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Research Article
Relationship of Age and Live weight to Linear Body Traits in Female Intensively Reared Boschveld Chicken in Namibia

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Abstract
Objective: The aim of this study was to investigate the relationship between linear body measurements and age and body weight in indigenous female chickens of the Boschveld breed in Namibia. **Materials and Methods:** Thirty-five chickens were reared from day-old to 18 weeks of age at the university farm. Neck length, shank length, comb length, keel length, chest girth, wing length, beak length and body length were measured weekly over 18 weeks. **Results:** The study found a strong, positive and significant correlation [r (17) $\geq$0.97$\leq$1, p<0.001] between age and linear body measurements and between body weight and linear body measurements [r (17) $\geq$0.96$\leq$0.99, p<0.001]. On a weekly basis, shank length, keel length, beak length, comb length, chest girth, neck length, wing length and body length increased on average by 0.47, 0.56, 0.13, 0.26, 1.44, 0.93, 0.95 and 1.15 cm respectively. For every 1 cm change in shank length, keel length, beak length, comb length, chest girth, neck length, wing length and body length, body weight increased on average by 217.8, 183.2, 750.5, 382.1, 69.2, 111.6, 0.104 and 86.5 g, respectively. Age was responsible for 94.5 and 99.4% of the variation in the linear body parameters, while body weight explained 92.5 and 97.8% of the variation up to 18 weeks of age. Neck length had the highest, positive and significant correlation to age [r (17) =1, p<0.001] and body weight [r (17) = 0.99, p<0.001] and was therefore considered the best predictor of the two parameters. Results of this study showed that neck length is an appropriate measure for predicting age and body weight in Boschveld chickens up to 18 weeks of age. **Conclusion:** The results of this study have a potential application in the monitoring of growth in poultry enterprises for timely diagnosis of stunted growth in female Boschveld chickens due to subtle pathology.

Key words: Body length, body weight, boschveld chicken, chest girth, shank length, stunted growth

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

A study of the mathematical relationships between principal components or linear body parameters and BW is not a new phenomenon. The relationships have been studied in cattle[1,2], small ruminants[3,4], rabbits[5] and even humans[6]. Results of such studies are the basis for the use of the weigh band to estimate weight in cattle[7], pigs[8] and goats[9].

The relationship between linear body measurements [body length (BdL), shank length (SL), chest girth (CG), keel length (KL), beak length (BL), wing length (WL), comb length (CL), back length (BcL), thigh length (TL), thigh circumference (TC), drumstick length (DsL)] that define body conformation of particular breeds versus age and/or BW has been extensively studied in both indigenous and commercial poultry breeds of chicken (*Gallus gallus domesticus*)[10-13], in ducks (*Anas Platyrhynchos*)[14,15], guinea fowl (*Numida meleagris*)[16], turkey (*Meleagris gallopavo*)[17], Japanese quail (*Coturnix japonica*)[18], partridge (*Perdix perdix*)[19], pigeon[20] and captive red-winged tinamou (*Rhynchotus rufescens*)[21] in the last two decades. On the African continent, reports have come from Southern Africa[22-24], West Africa[14,16,25-31], East Africa[32] and North Africa[15,33]. A few studies have also been undertaken on the Indian sub-continent[12,20,34], Middle East[19,35] and South America, Eastern Europe[36] and Indochina[37,38].

The relationship between the linear body measurements and BW lends its importance to marketing and selection of individuals for breeding[39]. It has been postulated that these linear body measurements (principal components) can predict future growth of an individual and its offspring and thus can be used to select breeding stock[19,33,39]. In addition, such parameters can also be used to estimate live weight including the carcass weight of a chicken[38] during informal marketing transactions where weighing scales may not be available[19,25,40]. One group of workers from Uganda have estimated the potential actual losses that both farmers and consumers incur in informal marketing transactions as a result of the underestimation of weight[32].

The study of the relationship between linear body parameters and weight involves taking body measurements and weights of chickens at various stages of growth. Algorithms are then used to determine the relationship and to find out the linear measurements that best predict chicken weight for that particular species or breed at a specific age[23,38,40]. The process involved in developing mathematical models to describe the relationship between BW and linear body measurements is universal but has been given many names including principal component analysis[11,12,35,41], path analysis[38] and factor analysis[23,33,40].

It has been previously pointed out that the best predictor of weight in a breed or species may change over time and thus the prediction of weight may only be true for specific ages of chicken[31]. Furthermore, the prediction of BW has been demonstrated to be dependent on species[17], breed[23,27], strain[11,42] and sex[32,33,39,40].

According to a number of authors, BW has been positively correlated with the linear body parameters SL, KL, CG, BL, WL, BdL[12,14,23,28,30,37,41-43]. There are conflicting reports about the linear body parameters that are highly correlated with BW in various species, breeds, strains and even sexes within breeds or strains. Workers from all over the world single out breast girth[10,14,18,30], BdL[12,37], shank width[19,23], back length[43], NL[43], KL[15] and WL[27] as the most reliable linear body parameters for predicting BW.

The relationship between linear body parameters and BW has been thoroughly studied in poultry, particularly in indigenous chicken. In spite of the abundant body of literature available from Africa and elsewhere on the relationship between linear body measurements and BW at various stages of growth in various poultry species and breeds of chicken, only a few have been published from Southern Africa[22-24]. Even then, only a handful of these publications make reference to the Boschveld[24]. To the best of our knowledge, there is no published literature on the correlation between linear body measurements and age and/or body weight on the Boschveld under Namibian intensive poultry production conditions.

