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Preliminary Study on Prediction of Body Weight from Morphometric Measurements of Goats through ANN Models

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SUMMARY

The Artificial Neural Network (ANN) models were developed for prediction of body weight using different linear body measurements in Attappady Black goats of Kerala, India. Data on body weight and body measurements recorded on 919 female goats from its breeding tract were used for the study. The whole data was classified into four age groups viz., 0-3, 3-6, 6-12, and above 12 months. From the whole data sets of different age groups 75 per cent were used to train the neural network model and remaining 25 per cent were used to test the model. Three different morphometric measurements viz., chest girth, body length and height at withers were used as input variables and body weight was considered as output variable. The network architecture used was a multilayer feed forward network with back propagation of error learning mechanism. The accuracy of prediction of body weight from ANNs analysis was higher when compared to MRA indicating that the ANN models were able to describe more variation in live weight. Maximum prediction accuracy (77.19%) and minimum SD ratio (0.4838) was noticed for 0-3 months age groups and the RMSE was maximum for >12 months age groups (2.7255). The phenotypic correlations between actual and predicted body weights were positive, and highly significant ($P < 0.01$) at all the age groups. The predicted body weights were perfectly acceptable when compared to the actual body weights. It was concluded that artificial neural network (ANN) models could be used as an alternative to traditional MRA for estimating the live weight using linear body measurements.

Keywords: Artificial neural networks, Attappady Black goat, Body measurements, Body weight prediction, Multiple regression analysis.

1. INTRODUCTION

The Attappady Black goat, a native goat breed of Kerala is mainly reared by the tribes of the Attappady hills in Palakkad district. These goats are known for their valuable meat and skin. Being a meat animal, the genetic improvement of the breed is aimed at increasing the meat production through scientific selection and planned breeding. For this purpose the knowledge on body weight is of prime importance to assess the production potential of these goats. Under rural conditions, it is very difficult to measure the live body weight accurately due to the lack of portable weighing balance and skilled technicians. This is especially true to the tribal goat farmers of Attappady hill region. Traditionally under these conditions the weight of the animal is predicted by regressing it on various body measurements, which can be measured readily. The multiple regression analysis is generally used for predicting the body weight from linear body measurements (Alade *et al*. 2010; Muhammad and Amin 1996; Thiruvenkadan 2005).

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This traditional regression method does not consider the muticolinearity among the independent variables and may lead to biased results. Multicollinearity occurs when variables are so highly correlated with each other that it is difficult to come up with reliable estimates of their individual regression coefficients. When two variables are highly correlated, they are basically measuring the same phenomenon or construct. In other words, when two variables are highly correlated, they both convey essentially the same information and can adversely affect the results of multiple regressions. Ramzan and Khan (2010) and Eyduran *et al*. (2010) also reported the problems relating to multicolinearity in multiple regression analysis.

However, in comparison with the regression methods the artificial neural networks (ANNs) represent a different approach. These solve particular problems through learning, by typical inputs and respective desired responses, unlike conventional methods that consist of the construction of an algorithm and its implementation as a computer program (Tadeusiewicz 1993). The ANNs are interconnected networks of artificial neurons that acquire knowledge by processing information in a manner analogous to the human brain and can be applied to non-linear and complex data, even if the data are imprecise and noisy. Even though, the ANNs have seen an explosion of interest over the last few years in diverse areas like finance, medicine, geology, engineering, physics and biology, their application in animal sciences and especially in small ruminant research is scanty (Grzesiak *et al*. 2003; Sharma *et al*. 2006; Gandhi *et al*. 2009). Prediction of body weight seems to be a complex problem as discussed above therefore it was decided to use ANN tools to measure its effectiveness over MRA techniques. Moreover so far no research work has been reported on ANN prediction of body weights using linear body measurements in goats. Hence, the present investigation was undertaken to apply the ANN models for prediction of body weight on the basis of morphometric measurements in Attappady Black goats.

2. MATERIALS AND METHODS

2.1 Data Generation

The data on 919 female Attappady Black goats were collected from the Attappady region, which is the home tract of the breed and detailed description of the breed may be seen in Stephen *et al*. (2005). The data were divided in to four different groups viz., 0-3, >3-6, > 6-12, and above 12 months according to the age of the goats. The body weight and body measurements viz., chest girth, body length and height at withers were measured as per Herrera *et al*. (1996).

