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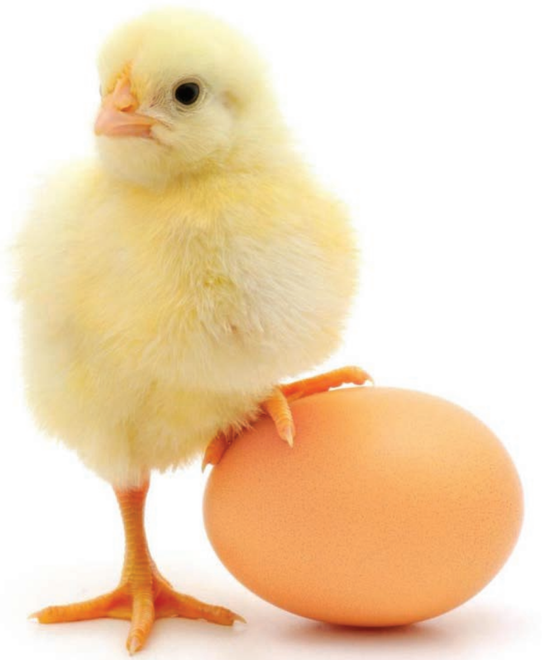

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Research Article
Statistical Modeling of Live Body Weight and Linear Body Measurements of Local Chicken at Different Agro-Ecologies of Ethiopia

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Abstract
Objective: This study was conducted to determine the relationship between live body weight and linear body measurements and to establish a model for predicting body weight using linear body parameters of the indigenous chickens of Ethiopia. **Materials and Methods:** A total of 520 adult chickens (130 males and 390 females) were randomized from three agro-ecologies (120 from lowland, 200 from midland and 200 from highland). Body parameters including beak length, body length, breast circumference, comb length, ear lobe length, shank circumference, shank length, wattle length and wingspan were measured using flexible measuring tape. Data were analyzed using SAS and SPSS. **Results:** Agro-ecology had significant effect ($p<0.05$) on body length, live body weight, breast circumference, shank circumference, shank length and wingspan. In indigenous chickens, the strong, positive and significant ($p<0.05$) correlation of body weight with breast circumference, body length and shank length indicate that, these variables could provide a good estimate in predicting body weight of chicken. Body length, chest circumference and shank length showed highest R^2 (0.599, 0.517 and 0.382), respectively. This indicates that 59.9, 51.7 and 38.2% of body weight variation in indigenous chicken of Ethiopia depends on body length, breast circumference and shank length, respectively. Equivalently, linear measurements with highest R^2 imply that they could be the best predictors of body weight of indigenous chickens in Ethiopia. Live body weight had significant ($p<0.05$) association with the linear body measurements; body length, chest circumference, shank length and wingspan to which the model has been subjected. Therefore, multiple linear regression model relating body weight and linear body measurements of Ethiopian indigenous chicken is $\hat{Y} = -0.949+0.039BoL+0.037SL+0.026BC+0.006WS$. **Conclusion:** Body length, shank length and breast circumference can be used to predict body weight of Ethiopian indigenous chicken compared to the other linear body measurements.

Key words: Agro-ecology, body weight, indigenous chickens, linear body parameter, predictive model

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

INTRODUCTION

In Ethiopia, most chicken populations are non-descriptive type. However, they showed a great variation in their production performance which might be due to their widespread distribution and adaptive response to different ecological conditions[1-3]. In Ethiopia, indigenous chicken is distributed in huge number (95.86%) across different agro-ecological zones[4] under a traditional family-based scavenging management system[5].

Morphometric traits are the quantitative analyses of the structure, shape and size of an organism. The derivation of live body weight from linear body measurements has been reported to be a practical and easy technique, especially for rural poultry breeders with lack of resources and materials[6].

Phenotypic correlation estimates between live body weight and linear body traits could guide the breeder in the choice of body size traits to incorporate into selection index. According to Olawunmi *et al.*[7] characterization of indigenous chickens is a necessary pre-requisite for the development of indigenous breed and rural poultry development.

In addition to body weight, a few conformation traits are known to be good indicators of physical growth and market value of indigenous chickens. Poultry breeders have tried to establish the relationship that exist between body weight and linear body parameters such as beak length, body length, chest circumference, comb length, ear lobe length, shank circumference, shank length, wattle length and wingspan. Relationships between body weight and linear body measurements are important for predicting body weight and can also be applied speedily in selection and breeding programmes[8]. Attah *et al.*[9], Sowande and Sobola[10] and Goe[11] used body measurements to predict body weight of different animal species in previous studies. However, there is little information on the prediction of body weight of chickens using linear body measurements[12,13]. This study was designed to determine the relationship between body weight and linear body measurements and to establish predictive model for estimating body weight using linear body measurements of Ethiopian indigenous chicken.