The objective of this study was to investigate the relationship between linear body measurements and age and BW in the Boschveld chicken under an intensive production system at Neudamm Farm, in a semi-arid region of Namibia. The Boschveld chicken is the only synthetic African indigenous breed developed in South Africa through a 3-way crossing of the Venda, the Matabele and the Ovambo chicken breeds[44] for rural production systems[24]. The chicken breed was imported into Namibia and has become one of the common breeds in the urban, peri-urban and rural backyard farming systems[45,46].

MATERIALS AND METHODS

Study animals: Thirty five Boschveld female chicks were hatched from eggs incubated in a HHD-YZ 96 automatic egg incubator and reared intensively for 18 weeks. Female hatchlings were selected by vent sexing and then selected against abnormalities[47]. Chicks were vaccinated against Marek's disease (Rismavac; day 0), Newcastle disease, infectious bronchitis (Hipraviar Clone + H120; day 10, 24, week 4, 8, 15), infectious bursal disease (Avipro Precise; day 17, 24), Coryza, egg drop syndrome (Coryza/EDS; day 28, week 12, infectious laryngotracheitis (LT-IVAX; day 28, Nobilis Laryngo-Vac; week 8) and fowl pox (Poulvac AE + Pox; week 8). Panacur was used to deworm the birds at week 7. All vaccines and drugs were supplied by Immuno-Vet Services (South Africa). All birds were maintained on clean water and Feedmaster rations *ad libitum* up to four weeks of age. Birds were fed an average of 50 g per bird (5-6th week), 60 g (7-8th week), 70 g (9-10th week), 80 g (11-12th week), 90 g (13-14th week), 100 g (15-16th week) and 110 g (17-18th week) in a well-ventilated room on littered concrete floors. The hatchlings were fed with pullet starter feed (20% protein, 3% fat, 6% fibre, .35% NaCl and 100ppm lasalocid sodium) till six weeks of age and changed onto pullet grower feed (16% protein, 2.5% fat, 10% fibre, 1.3% linoleic acid, .35% NaCl and 100 ppm lasalocid sodium) up to week 18.

Data collection: The study birds were identifiable through shank tags maintained throughout the study period. BW was measured on a digital balance (Sartorius). Shank, beak and comb length were measured using a pair of digital Vernier callipers (Gifer), chest girth and body length using a cloth tape measure (Singer) while wing, neck and keel length were measured using a 30 cm metal ruler (Staedtler). The protocol in Table 1, according to previous studies, was adhered to in the measurement of the listed body growth parameters[12,43,48-52]. Measurements were taken at the same time every day, as much as possible by the same individual, were taken twice and the average of the two measurements used to ensure accuracy.

Statistical analysis: The Shapiro-Wilk test was used to test for normality in the overall distribution of the data collected in this study with the results shown in Table 2.

A summary of the descriptive statistics of the body parameters of female Boschveld chickens over 18 weeks of intensive rearing was calculated using Microsoft Excel (2013). A Pearson correlation coefficient was computed to assess the relationship between the body parameters (BW, SL, KL, BL, CL, NL, WL and BdL) and age of chicken. A Pearson product-moment correlation coefficient was also computed to assess the relationship between the body parameters (SL, KL, BL, CL, NL, WL and BdL) and BW of the chicken. The inferences on strength of correlations were made based on the descriptions shown in Table 3.

Scatter plots correlating the body parameters to age and BW were drawn in Microsoft Excel (2013). The expected change in the Y variables (body parameters) per unit change in the X variables (age or BW) was determined from the linear equation of the trend line modelled within the scatter plot. The Statistical Package for Social Sciences (SPSS) version 25 was used for regression analysis where $p \leq 0.05$ was considered significant.

RESULTS

Table 4 shows the mean of the parameters that were measured for week 1 and week 18. Average hatchling BW was 32.7±6.2 g, while the mean body weight at 18 weeks was 1564±338 g. Mean body length was 5.75±1.03 cm and 23.7±2.21 cm in week one and week 18 respectively.

As shown in Fig. 1, there was a very strong positive correlation between age and BW [r (17) = 0.99, p<0.001]. Body weight increased by an average of 104.3g per week. The age of the birds explained 98.4% of the variation in BW of the chickens.

Results of this study (Fig. 1) showed that there was a very strong positive correlation [$r(17) \geq 0.97 \leq 1$, p<0.001] between age and linear body parameters, that is, SL [r (17) = 0.99, p<0.001], KL [r (17) = 0.99, p<0.001], BL [r (17) = 0.99, p<0.001], CL [r (17) = 0.99, *p*<0.001], CG [*r* (17) = 0.98, p<0.001], NL [r (17) = 1, p<0.001], WL [r (17) = 0.97, p<0.001] and BdL [r (17) = 0.98, p<0.001]). On a weekly basis, SL, KL, BL, CL, CG, NL, WL and BdL increased on average by 0.47, 0.56, 0.13, 0.26, 1.44, 0.93, 0.95 and 1.15 cm, respectively. Age was

Table 1: Anatomical landmarks used in the measurement of body parameters in chickens

