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Morphometry of Ganjam goats of Odisha and age specific body weight prediction from linear body measurements

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Abstract
The present investigation was conducted to study the body weight and measurements of Ganjam goats, their inter-relationship and predictability of the body weight from body measurements at around birth, 3, 6, 9 and 12 months of age. Data on body weight (kg), body length (cm), wither height (cm) and chest girth (cm) of Ganjam goats of Odisha were recorded in 1249 goats with 607 males and 642 females during the period 2015 to 2017. The correlation coefficients of the body weight, body length, wither height and chest girth for all the age groups were found to be positive and moderate to high in magnitude and statistically significant (P<0.01). All the regression models developed with each of the three body measurements were found to be statistically highly significant (P<0.01) and the R^2 value ranged from 15 percent to 89 percent across age groups. Chest girth had higher correlation coefficient with the body weight as compared to other two body measurements in almost all the age groups and accounted for maximum variation in the body weight. The best-fitted regression equations were -7.48+0.07*BL+0.06*WH+0.16*CG for age group 1(0-2 month), the equation: -12.84+ 0.12*BL +0.32*CG for age group 2(3 month), the equation: -10.20 + 0.37 *CG for age group 3(6 month), the equation: -15.48+0.07*BL+0.10*WH+0.34*CG for age group 4 (9 month) and the equation: -13.95+0.27*BL +0.25*CG for age group 5 (12 month). It was concluded that the body length, wither height and chest girth at 0 to one year age in Ganjam goats can be used to predict live weight. Chest girth was the most important predictor of the live weight. The prediction equation developed can be used in the absence of weighing scale to predict the body weight with fair accuracy in the field condition.

Keywords: Ganjam goats, prediction, morphometry, regression equation, R-squares

1. Introduction
Small ruminants, especially goats play a significant role in the economy of farmers by producing meat, milk, manure, wool and other fibres. Goats are very much tolerant to hot climate and are capable of adapting to various agro-climatic conditions ranging from arid dry to cold arid to hot humid. The major component of the output from goat is meat that constituted 13.53 percent of the total annual meat production in the year 2017-18 in India (Anonymous, 2019) [1]. Body weight of the goat is one of the most important economic character that significantly determines the price of the goat. Accurate assessment of the body weight of goats is of utmost importance to farmers before the sale of the goats. In the absence of weighing scales, body measurements can be used to predict the body weight of goats as done by several workers (Sharma and Das [2], Thiruvenkadan [3], Seifemichael *et al.* [4], Barhe *et al.* [5] and Hopker *et al.* [6]).

India possess 26 recognised breeds of goats and Ganjam goat breed is one of the recognised breeds of Odisha. It is mainly distributed in the Ganjam, Gajapati and Nayagarh district of Odisha. Golla farmers mainly raise these goats in extensive system in a semi-nomadic way. The farmers do not provide any supplementary feed to the animals whether they are kept in the jungles or in the villages. The Golla farmers, four to five in numbers, pool their animals and move from place to place in search for browsing material. Here the flock size varies from 100 to 500. Sale of these goats mostly takes place in the browsing field and the price is estimated by visual evaluation of body weight from the overall body dimensions. Body weights at different ages in Ganjam goats have been reported by Rao *et al.* [7] and Karna *et al* [8]. but information available on the body measurements and their relationship with body weight is scanty. Therefore, the present investigation was undertaken to study the body weight and measurements of Ganjam goats, their inter-relationship, and predictability of the body weight from body measurements.

2. Materials and Methods

2.1 Location of Study and Flock Details

The study area comprised of four field centres namely: Chhatrapur, Rambha, Khallikote and Jirabadi of All India Coordinated Research Project on goat improvement in the Ganjam District of Odisha located at 19.35-19.92^{0}N and 84.98^0 -85.12^{0}E. Ganjam district is the home tract of the Ganjam breed of goat which is the most important recognised goat breed of Odisha. Out of the four clusters, three clusters Chhatrapur, Rambha and Khallikote belong to the 4th Agroclimatic zone i.e. east and the South Eastern coastal plane and experience relatively higher maximum and minimum temperature and lower rainfall as compared to the 4th cluster which remains in the 5th Agroclimatic zone of Odisha. The average maximum and minimum temperature experienced in these areas ranged from 37 ^{0}C to 39 ^{0}C and 10.8 ^{0}C to 11.5 ^{0}C respectively. The mean annual rainfall ranged from 1577mm to 1597mm.