2.2 Artificial Neural Network (ANN)

A multilayer feed forward network with back propagation of error learning mechanism is the most commonly used neural network architecture and have shown excellent results in dealing with functional approximation problems. In back-propagation technique, input vector and the corresponding target vectors are used to train a network until it can approximate a prediction function. A properly trained network is likely to give reasonable output when presented with new inputs. Schematic diagram of multilayer feed forward network with one hidden layers is shown in Fig. 1.

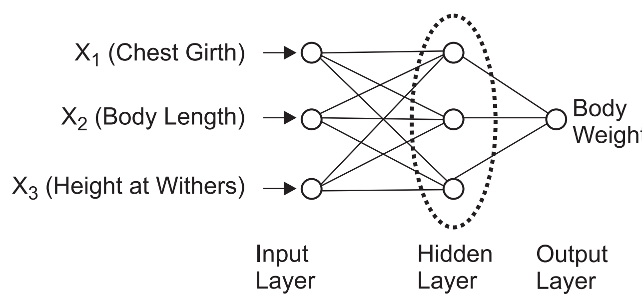

Fig. 1. Neuron connections in a systematic ANN.

In the present study, a multilayer feed forward neural network with back propagation of error learning mechanism was developed using Neural Network Toolbox (NNT) of MATLAB 7.0 (2006) to predict the body weight. The network had 3 nodes at input layer and one node at output layer for producing the network response. The input and output layer of the network included the variables as follows:

Input Parameters:

- CG – Chest Girth
- BL – Body Length
- HAW – Height at Withers

Output Parameters:

- BW – Body Weight

The whole data set was seperated at random into two subsets viz., the training set consisting of 75 per cent and testing subset comprising of 25 per cent. The training sets were used to train the neural network models and the testing sets were used to validate the models.

The network was tested with 1 and 2 hidden layers with 3 to 25 neurons in each hidden layer. Initial weights and bias matrix was randomly initialized between –1 to 1. A non-linear transformation (or activation) function *tangent sigmoid* (eq. 1) was used to compute the output from summation of weighted inputs of neurons in each hidden layer. A *pure linear* transformation function was used at output layer for getting network response.

$$f(x) = \frac{1}{1+e^{-\alpha x}} \quad (1)$$

where, x is weighted sum of inputs and α is a constant.

The designed network was trained in supervisory mode with Bayesian regularization back propagation algorithm available in ANN tool box of MATLAB 7.0 (2006) to evaluate the performance of ANN models. This algorithm has the ability to adjust the network parameters like learning rate, performance goal etc. automatically as per the situation to avoid the problem of over prediction. Therefore this algorithm was selected for ANN model.

The network was trained using above mentioned learning algorithms for up to 2000 epochs or till the algorithms truly converged. The input and target data was preprocessed so that the mean is 0 and the standard deviation is 1 using the feature *prestd* available in NNT as per the requirement of algorithms. The parameters like learning rate, performance/error goal, learning rate increment etc. were used at the default setting of the algorithms in the MATLAB. Most of the time it was observed that algorithms were truly converged which means that performance/error goal was achieved. The network was trained with training data set for a number of times to get consistent results. The prediction performance was tested using a new data set (test data).

2.3 Multiple Regression Analysis (MRA)

To compare the effectiveness of the ANNs for prediction of body weight; the MRA models at different age groups were developed using the three body measurements viz., chest girth, body length and height at withers as input variables to predict the body weight. The same training data sets were used to develop the regression equations and the effectiveness of predictions from MRA models was tested using test data sets.

2.4 Statistical Analysis

Pearson's correlation coefficients were estimated between body weight and body measurements. The performance of both ANN model and the MRA model were compared using various criteria viz., coefficient of determination (R^2), residual mean square error (RMSE) and SD ratio as given by Grzesiak *et al.* (2003). The actual and predicted body weights were compared by using paired '*t*' test.

$$R^2 \text{ value} = \frac{\text{Total sum of squares} - \text{Error sum of squares}}{\text{Total sum of squares}} \times 100 \quad (2)$$

$$\text{RMSE} = \sqrt{\frac{1}{N}\left[\sum_{1}^{N}\left(Q_{\exp} - Q_{cal}\right)^2\right]} \quad (3)$$

where, Q_{exp} = Observed value,
Q_{cal} = Predicted value
N = Number of observations

$$\text{SD ratio} = \sqrt{\frac{\sum (E_i - \bar{E})^2}{\sum (Y_i - \bar{Y})^2}} \quad (4)$$

where, E_i is the individual error of a data set
$\bar{E}$ is the mean error of data set
Y_i are actual values
$\bar{Y}$ is the mean actual value