Parameters	Anatomical landmarks	References
Shank length (SL)	Distance from the hock joint to the 3rd tarsometatarsal joint	Ahmed *et al.*[42]
Wing length (WL)	Distance from the shoulder to the extremity of terminal phalanx	Ajayi *et al.*[52]
Body length (BdL)	The distance from the base of neck to the ischial tuberosity	Atansuyi *et al.*[30]
Chest Girth (CG)	This is measured as the body circumference just behind the wings	Atansuyi *et al*,[30]
Beak length (BL)	Distance between the rictal apterium to the end of the maxillary nail	Saikhom *et al.*[12]
Comb length (CL)	Distance from comb's insertion to beak to the end of the comb's lobe.	Francesch *et al.*[51]
Neck length (NL)	Distance between occipital condyle and cephalic borders of the coracoids	Ahmed *et al.*[44]
Keel length (KL)	keel bone length from the V-joint to the end of the sternum	Fayeye *et al.*[50]

responsible for 94.5 and 99.4% of the variation in the linear body parameters for up to 18 weeks of age. Neck length had the strongest and WL, the weakest positive correlation to age in Boschveld pullets. When ranked in terms of the strength of positive correlation with age, NL>KL>SL>BL>CL>CG> BdL>WL.

Results in Fig. 2 show that there was a strong positive correlation [r (17) ≥0.96≤0.99, p<0.001] between BW and linear body parameters, that is, SL [r (17) = 0.99, p<0.001], KL [r (17) = 0.98 p<0.001], BL [r (17) = 0.97, p<0.001], CL [r (17) = 0.96, p<0.001], CG [r (17) = 0.97, p<0.001], NL [r (17) = 0.99, p<0.001], WL [r (17) = 0.96, p<0.001] and BdL [r (17) = 0.97, p<0.001]. For every cm change in SL, KL, BL, CL, CG, NL, WL and BdL, BW increased on average by 217.8, 183.2, 750.5, 382.1, 69.2, 111.6, 0.104 and 86.5 g, respectively. Linear body parameters explained between 92.5 and 97.8% of the variation in BW for up to 18 weeks of age. Neck length had the strongest and WL, the weakest positive correlation to body weight in the pullets. When ranked in terms of the strength of the positive correlation to body weight, NL>SL>KL>BL>CG> BdL>CL>WL.

Table 2: Shapiro-Wilk test scores (W) of female boschveld chicken parameters measured from hatching to 18 weeks of age

Parameters	Shapiro-Wilk score	R^2
BW	0.96	0.93
SL	0.97	0.95
KL	0.98	0.97
BL	0.98	0.95
CL	1.00	1.00
CG	0.96	0.93
NL	0.98	0.97
WL	0.95	0.91
BdL	0.96	0.92

Table 3: Descriptions assigned to the ranges of the values of correlation coefficients (*r*)

R-value	Description
0-0.19	very weak
0.2-0.39	Weak
0.4-0.59	Moderate
0.6-0.79	Strong
0.8-1.0	very strong

Table 4: Mean and standard deviation of linear body parameters in the Boschveld chicken for week 1 and week 18 (n = 35)

Parameters	Week one	SD	Week 18	SD
Mean BW (g)	32.70	6.20	1564.00	338
Mean SL (cm)	2.34	0.23	9.79	1.06
Mean KL (cm)	2.13	0.65	11.64	1.02
Mean BL (cm)	1.55	0.19	3.78	0.36
Mean CL (cm)	0.00	0.00	5.32	5.19
Mean CG (cm)	7.32	0.84	30.40	6.05
Mean NL (cm)	3.22	0.62	18.70	1.72
Mean WL (cm)	4.90	0.87	20.00	1.58
Mean BdL (cm)	5.75	1.03	23.70	2.21