2.2 Flock Details and Data Collection

The goats were entirely reared in range system by the poor and marginal farmers. The flock size of Ganjam goats ranged from 40 to 500. The goats are mostly reared in range system. The farmers move along with their flocks in search of browsing material in most part of the years. Data on body weight (kg), body length (cm), wither height (cm) and chest girth (cm) were recorded on 1249 Ganjam goats during the period 2015 to 2017. Out of the total goats recorded, males and females were 607 and 642, respectively. The goats were from birth to one year of age.

The body weights (BW) of goats were recorded in Kg by using an electronic weighing scale with precision upto 100g. The linear body measurements were recorded using a measuring tape with graduation in centimetre. The body length (BL) was measured from the point of pin bone to point of shoulder (Scapula). The wither height (WH) was measured as the distance from the ground level to the level of wither of the animal in standing position. The chest girth (CG) was measured by taking the measurement of circumference of the chest just behind the front leg.

2.3 Statistical Analysis of Data

The whole body of data on weight and measurements were divided into five age group class viz. Age group 1 to Age group 5. Age group 1 (Agrp 1) included goats from birth to 2 months of age, Age group 2 (Agrp 2) for goats of 3 months of age and Age group 3, 4 and 5 included goats of 6 months, 9 months and one year of age, respectively. The descriptive statistics and regression analysis were carried out using SAS software package (version 9.3 for Windows) [9] and graphics were produced using R software (version 4.0.0,) [10]. The regression analysis was done with a single predictor first, then taking two predictor variables and then taking all three measurements. The best fitted regression equation was selected using step-wise regression method taking all the three predictors i.e. body length (BL), wither height (WH) and chest girth (CG) to predict the body weight. The regression analysis was done for each age group separately. The Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE) were estimated for the best fitted regression equation for each age groups as described by Topal and Boulkbasi [11].

3. Results and Discussion

3.1 Body weights and body measurements

The detailed age group-wise descriptive statistics of body weight and measurements are presented in table 1. The distribution of body weights and the measurements are presented in chart.1. The mean body weight of Ganjam goats in the present investigation for all the five age groups are in agreement with the report made by Karna *et al.* [8] and a little higher in almost all the age groups. This may be because the selected superior males were provided to the farmers of area along with due health care and prophylaxis measures (Karna [12]). The mean body measurements viz. body length, wither height and chest girth reported here established that Ganjam is a goat breed of medium size, which has a higher body size than Black Bengal goats (Kumari *et al.* [13], Habib *et al.* [14], Jalil *et al.* [15]). The body weights for the age group 1 reported is higher than the birth weight reported for Ganjam kids at birth by Karna *et al.* [8] as the age group 1 included kids upto two months of age. It may be due to the improvement in the growth of the goats due to provision of superior bucks, health care and prophylactic measures taken on the flocks during the period (Karna [12]).

3.2 Relationship of Body Weight with Morphometry

The correlation matrix of the body weight, body length, wither height and chest girth for all the age groups are presented in the table 2. All the correlations were found to be positive and moderate to high in magnitude and statistically significant (P<0.01). The magnitude of correlation ranged from 0.86 to 0.92 for age group 1, 0.55 to 0.87 in age group 2, 0.39 to 0.72 for age group 3, 0.48 to 0.77 in age group 4 and 0.55 to 0.68 in age group 5. Chest girth had correlation coefficient of greater magnitude with the body weight as compared to other two body measurements in almost all the age groups. Positive correlations of similar magnitude among body weight and body measurements have been reported in Malabari goats (Alex *et al.* [16]), in Attapady Black goats (Raja *et al.* [17]), in Maefur goats (Berhe [5]) and in Kanni Adu goats (Thiruvankadan [3]). The moderate to high correlation of the body weight with body measurements indicated that reliable prediction of body weight is possible from body measurements.