MATERIALS AND METHODS

Description of the study sites

Sampling methods: The study sites were identified using purposive sampling technique by considering existence of indigenous chicken population, dissemination of exotic chickens and agro-ecology.

Experimental chicken and parameters: A total of 520 adult chickens (130 males and 390 females) were randomly selected from three agro-ecologies (120 from lowland, 200 from midland and 200 from highland).

Live body weight measurement: Body weight of each experimental chicken was measured using spring scale.

Linear body measurements: Linear body measurements of beak length (BeL), body length (BL), body weight (BW), breast circumference (BC), comb length (CL), ear lobe length (ElL), shank circumference (SC), shank length (SL), wattle length (WL) and wingspan (WS) were determined (Table 1).

Data analysis: The data were analyzed using statistical analysis system (SAS) and Statistical Package for Social Science (SPSS). The correlation between live body weight and linear body measurements was determined using Pearson's product moment correlation coefficient (r). Linear regression analysis of the linear body parameters was also performed using the following simple and multiple linear regression models:

Simple regression model:

$$Y = B+\beta X \quad (1)$$

Multiple regression models:

$$Y = B+\beta 1X1+\beta 2X2+ \cdots +\beta kXk \quad (2)$$

Table 1: Description of linear live body weight and body measurements of the chicken

Parameters	Description
Beak length	Taken from the rectal apterium to the maxillary nail
Body length	Length between the tip of the *rostrum maxillae* (beak) and that of the *cauda* (tail, without feathers); the bird's body should be completely drawn throughout its length
Live body weight	Live weight when placed on a top loading measurement scale
Breast circumference	Taken at the tip of the *pectus* (hind breast)
Shank length	Length in cm of the shank from the hock joint to the spur of either leg
Wattle length and wingspan	Length in cm between tips of right and left wings after both are stretched out in full

FAO[14]

Where:

	:	Dependent variable (body weight)
Xs	:	Independent variables (BeL, BoL, CC, CL, ELL, SC, SL, WL, WS)
B	:	The intercept
βs	:	The slopes

RESULTS

Mean values for body weight and linear body measurements of cocks and hens are presented in Table 2 a and b. There was significant ($p<0.05$) difference in all linear body measurements and body weight for cocks and hens.

Agro-ecology effect: Agro-ecology had significant effect ($p<0.05$) on body length, live body weight, Breast circumference, shank circumference, shank length and wingspan. However, had no significant effect ($p>0.05$) on beak length, comb length, ear lobe length and wattle length.

Sex effect: Sex had a significant effect ($p<0.05$) on all linear body measurement and body weight of chickens. Male chickens were higher than the female chicken for all linear body measurements and live body weight.

Sex by agro-ecology: Sex by agro-ecology interaction had no significant effect ($p>0.05$) on all the linear body measurements and body weight of indigenous chicken.

Correlation between linear body measurements and body weight: Live body weight had significant and positive correlation with all linear body measurements (Table 3). The

Table 2a: Descriptive statistics of body weight (kg) and linear body measurements (cm) of Ethiopian local chicken as affected by agro-ecology, sex and their interaction

		Mean±SE				
Effects	N	BeL	BoL	LW	CC	CL
Agro-ecology		Ns	0	0	0	Ns
Low	120	2.31±.033	23.83±.243^a	1.10±.020^a	24.72±.292^a	2.58±.109
Mid	200	2.35±.024	24.80±.239^b	1.23±.020^b	25.67±.303^b	2.42±.097
High	200	2.30±.024	23.72±.234^a	1.08±.022^a	24.18±.246^a	2.38±.099
Sex		*	*	*	*	*
Cock	130	2.40±.028^b	26.07±.272^b	1.30±.027^b	26.35±.304^b	4.38±.100^b
Hen	390	2.29±.018^a	23.52±.153^a	1.09±.013^a	24.38±.192^a	1.80±.028^a
Sex by agro-ecology		Ns	Ns	Ns	Ns	Ns
LL, male	30	2.39±.062	25.08±.549	1.26±.05	25.84±.688	4.34±.136
LL, female	90	2.29±.036	23.41±.317	1.05±.028	24.34±.383	1.99±.078
ML, male	50	2.49±.048	27.14±.430	1.39±.038	27.55±.515	4.38±.105
ML, female	150	2.31±.028	24.01±.245	1.17±.022	25.04±.296	1.77±.061
HL, male	50	2.31±.048	25.60±.423	1.23±.037	25.46±.517	4.40±.103
HL, female	150	2.29±.028	23.09±.244	1.03±.021	23.74±.299	1.71±.060