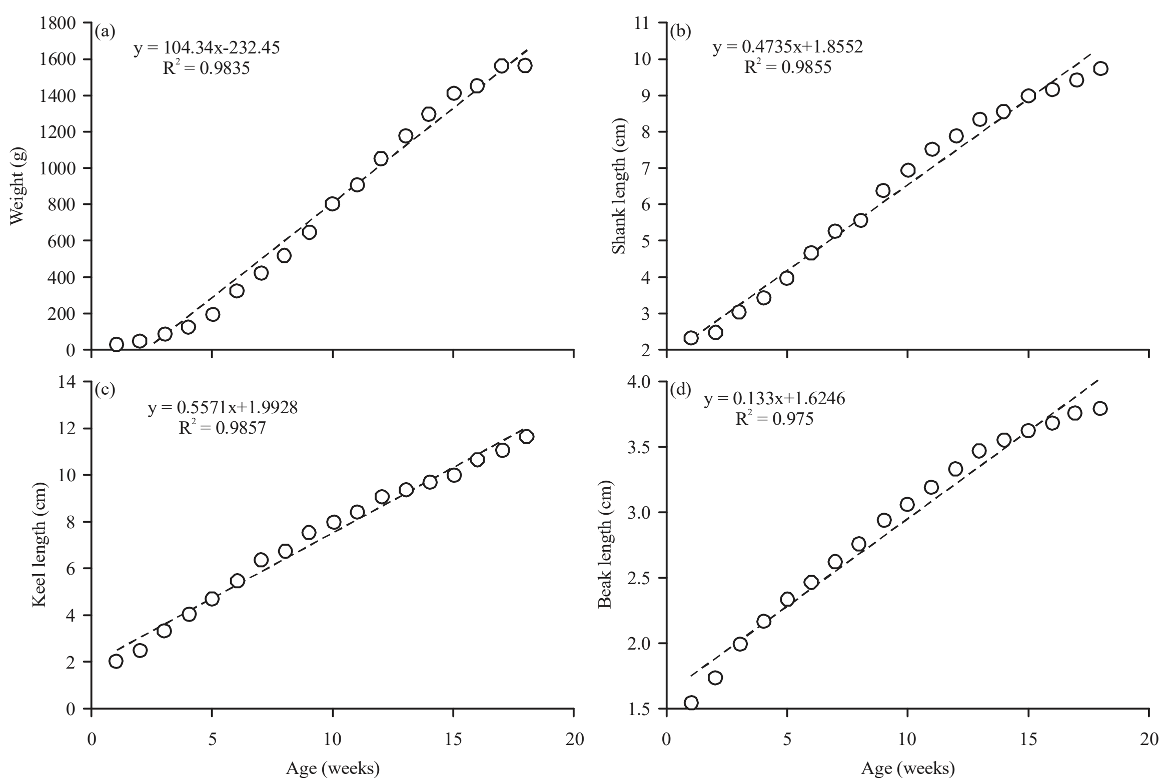

Fig. 1(a-i): Continue

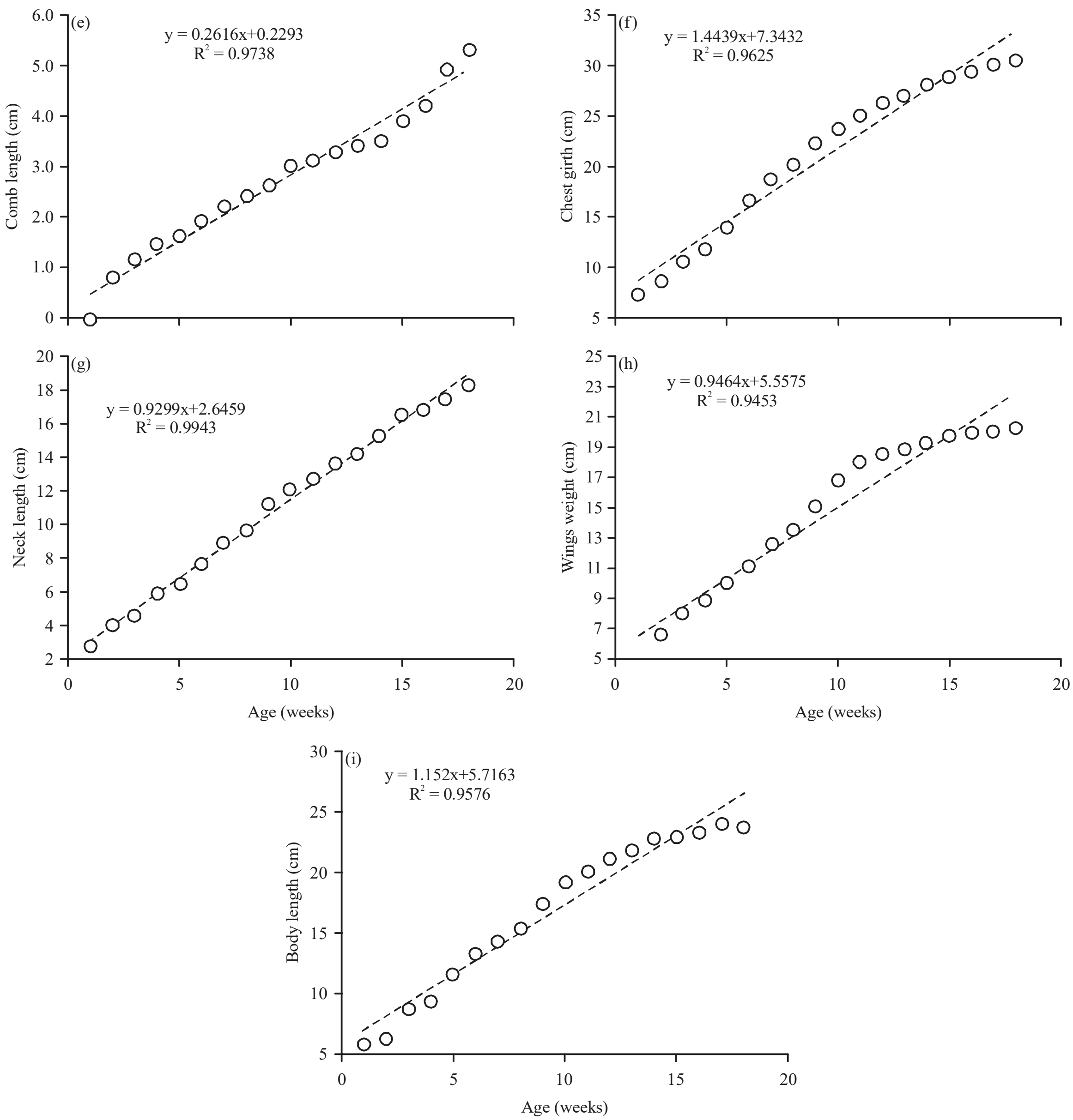

Fig. 1(a-i): Correlation between body parameters and age in the Boschveld chickens (n = 35)

DISCUSSION

This study focussed on finding out the best linear body parameters that can be used to predict age and body weight in female Boschveld chickens. Consequently, findings from this study only apply to this breed and sex because previous studies have confirmed that the relationship between linear body measurements and weight varies with breed strain of chicken[11,40], sex[27,39], in ducks, turkeys[17] and in chicken[30,31,37]. However, in chicken, there are conflicting reports about which sex has the strongest correlation between BW and linear body measurements. Some authors claim that the male chicken has the strongest correlation[30], while other authors claim it is the female chicken[31,37]. The relationship between age, body weight and linear body measurements can be used for genetic improvement of bird growth through the selection of birds with the best traits[53].