3.3 Prediction Equations

3.3.1 Prediction Equations from Single Predictors

The prediction equations from single body measurement as predictor variables, the p-values, R square, Root Mean Squares Error (RMSE) or residual standard error are presented in table 3. All the models developed with each of the three body measurements were found to be statistically highly significant (P<0.01) and the R^2 value ranged from 15 percent to 89 percent across age groups. It indicated that all the three predictor variables had substantial predictive value. The regression equation of the chest girth on body weight for age group one had the highest coefficient of determination of 89 percent followed by the equation developed from wither height (82 percent) and the one developed from body length (81 percent). Chest girth accounted for maximum variation in the body weight as evident from the R^2 value obtained for age group 2, 3 and 4 whereas it was almost at par with body length for age group 5. The present finding is in agreement with the observations made by Topal *et al.* [18], Thiruvenkadan [3], Alex *et al.* [16], Raja *et al.* [17] and Habib *et al.* [14]. The chest girth seemed to have a greater influence on body weight as it is indicator of the body mass content in terms of bones, muscles, major internal organs as suggested by Thiruvenkadan [3], Mayaka *et al.* [19]. In addition to that chest

girth can be measured with greater accuracy than the other two body measurements.

3.3.2 Prediction Equations with Multiple Predictors

The prediction equations from two body measurement as predictor variables, the p-values, R square, Root Mean Squares Error (RMSE) or residual standard error are presented in table 4 and from all three predictors are presented in table 5. All possible combinations of predictor variables were used to get the regression equation for prediction. The best one is chosen after taking into account the adjusted R^2, Root mean square error or residual standard error or sigma, the p-value of the model fit. That is why a step-wise regression method executed by SAS software [9] resulted in selection of the best fitted regression equation for each of the age groups. The best-fitted equations were- 7.48+0.07*BL+0.06*WH+0.16*CG for age group 1, the equation: -12.84+ 0.12*BL +0.32*CG for age group 2, the equation: -10.20 + 0.37 *CG for age group 3, the equation: -15.48 + 0.07*BL + 0.10*WH+0.34*CG for age group 4 and the equation: -13.95+0.27*BL +0.25*CG for age group 5. These equations had adjusted R^2 value of 0.93, 0.80, 0.49, 0.63 and 0.61 for age group 1, 2, 3, 4 and 5 respectively. The best-fitted regression equation for age group 2 did not have wither height in it as it's coefficient became non-significant after addition in the model and it was eliminated. Similarly the wither height and body length got could not be included for the equation at age group 3 because they became non-significant once included in the model (P>0.15). For the equation for the age group 5, wither height was not included as its coefficient was not significant (P>0.15). The mean absolute error (MAE) calculated using the best-fitted equation for body weights were calculated to be 0.37±0.02, 0.79±0.14, 1.13±0.05, 1.35±0.06 and 1.60±0.09 kg for age group 1 to 5 respectively. The mean absolute percentage error (MAPE) using the best fitted regression equations were 9.91±0.72, 9.65±0.54, 11.59 ±0.57, 9.92 ±0.48 and 8.99±0.56 for age group 1 to 5 respectively.

The chest girth was the principal predictor variables among the three linear body measurements. However, the other two variables did account for significant amount of the variation in the body weight justifying their inclusion in the final model in age group 1, 2, 4 and 5. The present findings are in agreement with the earlier reports made by Thiruvenkadan [3], Raja *et al.* [17], Berhe [5] and Habib *et al.* [14].

4. Conclusion

The correlation coefficients of live weight with the body length, wither height and chest girth at 0 to one year age in Ganjam goats were highly significant (P<0.01) and moderate to high in magnitude. Chest girth is the most important predictor of the live weight. However, the other two measurements can be used in combination with the chest girth to predict the body weight more accurately. The prediction equation developed can be used in the absence of weighing scale to predict the body weight with fair accuracy in the field condition.

Table 1: Basic statistics of body weight (BW) in kg, body length (BL) in cm, wither height (WH) in cm and chest girth (CG) in cm for Age group 1 to 5.