^{a,b}Means on the same column with different superscripts within the specified age group are significantly different ($p<0.05$), Ns: Non-significant, N: Number of chickens, BeL: Beak length, BoL: Body length, LW: Live body weight, CC: Chest circumference, CL: Comb length, LL: Lowland, ML: Midland, HL: Highland, kg: kilo gram, cm: centimetre

Table 2b: Descriptive statistics of live body weight (kg) and linear body measurements (cm) of Ethiopian local chicken as affected by agro-ecology, sex and their interaction

		Mean±SE				
Effect	N	ELL	SC	SL	WL	WS
Agro-ecology		Ns	0	0	Ns	0
Low	120	1.50±.046	2.47±.050^a	6.75±.101^a	2.29±.097	37.56±.319^b
Mid	200	1.66±.170	2.64±.046^b	7.32±.093^b	2.29±.060	38.57±.244^c
High	200	1.47±.030	2.58±.048^{ab}	6.70±.092^a	2.20±.062	36.15±.257^a
Sex		*	*	*	*	*
Cock	130	1.98±.259^b	3.03±.056^b	7.66±.098^b	3.50±.058^b	39.44±.370^b
Hen	390	1.41±.020^a	2.42±.029^a	6.71±.064^a	1.84±.026^a	36.73±.163^a
Sex by agro-ecology		Ns	Ns	Ns	Ns	Ns
LL, male	30	1.69±.276	2.96±.106	7.24±.218	3.67±.102	39.29±.608
LL, female	90	1.43±.159	2.31±.061	6.59±.126	1.83±.059	36.98±.350
ML, male	50	2.35±.212	3.12±.080	8.20±.170	3.46±.079	41.25±.471
ML, female	150	1.43±.123	2.48±.048	7.03±.100	1.90±.046	37.68±.272
HL, male	50	1.78±.214	2.98±.082	7.37±.169	3.44±.081	37.72±.465
HL, female	150	1.37±.125	2.44±.044	6.48±.098	1.79±.043	35.63±.267

^{a,b,c}Means on the same column with different superscripts within the specified age group are significantly different ($p<0.05$), Ns: Non-significant, N: Number of chickens, ELL: Ear lobe length, SC: Shank circumference, SL: Shank length, WL: Wattle length, WS: Wing span, LL: Lowland, ML: Midland, HL: Highland, kg: Kilo gram, cm: centimetre

Table 3: Phenotypic correlation and their statistical significance among live body weight and morphometric traits in indigenous chicken

Traits	LW	BL	BC	WS	SL	SC	CL	WL	ELL	BkL
LW										
BL	0.771 < 0.0001									
BC	0.740 < 0.0001	0.620 < 0.0001								
WS	0.485 < 0.0001	0.482 < 0.0001	0.426 < 0.0001							
SL	0.611 < 0.0001	0.571 < 0.0001	0.546 < 0.0001	0.386 < 0.0001						
SC	0.409 < 0.0001	0.457 < 0.0001	0.297 < 0.0001	0.352 < 0.0001	0.521 < 0.0001					
CL	0.366 < 0.0001	0.392 < 0.0001	0.307 < 0.0001	0.361 < 0.0001	0.351 < 0.0001	0.433 < 0.0001				
WL	0.338 < 0.0001	0.370 < 0.0001	0.242 < 0.0001	0.313 < 0.0001	0.313 < 0.0001	0.399 < 0.0001	0.693 < 0.0001			
ELL	0.226 < 0.0001	0.203 < 0.0001	0.208 < 0.0001	0.245 < 0.0001	0.183 < 0.0001	0.270 < 0.0001	0.304 < 0.0001	0.315 < 0.0001		
BkL	0.150 < 0.0006	0.200 < 0.0001	0.091 < 0.0387	0.163 < 0.0002	0.120 < 0.0061	0.122 < 0.0053	0.216 < 0.0001	0.132 < 0.0025	0.072	0.0996

LW: Live weight, BL: Body length, BC: Breast circumference, WS: Wingspan, SL: Shank length, SC: Shank circumference, CL: Comb length, WL: Wattle length, ELL: Ear lobe length, BkL: Beak length

Table 4: Predictive equation and level of strength of linear body measurements using simple regression model

Variables	Equation	SE	R^2
BeL	Y = 0.850+0.127BeL	0.036	0.023
BoL	Y = -0.529+0.069BoL	0.002	0.599
BC	Y = -0.220+0.055BC	0.002	0.517
CL	Y = 0.952+0.079CL	0.009	0.134
ELL	Y = 1.11+0.022ELL	0.008	0.014
SC	Y = 0.668+0.185SC	0.018	0.167
SL	Y = 0.182+0.138SL	0.007	0.382
WL	Y = 0.901+0.108WL	0.013	0.115
WS	Y = -0.294+0.038WS	0.003	0.239