The strong, positive and highly significant correlation between age and BW [r (17) =, $p<0.001$] that was observed in this study confirmed that both age and weight had similar correlations with linear body parameters. These results also showed that up to 18 weeks of age, BW increased with an average of 104.3 g per week and that the age of the birds accounted for 98.4% of the variation in BW of female

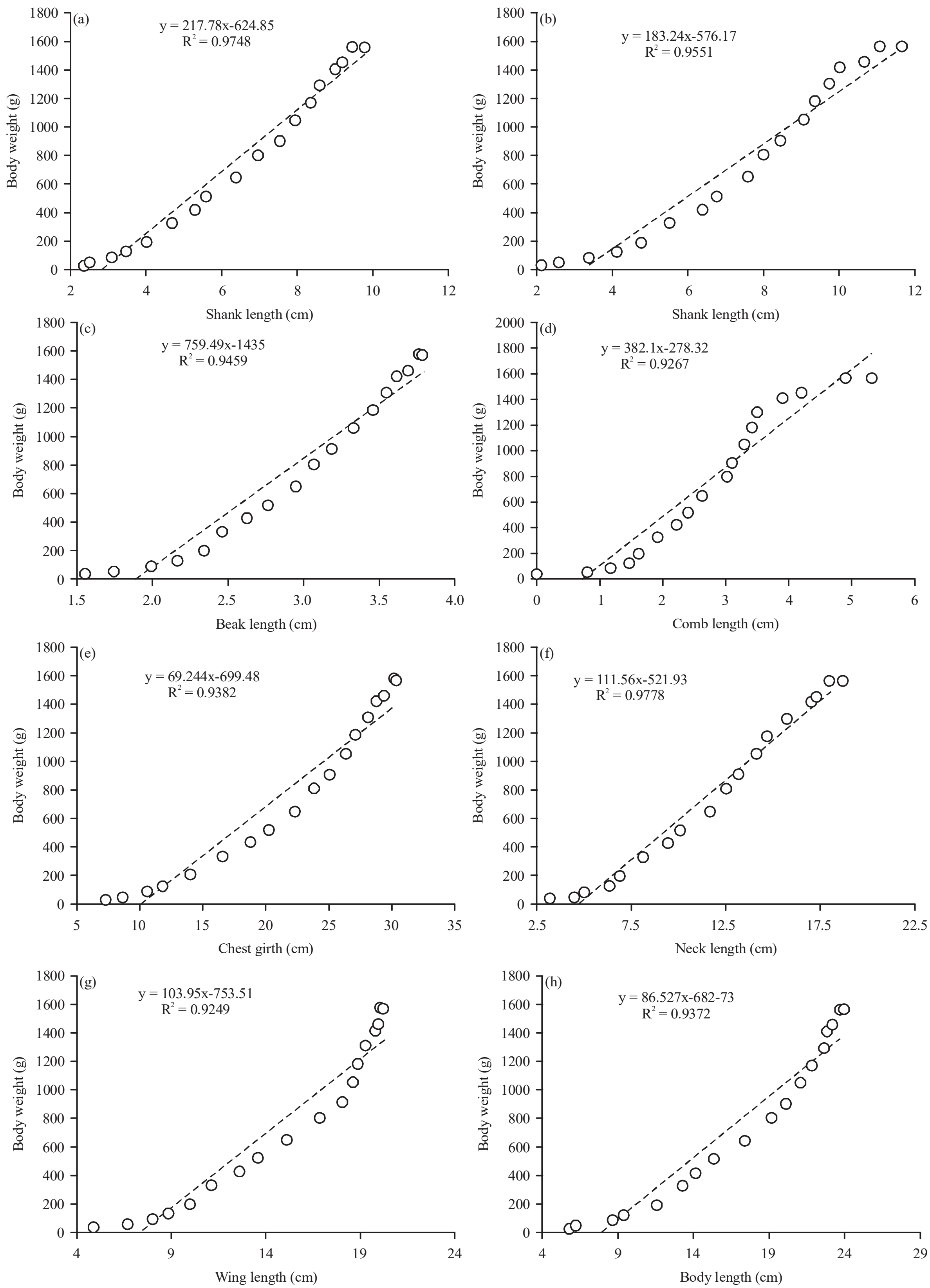

Fig. 2(a-h): Correlation between body parameters and BW in growing female Boschveld chickens (n = 35)

Boschveld chickens. These findings suggest that age can be substituted for weight in female Boschveld chickens from a day old until 18 weeks of age. Interestingly, this assertion has also not been made or reported by previous studies.

Results of this study revealed a strong and highly significant positive correlation [r (17) $\geq$0.97$\leq$1, p<0.001] between age and linear body parameters (SL, KL, BL, CL, CG, NL, WL and BdL). The authors could not find any previous reports confirming the relationship between body parameters and age in Boschveld chickens. Rather, a number of previous studies have focussed on describing the relationship between linear body parameters and BW at specific ages of birds[15,19,48] or over a period of time[25,42]. The few studies that have made reference to age have carried out regression studies of age against productivity parameters in female Boschveld chicken[24]. Neck length had a positive, significant and highest correlation with age and was therefore considered as the best predictor of this trait.