3. RESULTS

3.1 Body Measurements and Body Weights

Table 1 summarises the average linear body measurements and weights obtained for goats of different age groups. Among the different body measurements, the height at withers was highest followed by the chest girth and body length. This trend was noticed till six months of age and in goats above

Table 1. Mean (± SE) body measurements and weight of Attappady Black goats

Age group	No. of Animals	Chest Girth (cm)	Body length (cm)	Height at withers (cm)	Body weight (Kg)
0-3 Months	93	40.47 ± 0.60	37.66 ± 0.62	41.76 ± 0.73	5.28 ± 0.25
3-6 Months	134	49.47 ± 0.42	46.46 ± 0.41	50.62 ± 0.43	9.82 ± 0.26
6-12 Months	227	57.80 ± 0.32	53.54 ± 0.34	57.72 ± 0.32	14.61 ± 0.23
> 12 Months	465	67.29 ± 0.28	61.33 ± 0.27	65.49 ± 0.24	23.05 ± 0.28

six months the chest girth was maximum followed by height at withers and body length.

The phenotypic correlations of body measurements with body weight were positive, and highly significant ($P < 0.01$). Among the three body measurements chest girth had maximum correlation with body weight (Table 2). Mukherjee *et al*. (1986) and Singh *et al*. (1987) also reported the highest and significant correlation value of chest girth with bodyweight in Brown Bengal does and Grey Bengal goats, respectively.

Table 2. Phenotypic correlations between body weight and body measurements in Attappady Black goats

Age	No. of observa-tions	Chest girth	Body length	Height at withers
0-3 Months	93	0.882**	0.872**	0.849**
3-6 Months	134	0.718**	0.695**	0.779**
6-12 Months	227	0.707**	0.509**	0.538**
> 12 Months	465	0.798**	0.593**	0.652**

** Highly significant ($P < 0.01$)

3.2 Artificial Neural Network (ANN)

The neural networks developed were trained using the training data sets to predict the body weight at different age groups and a maximum goal of 99% accuracy was set to be achieved in 2000 epochs (cycles). Several combinations of hidden layers (1-2 layers) with varying number of neurons (3-25 neurons) were experimented to train the networks. The optimum network parameters for different age groups are presented in Table 3.

In 0-3 months age group the best results were obtained with the combination of 2 hidden layers with 15 and 5 in neurons in each hidden layer in 168 epochs. This model gave the maximum R^2-value of prediction (86.75%) when the network was trained and then simulated with test data set it gave an accuracy of 77.19%. The various criteria for judging the effectiveness of prediction are given in Table 4.

Table 3. Optimum network parameters for different age groups

Age groups	No. of hidden layers	No. of neurons in each hidden layer		Number of epochs	Data portioning strategy (% of data)	
		Layer1	Layer2		Training	Testing
0-3 Months	2	15	5	658	75	25
3-6 Months	2	10	5	335	75	25
6-12 Months	2	10	15	568	75	25
> 12 Months	2	9	4	431	75	25

Table 4. Various criteria of judging the effectiveness of MRA and ANN analyses

0-3 Months (93)				
	Training data set		Test data set	
	MRA	ANN	MRA	ANN
No. of observations	69	69	24	24
R^2- value	82.60	86.75	70.22	77.19
RMSE	0.9330	0.8142	1.3666	1.1960
SD Ratio	0.4172	0.4055	0.5437	0.4838
Pearson's correlation coefficient	0.9088**	0.9314**	0.8542**	0.8791**
3-6 Months (134)				
	Training data set		Test data set	
	MRA	ANN	MRA	ANN
No. of observations	100	100	34	34
R^2- value	67.70	73.77	55.95	63.16
RMSE	1.7189	1.5490	1.9859	1.8161
SD Ratio	0.5683	0.5121	0.6635	0.6069
Pearson's correlation coefficient	0.8228**	0.8590**	0.7482**	0.7958**
6-12 Months (227)				
	Training data set		Test data set	
	MRA	ANN	MRA	ANN
No. of observations	170	170	57	57
R^2- value	52.64	57.52	50.51	57.12
RMSE	2.2627	2.1429	2.4424	2.2735
SD Ratio	0.6882	0.6517	0.7013	0.6519
Pearson's correlation coefficient	0.7256**	0.7586**	0.7148**	0.7588**
>12 Months (465)				
	Training data set		Test data set	
	MRA	ANN	MRA	ANN
No. of observations	349	349	116	116
R^2- value	63.49	67.35	72.59	75.48
RMSE	3.2840	3.1054	2.8817	2.7255
SD Ratio	0.6043	0.5714	0.5233	0.4940
Pearson's correlation coefficient	0.7968**	0.8207**	0.8545**	0.8725**