Traits	Parameters	Age groups				
		1	2	3	4	5
BW	Mean	4.57	8.77	10.17	14.25	18.75
	Std Dev	1.86	2.27	1.99	3.01	3.38
	N	175	231	277	349	217
BL	Mean	36.98	46.30	52.44	53.79	59.75
	N	175	231	277	349	217
WH	Std Dev	6.66	5.77	4.30	5.93	6.00
	Mean	41.11	47.89	55.70	58.31	62.78
	N	175	231	277	349	217
CG	Mean	38.94	48.69	55.08	57.80	63.61
	Std Dev	5.94	5.17	3.75	4.78	5.32
	N	175	231	277	349	217

NB: 1=Age group 0-2 month, 2=Age group 3 month, 3=Age group 6 month, 4= Age group 9 month, 5=Age group 12 month

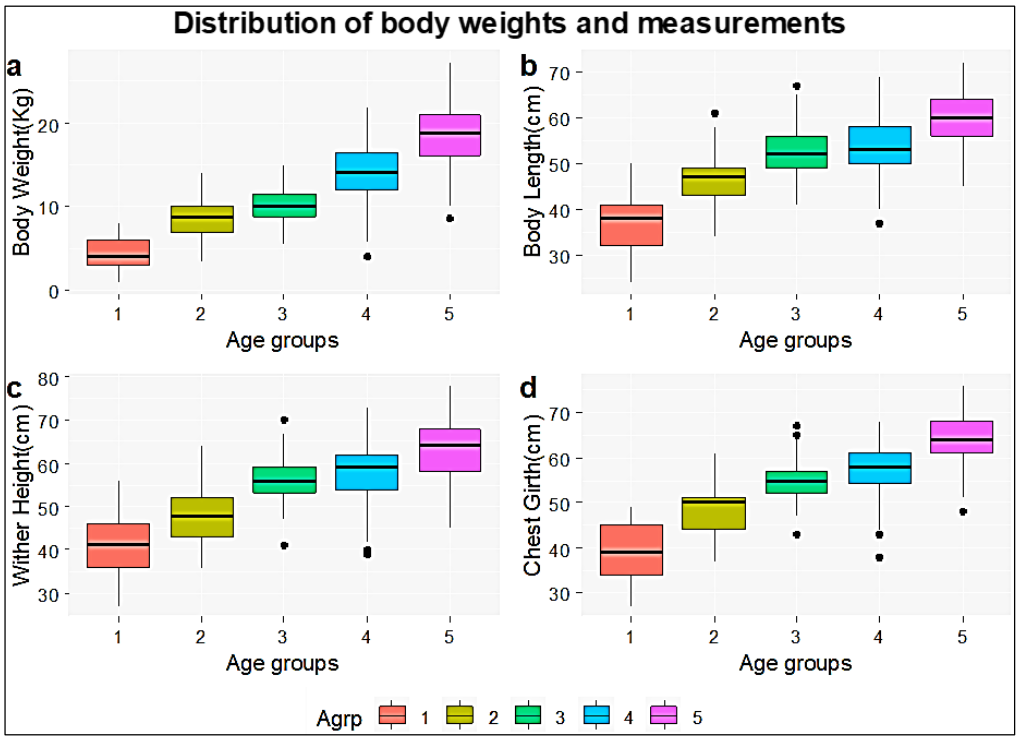

Chart 1: Distribution of weights and measurements

Table 2: Age-group-wise Correlation coefficients matrix of Body Weight and Measurements at age groups 1 to 5.

Age Groups/traits	Body Weight(BW)	Body Length(BL)	Wither Height(WH)	Chest Girth(CG)
1. BW	1.00	0.90	0.88	0.92
BL	0.90	1.00	0.88	0.86
WH	0.88	0.88	1.00	0.87
CG	0.92	0.86	0.87	1.00
2. BW	1.00	0.66	0.56	0.87
BL	0.66	1.00	0.58	0.55
WH	0.56	0.58	1.00	0.58
CG	0.87	0.55	0.58	1.00
3. BW	1.00	0.39	0.50	0.72
BL	0.39	1.00	0.53	0.49
WH	0.50	0.53	1.00	0.67
CG	0.72	0.49	0.67	1.00
4. BW	1.00	0.53	0.66	0.73
BL	0.53	1.00	0.62	0.48
WH	0.66	0.62	1.00	0.77
CG	0.73	0.48	0.77	1.00
5. BW	1.00	0.68	0.55	0.66
BL	0.68	1.00	0.68	0.60
WH	0.55	0.68	1.00	0.60
CG	0.66	0.60	0.60	1.00