In this study, a highly significant interrelationship [r (17) $\geq$0.96$\leq$99, p<0.001] between BW and linear body parameters (SL, KL, BL, CL, CG, NL, WL and BdL) was determined. For every cm change in SL, KL, BL, CL, CG, NL, WL and BdL, BW increased by averages of 217.8, 183.2, 750.5, 382.1, 69.2, 111.6, 0.104and 86.5 g, respectively. Linear body parameters were able to explain between 92.5% and 97.8% of the variation in BW for up to 18 weeks of age. The positive correlation between linear body measurements and body weight mean that all linear body traits can be selected at the same time to improve chicken weight. Results of this study are in agreement with the findings of a study by Alimi[53] who reported a high, positive and significant relationship between linear body measurements and body weight. There is an abundant body of literature with conflicting reports about the linear body parameter with the highest correlates with body weight in poultry[15,25,28,48,30,40,43]. According to our results, NL showed the highest correlation with BW, meaning that it was the best predictor of BW. Our results are in agreement with one study[43] that also identified NL as having the strongest positive correlation with body weight. A number of previous studies did not identify the specific linear body parameter with the highest correlation with body weight[28,48,41]. Rather, they highlighted the presence of a strong positive correlation and also state a range of the correlation coefficient between linear body parameters and weight without necessarily identifying the order of the strength of these correlations. Some studies identified CG as having the strongest positive correlation to body weight in chickens[12,25,30,32,40,53], while others point out SL[11,18,26,36]. Still other studies have identified KL[15] and shank thickness[38] as the most important predictors of body weight in chicken. Recent studies have identified BdL as having the highest correlation with body weight[12,23]. The mean body weight of a Boschveld chicken of 1564$\pm$338 g at 18 weeks of age was comparable to body weights of South African indigenous chickens of 1.7-1.88 kg[22].

Linear body measurements are useful on commercial poultry farms where they can be used to facilitate timeous diagnosis of early growth problems such as stunting to prevent significant losses later at harvest, as well as to estimate age or weight for marketing purposes using predictive equations, especially in situations where weighing scales are not available. An element that must be taken into consideration when choosing a linear body parameter for predicting body weight is convenience of measurement. Although neck length was considered the best trait for predicting both age and weight in this study, it is subject to variation between individuals taking the measurement. Therefore, the second best parameter as determined by this study, SL, is recommended in place of NL, for use in marketing and breeding selection procedures as it has less measurement variation. Though NL was determined as the most practical measure from our results, the high correlation (over 96%) of all the linear body measurements means that any of them can technically be used as objective estimates of body weight[54] or age for the purposes of breeding selection or for informal marketing transactions especially in the rural areas. It is recommended that future studies be carried out in male or in both male and female Boschveld chickens to find out if there are any sex differences between linear body measurements.

CONCLUSION

This study demonstrated a strong positive relationship between linear body measurements (SL, KL, BL, CL, CG, NL, WL and BdL) and age and body weight in female Boschveld chicken indicating that increases in the growth rate of any of the body traits will result in increased live weight gains. It is further concluded that any values of the studied body measurements can be used to predict chicken weight and age but NL was determined to provide the best prediction of these traits.

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REFERENCES

1. Sawanon, S., P. Boonsaen and P. Innuruk, 2011. Body measurements of male Kamphaengsaen beef cattle as parameters for estimation of live weight. Kasetsart J. Nat. Sci., 45: 428-434.