BeL: Beak length, BoL: Body length, BW: Body weight, BC: Breast circumference, CL: Comb length, ELL: Ear lobe length, SC: Shank circumference, SL: Shank length, WL: Wattle length, WS: Wingspan, SE: Standard error and R^2: Coefficients of determination

Table 5: Parameter estimation to develop multiple linear regression models for Ethiopian chickens using multiple linear regression procedure

Variables	Parameter estimate/Slope	SE	Level of significance
BeL	0.002	0.020	0.9066
BoL	0.039	0.003	<0.0001
BC	0.026	0.002	<0.0001
CL	-0.004	0.007	0.5879
ELL	0.004	0.005	0.4082
SC	-0.009	0.013	0.5109
SL	0.037	0.007	<0.0001
WL	0.013	0.011	0.2328
WS	0.006	0.002	0.0032

BeL: Beak length, BoL: Body length, BC: Chest circumference, CL: Comb length, ELL: Ear lobe length, SC: Shank circumference, SL: Shank length, WL: Wattle length, WS: Wingspan and SE: Standard error

strong, positive and significant correlations of live body weight with considerable traits can enable us in predicting the values of one trait based on the other trait.

Live weight had highly significant (<0.0001) positive correlation with body length (77.1%), breast circumference (74%) and shank length (61.1%) of indigenous chicken. This indicate that about 77, 74 and 61% of variation in body weight of indigenous chickens might be due to body length, breast circumference and shank length, respectively. Therefore, body length, breast circumference and shank length could be used to predicate the body weight of indigenous chicken.

Predicting body weight: Predictive equations relating to body weight and linear body measurements are shown in Table 4. Coefficients of determination (R^2) ranged from 0.014-0.599 for ELL (least) to BoL (highest). The highest R^2 values were observed for body length (0.599), breast circumference (0.517) and shank length (0.382) respectively. This indicates that 59.9, 51.7 and 38.2% of body weight difference in indigenous chicken of Ethiopia depends on body length, breast circumference and shank length, respectively.

Table 5 shows that body weight had significant ($p<0.05$) association with the linear body measurements, body length, chest circumference, shank length and wingspan. However, body weight had no significant ($p>0.05$) association with beak length, comb length, ear lobe length, shank circumference and wattle length. All the non-significantly associated linear body measurements were removed from the model. Therefore, multiple linear regression model relating body weight and linear body measurements of Ethiopian indigenous chicken is given below:

$$\hat{Y} = -0.949+0.039BoL+0.037SL+0.026BC+0.006WS$$

Where:

$\hat{Y}$: Estimated body weight
BoL : Body length
SL : Shank length
BC : Breast circumference
WS : Wingspan

DISCUSSION

For measurable traits, the current study is in line with the report of Tadelle *et al.*[1], Halima *et al.*[2], Aberra and Tegene[15] and Nigussie[16] who stated that male chickens had better performance than females for measurable traits. This indicates that, sex is the main cause of variation in measurable traits of indigenous chicken of Ethiopia.

Similarly a previous study conducted by Alabi *et al.*[17] showed high, positive and significant correlation of body weight with body length, breast circumference and shank length and suggested that improvement in live body weight of indigenous chicken would lead to improvement in linear body measurements in Nigeria and South Africa.

R^2 values obtained in this study were lower than the result of a previous study conducted by Ukwu *et al.*[8] (R^2 ranged from 0.659-0.802) in Nigerian indigenous chicken; however, higher than that of the Gwaza *et al.*[13] (R^2 ranged from 0.02-0.194) in French Broiler Guinea Fowl. This could be due to the breeds variation, environment and management alteration. In other words, linear measurements with highest R^2 imply that they could be the best predictors of body weight of indigenous chicken in Ethiopia.

Tadele[18] in Bench Maji reported that R^2 values ranged from 0.19-0.25 which is in between the R^2 values of the current study which ranged from 0.014-0.599 indicating that the calculated equations could be used to predict the live body weight of chicken. Predictive equations provide a readily available tool in body weight estimation. This is particularly true in rural areas where weighing scales are not available as reported by Alabi *et al.*[17] and Liyanage *et al.*[19].

CONCLUSION

The results of this study indicated that there were positive correlations between body weight and linear body parameters. It also reported that body weight could be predicted using linear body measurements. Body length, Shank length and Breast circumference had the highest slopes and prioritized to predict body weight of Ethiopian indigenous chicken compared to the other linear body measurements. Such a relationship could be taken in selection programs for genetic improvement of body weight gain in Ethiopian indigenous chicken. Thus, it is better to apply selection based on body length, shank length and breast circumference to design breeding program for genetic improvement of body weight in Ethiopian indigenous chicken.

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