** Highly significant (P<0.01)

3.3 Multiple Regression Analysis

To compare the effectiveness of ANN prediction, MRA was done with the training sets of different age groups and separate equations for predicting body weight (BW) were developed based on chest girth (CG), body length (BL) and height at withers (HAW) and the equations are given below:

Age group	Equation	R^2 value (%)
0-3 months	BW = –10.5421 + 0.3425CG + 0.0784BL – 0.0230HAW	82.60
3-6 months	BW = –17.6877 + 0.139CG +0.0320BL + 0.3777HAW	67.70
6-12 months	BW = –16.7359 + 0.4249CG +0.427BL + 0.0772HAW	52.64
>12 months	BW = –32.1347 + 0.5957CG +0.1558BL + 0.0842HAW	63.49

4. DISCUSSION

The prediction accuracy of ANN models developed was validated using the test data sets and varied for different age groups. The accuracy was maximum for 0-3 months (77.19%) and was minimum in 6-12 months (57.12%). The prediction accuracy showed a declining trend till this age group and increased for >12 months group. The same trend was noticed for SD ratio as well as the Pearson's correlation coefficient also. Where as the RMSE value was minimum in 0-3 months age group and showed an increasing trend till and was maximum for >12 months age group (Fig. 3).

In MRA the accuracy of prediction of body weight was maximum (82.60%) in 0-3 months and was lowest in 6-12 months age group (Table 4) and almost similar range of estimates were reported by Mayaka et al. (1995) and Thiruvenkadan (2005). In >12 months age group the root mean square errors (RMSE) from the training data set was higher as compared to the test data set revealing that fitting the above multiple regression equation to the test data set were more effective. Similarly, the SD ratio was also higher from the training data set than that from the test data set.

In all the age groups, the ANN models gave higher R^2-values and lower RMS and SD ratios indicating that the ANN model prediction were able to describe more variation in live weight in comparison to MRA models (Table 4). Moreover the estimates of correlation between predicted body weight from ANNs and MRA models with the actual body weight were higher and highly significant ($P < 0.01$). The regressions of ANN predicted body weights on the actual body weights measured at different age groups are presented in Fig. 2.

The comparison of means by paired '*t*' test revealed non-significant difference between the actual and predicted body weights (Table 5). In general it was observed that the predicted body weight from ANN models gave the lower standard deviation and CV (%) indicating that fitting of this model smoothened the predicted values to the maximum extent in comparison to MLR model. Moreover the RMS error values were minimum in 0-3 months age group and had maximum values in above 12 months age groups and showed the

Table 5. Actual and predicted body weight (kg) in test data sets

	N	Mean	SD	CV %
0-3 Months				
Actual weight	24	5.40 [a]	2.56	52.21
ANN	24	5.43 [a]	2.32	47.31
MRA	24	5.51 [a]	2.59	52.89
3-6 Months				
Actual weight	34	9.56 [a]	3.04	52.09
ANN	34	9.58 [a]	2.29	39.30
MRA	34	9.61 [a]	2.30	39.44
6-12 Months				
Actual weight	57	14.74 [a]	3.50	46.39
ANN	57	14.52 [a]	2.56	33.92
MRA	57	14.54 [a]	2.69	35.58
>12 Months				
Actual weight	116	23.04 [a]	5.53	51.32
ANN	116	22.85 [a]	4.42	41.07
MRA	116	22.94 [a]	4.37	40.60

[a] Means bearing same superscript at same age group did not differ significantly.