2. Lukuyu, M.N., J.P. Gibson, D.B. Savage, A.J. Duncan, F.D.N. Mujibi and A.M. Okeyo, 2016. Use of body linear measurements to estimate liveweight of crossbred dairy cattle in smallholder farms in Kenya. SpringerPlus, Vol. 5. 10.1186/s40064-016-1698-3
3. Adeyinka, I.A. and I.D. Mohammed, 2006. Relationship of live weight and linear body measurement in two breeds of goat of Northern Nigeria. J. Anim. Vet. Adv., 5: 891-893.
4. Younas, U., M. Abdullah, J.A. Bhatti, T.N. Pasha, N. Ahmad, M. Nasir and A. Hussain, 2013. Inter-relationship of body weight with linear body measurements in hissardale sheep at different stages of life. J. Anim. Plant Sci., 23: 40-44.
5. Chineke, C.A., 2005. The relationships among body weights and linear dimensions in rabbit breeds and crosses. J. Anim. Vet. Adv., 4: 775-784.
6. Popovic, S., D. Bjelica, G. Georgiev, D. Krivokapic and R. Milasinovic, 2016. Body height and its estimation utilizing arm span measurements in Macedonian adults. Anthropologist, 24: 737-745.
7. Dingwell, R.T., M.M. Wallace, C.J. McLaren, C.F. Leslie and K.E. Leslie, 2006. An evaluation of two indirect methods of estimating body weight in holstein calves and heifers. J. Dairy Sci., 89: 3992-3998.
8. Abonyi, F.O., C.V.O. Omeh and N.S. Machebe, 2012. Neonatal mortality of pigs in Nsukka, Southeast Nigeria. Afr. J. Biotechnol., 11: 13228-13234.
9. De Villiers, J.F., S.T. Gcumisa, S.A. Gumede, S.P. Thusi and T.J. Dugmore *et al*., 2009. Estimation of live body weight from the heart girth measurement in Kwa Zulu-Natal goats. Applied Anim. Husbandry Rural Dev., 2: 1-8.
10. Adeleke, M.A., S.O. Peters, M.O. Ozoje, C.O.N. Ikeobi, A.M. Bamgbose and O.A. Adebambo, 2011. Genetic parameter estimates for body weight and linear body measurements in pure and crossbred progenies of Nigerian indigenous chickens. Livest. Res. Rural Dev., Vol. 23, No. 1.
11. Udeh, I. and C.C. Ogbu, 2011. Principal component analysis of body measurements in three strains of Broiler chicken. Sci. World J., 6: 11-14.
12. Saikhom, R., A.K. Sahoo, S. Taraphder, S. Pan and U. Sarkar *et al*., 2018. Principal component analysis of morphological traits of Haringhata black chickens in an organized farm. Explor. Anim. Med. Res., 8: 64-68.
13. Yakubu, A. and M.M. Ari, 2018. Principal component and discriminant analyses of body weight and conformation traits of Sasso, Kuroiler and indigenous Fulani chickens in Nigeria. J. Anim. Plant Sci., 28: 46-55.
14. Teguia, A., H.M. Ngandjou, H. Defang and J. Tchoumboue, 2008. Study of the live body weight and body characteristics of the African Muscovy duck (*Caraina moschata*). Trop. Anim. Health Prod., 40: 5-10.
15. Gouda, G.F., W.A.H. Ali and K.A. Ali, 2016. Using early live body performance traits of ducks to predict marketing weight. Egypt. Poult. Sci. J., 36: 895-904.
16. Brown, M.M., B. Alenyorege, G.A. Teye and R. Roessler, 2017. Phenotypic diversity, major genes and production potential of local chickens and guinea fowl in Tamale, Northern Ghana. Asian-Aust. J. Anim. Sci., 30: 1372-1381.
17. Ogah, D.M., 2011. Assessing size and conformation of the body of Nigerian Indigenous Turkey. Slovak J. Anim. Sci., 44: 21-27.
18. Victoria, O., T.R. Fayeye, K.L. Ayorinde and H. Olojede, 2014. Relationship between body weight and linear body measurements in Japanese quail (*Coturnix coturnix japonica*). J. Scient. Res., 6: 175-183.
19. Caglayan, T., K. Kirikci, A. Gunlu and S. Alasahan, 2011. Some body measurements and their correlations with live weight in the rock partridge (*Alectoris graeca*). Afr. J. Agric. Res., 6: 1857-1861.
20. Parvez, M.N.H., M.T.D. Akter and M.J.U. Sarder, 2016. Phenotypic characteristics and biometrical study on different breeds of pigeon in Northern Bangladesh. Bangladesh J. Vet. Med., 14: 135-139.
21. Dos Santos Correia, L.E.C., C.S. Paranzini, E. de Fatima, K.M.D.S. Aguiar and K.H.N.P. Pereira *et al*., 2018. Evaluation of growth traits in captive red-winged tinamou (*Rhynchotus rufescens*) raised in different production environments. J. Anim. Plant Sci., 37: 6008-6018.
22. Alabi, O.J., J.W. Ngambi, D. Norris and S.S.A. Egena, 2012. Comparative study of three indigenous chicken breeds of South Africa: Body weight and linear body measurements. Agric. J., 3: 220-225.
23. Malomane, D.K., D. Norris, C.B. Banga and J.W. Ngambi, 2014. Use of factor scores for predicting body weight from linear body measurements in three South African indigenous chicken breeds. Trop. Anim. Health Prod., 46: 331-335.
24. Okoro, V.M.O., K.E. Ravhuhali, T.H. Mapholi, E.F. Mbajiorgu and C.A. Mbajiorgu, 2017. Effect of age on production characteristics of Boschveld indigenous chickens of South Africa reared intensively. S. Afr. J. Anim. Sci., 47: 157-167.
25. Ajayi, F.O., O. Ejiofor and M.O. Ironkwe, 2008. Estimation of body weight from linear body measurements in two commercial meat-type chicken. Global J. Agric. Sci., 7: 57-59.
26. Ukwu, H.O., V.M.O. Okoro and R.J. Nosike, 2014. Statistical modelling of body weight and linear body measurements in Nigerian indigenous chicken. IOSR J. Agric. Vet. Sci., 7: 27-30.
27. Ndofor-Foleng, H.M., V. Oleforuh-Okoleh, G.A. Musongong, J. Ohageni and U.E. Duru, 2015. Evaluation of growth and reproductive traits of Nigerian local chicken and exotic chicken. Indian J. Anim. Res., 49: 155-160.
28. Oguntunji, A.O. and K.L. Ayorinde, 2015. Sexual size dimorphism and sex determination by morphometric measurements in locally adapted Muscovy duck (*Cairina moschata*) in Nigeria. Acta Agric. Slovenica, 104: 15-24.
29. Oleforuh-Okoleh, V.U., R.F. Kurutsi and H.M. Ideozu, 2017. Phenotypic evaluation of growth traits in two Nigerian local chicken genotypes. Anim. Res. Int., 14: 2611-2618.