NB: All the correlations were significant at 1% (P<0.01)

Table 3: Prediction equation of Body weight from each of the body measurements for different age groups (1 to 5) and statistical parameters for fitted regressions

Age group	N	Regression equation	p-value	R^2	Sigma (RMSE)
1	175	-6.17 + 0.29 * BL	<0.001	0.81	0.81
		-5.85 + 0.25*WH	<0.001	0.82	0.78
		-6.92+0.29 *CG	<0.001	0.89	0.62
2	231	-6.66+ 0.33* BL	<0.001	0.42	1.73
		-1.66+ 0.22*WH	<0.001	0.31	1.89
		-9.91+0.38*CG	<0.001	0.76	1.11
3	277	0.72 + 0.18* BL	<0.001	0.15	1.84
		-2.64+ 0.23*WH	<0.001	0.25	1.73
		-10.20 + 0.37 +CG	<0.001	0.49	1.43
4	349	-0.86 + 0.28 * BL	<0.001	0.30	2.52
		-6.44+0.35*WH	<0.001	0.49	2.15
		-13.57 + 0.48 *CG	<0.001	0.59	1.94
5	217	-6.14 + 0.42 *BL	<0.001	0.51	2.36
		-1.73 + 0.33*WH	<0.001	0.34	2.76
		-8.91+ 0.43*CG	<0.001	0.47	2.46

Table 4: Prediction equation of Body weight from taking two predictors (body measurements) for different age groups.

Age Group	N	Regression Equation	p-value	Adj.R^2	Sigma (RMSE)
1	175	-.6.69 + 0.15*BL + 0.14* WH	<0.001	0.87	0.67
		-7.25 + 0.1*WH + 0.2*CG	<0.001	0.92	0.52
		-7.44 + 0.11*BL + 0.2 *CG	<0.001	0.92	0.52
2	231	-8.02 + 0.25* BL + 0.1 *WH	<0.001	0.47	1.66
		-10.39 + 0.03*WH + 0.36*CG	<0.001	0.77	1.10
		-12.85 + 0.13 *BL + 0.32*CG	<0.001	0.80	1.00
3	277	-4.45 + 0.08*BL + 0.19*WH	<0.001	0.26	1.71
		-10.43 + 0.02*WH + 0.36*CG	<0.001	0.48	1.43
		-10.79 + 0.03*BL + 0.35*CG	<0.001	0.48	1.43
4	349	-7.92 + 0.09 *BL + 0.3 * WH	<0.001	0.50	2.12
		-14.35 + 0.15*WH + 0.34*CG	<0.001	0.62	1.85
		-15.63 + 0.11*BL + 0.41*CG	<0.001	0.62	1.85
5	217	-8.21 + 0.35 *BL + 0.1 *WH	<0.001	0.53	2.32
		-11.89+ 0.15*WH + 0.33*CG	<0.001	0.51	2.36
		-13.95 + 0.28*BL + 0.25*CG	<0.001	0.62	1.85

Table 5: Prediction equation of Body weight from taking all predictors (body measurements) for different age groups.

Age Group	N	Regression equation	p-value	Adj.R^2	Sigma (RMSE)
1	175	-7.48+0.07*BL+0.06*WH+0.16*CG	<0.001	0.93	0.48
2	231	-12.79 + 0.13*BL - 0.01*WH +0.33*CG	<0.001	0.80	1.01
3	277	-10.85 +0.03*BL +0.01*WH + 0.35*CG	<0.001	0.48	1.43
4	349	-15.48+0.07*BL+0.10*WH+0.34*CG	<0.001	0.63	1.81
5	217	-14.18 + 0.27*BL+ 0.02*WH + 0.25*CG	<0.001	0.61	2.10

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