present study is slightly higher (51% of variance) than one reported by Egena *et al*. (2014). The difference could be due to unequal number of body measurement included in the model. Egena *et al.* (2014) also included wing length and shank thickness, which were not considered in the present study. The use of principal component scores gave a better and more reliable assessment of body weight.

Conclusion

Linear traits such as breast circumference, body length and shank circumference have been shown to be strongly related with body weight. Higher communalities obtained from breast circumference, body length and shank circumference showed the remarkable contribution made by these traits in determining the BW of indigenous chickens The results suggest that PCA could be used in breeding programmes to select animals based on a group of variables rather than on isolated traits. The use of principal components (PC1 and PC2) was more appropriate in predicting body weight of non-descript breeds of indigenous chicks.

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Authors' contributions

B.N. Vilakazi collected data and this work is part of her MSc work. C.N. Ncobela re-analyzed the data and wrote the manuscript. N.W. Kunene conceived the idea and assisted during the MSc writing. F. Panella improved the writing of the manuscript.

Conflict of interest

Authors wish to declare that there is no conflict of interest with this publication

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