30. Semakula, J., P. Lusembo, D.R. Kugonza, D. Mutetikka, J. Ssennyonjo and M. Mwesigwa, 2011. Estimation of live body weight using zoometrical measurements for improved marketing of indigenous chicken in the Lake Victoria basin of Uganda. Livestock Res. Rural Dev., Vol. 23.
31. Dahloum, L., N. Moula, M. Halbouche and S. Grasteau, 2016. Phenotypic characterization of the indigenous chickens (*Gallus gallus*) in the Northwest of Algeria. Arch. Anim. Breed., 59: 79-90.
32. Tabassum, F., M.A. Hoque, F. Islam, C.H. Ritchil, M.O. Faruque and A.K.F.H. Bhuiyan, 2014. Phenotypic and morphometric characterization of indigenous chickens at Jhenaigati upazila of Sherpur district in Bangladesh. SAARC J. Agric., 12: 154-169.
33. Abdullah, S.M. and A.S. Shaker, 2018. Principal component analysis of internal egg traits for four genetic groups of local chicken. Egypt. Poult. Sci. J., 38: 699-706.
34. Kokoszynski, D., Z. Bernacki, M. Saleh, K. Steczny and M. Binkowska, 2017. Body conformation and internal organs characteristics of different commercial broiler lines. Brazil. J. Poult. Sci., 19: 47-52.
35. Moula, N., 2016. Characterization of the Kabyle breed of hen (Thayazit Lekvayel) and its farming system in the region of Chemini and Bouzeguene (Algeria). Proceedings of the International Conference, Agriculture Development in the Context of International Integration: Opportunities and Challenges, December 7-8, 2016, Agriculture University Press, Hanoi, Vietnam, pp: 49-56.
36. Tyasi, T.L., N. Qin, X. Niu, X. Sun and X. Chen *et al*., 2018. Prediction of carcass weight from body measurement traits of Chinese indigenous Dagu male chickens using path coefficient analysis. Indian J. Anim. Sci., 88: 744-748.
37. Egena, S.S.A., A.T. Ijaiya and R. Kolawole, 2014. An assessment of the relationship between body weight and body measurements of indigenous Nigeria chickens (*Gallus gallus domesticus*) using path coefficient analysis. Livestock Res. Rural Dev., Vol. 26, No. 3.
38. Assan, N., 2013. Bioprediction of body weight and carcass parameters from morphometric measurements in livestock and poultry. Scient. J. Rev., 2: 140-150.
39. Ogah, D.M., A.A. Alaga and M.O. Momoh, 2009. Principal component factor analysis of the morphostructural traits of muscovy duck. Int. J. Poult. Sci., 8: 1100-1103.
40. Ojedapo, L.O., S.R. Amao, S.A. Ameen, T.A. Adedeji, R.I. Ogundipe and A.O. Ige, 2012. Prediction of body weight and other linear body measurement of two commercial layer strain chickens. Asian J. Anim. Sci., 6: 13-22.
41. Adenaike, A.S., U. Akpan and C.O.N. Ikeobi, 2016. Principal components regression of body measurements in five strains of locally adapted chickens in Nigeria. Anim. Health Prod., 64: 105-115.
42. Ekka, R., N.C. Behura, L. Samal, G.D. Nayak, P.K. Pati and P.K. Mishra, 2016. Growth performance and linear body measurements of Hansli, CSML and Hansli × CSML cross under intensive system of rearing. J. Livestock Sci., 7: 114-121.
43. Ahmed, I.A., I.A. Adeyinka, G.N. Akpa, M. Kabir and I. Abubakar *et al*., 2017. Interrelationships between body weight and conformation traits in Ross commercial broiler strain. Proceedings of the 54th Annual Congress of the Nigerian Veterinary Medical Association, November 6-10, 2017, Ahmadu Bello University Press Ltd., Kano, Nigeria, pp: 14-19.
44. Hans, L., 2012. Indigenous chicken in Africa. Aviculture Europe. http://www.aviculture-europe.nl/nummers/12E04A10.pdf.
45. Petrus, N.P, I. Mpofu and E. Lutaaya, 2011. The care and management of indigenous chicken in Northern communal areas of Namibia. Livestock Res. Rural Dev., Vol. 23.
46. Masaire, E., O. Madzingira, A. Samkange, E. Kandiwa, B. Mushonga and A.S. Bishi, 2018. Characterization of poultry production and management systems in the communal areas of Namibia. Afr. J. Poult. Farm., 6: 265-276.
47. Tudor, D.C., 1979. Congenital defects of poultry. World Poultry Sci. J., 35: 20-26.
48. Atansuyi, A., I. Olaseinde and C. Chineke, 2018. Estimation of body weight from linear body measurements in four-chicken genotypes using linear and quadratic functions. J. Sust. Technol., 9: 14-24.
49. Fayeye, T.R., K.L. Ayorinde, V. Ojo and O.M. Adesina, 2006. Frequency and influence of some major genes on body weight and body size parameters of Nigerian local chickens. Res. Rural Dev., Vol. 18.
50. Francesch, A., I. Villalba and M. Cartana, 2011. Methodology for morphological characterization of chicken and its application to compare Penedesenca and Empordanesa breeds. Anim. Genet. Resour./Resour., 48: 79-84.
51. Ajayi, O.O., M.A. Adeleke, M.T. Sanni, A. Yakubu and S.O. Peters *et al*., 2012. Application of principal component and discriminant analyses to morpho-structural indices of indigenous and exotic chickens raised under intensive management system. Trop. Anim. Health Prod., 44: 1247-1254.
52. Omeje, S.S. and C.C. Nwosu, 1986. Growth and egg production evaluation of F_2 and backcross progeny chicks from Nigerian chicken by gold-link crosses. Proc. World Cong. Genet. Applied Livestock Prod., 10: 304-310.
53. Alimi, J.M., 2012. Correlation analysis between body weight and linear body measurements in broiler chickens. http://unaab.assetjournal.edu.ng.
54. Adeniji, F.O. and K.L. Ayorinde, 1990. Prediction of body weight from linear body measurements of chickens. Niger. J. Anim. Prod., 17: 42-47.