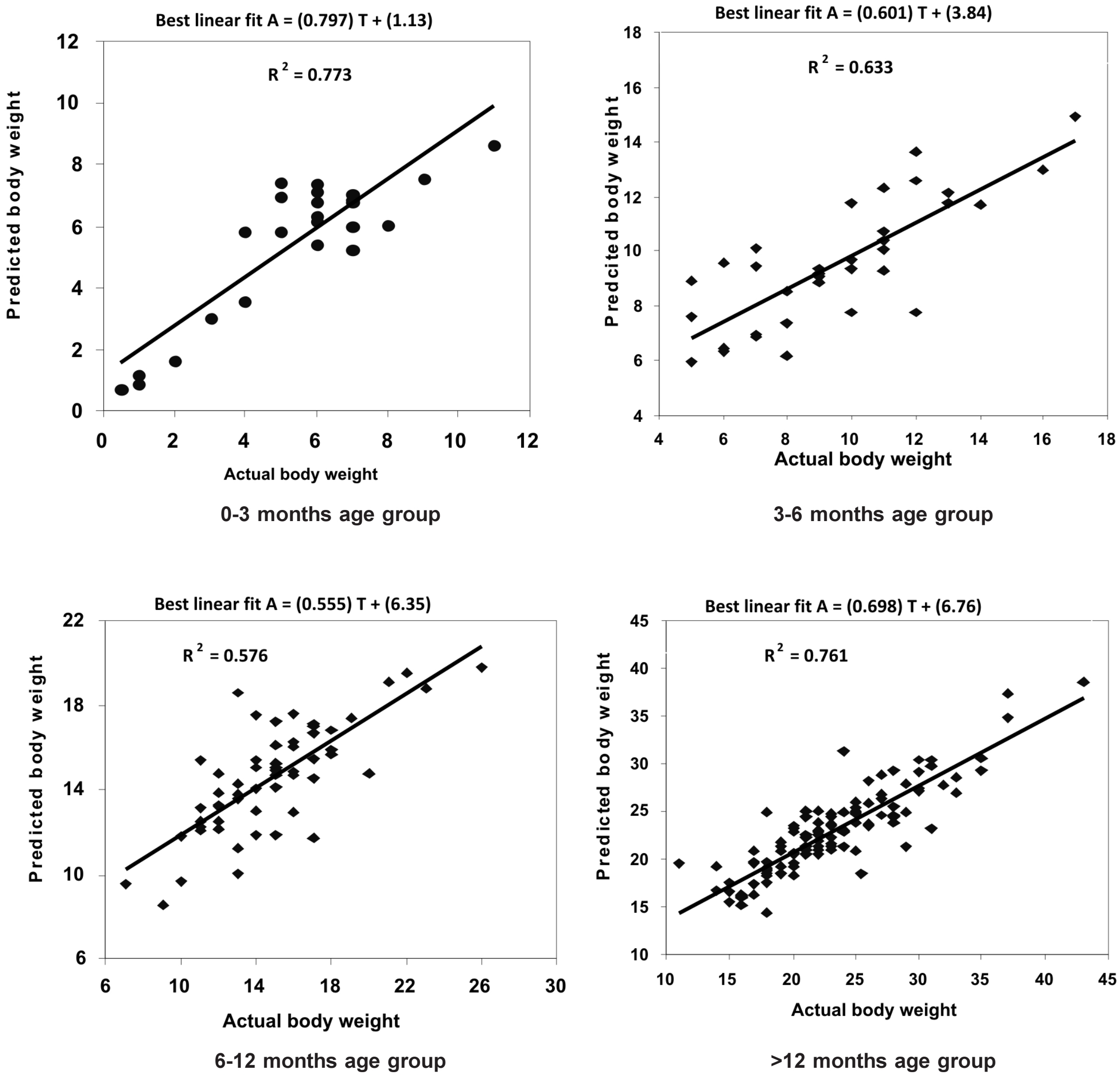

Fig. 2. Regressions of ANN predicted on the actual body weights in different age groups
A = Predicted body weight T = Observed body weight

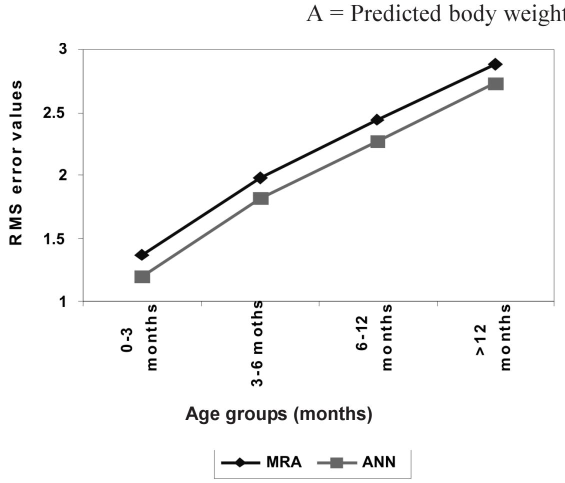

Fig. 3. Prediction efficiency of ANN and MRA models on different age groups of goats

increasing trend of RMS error values as the age advanced, suggests that wide range of variation in the values as the age increased (Fig. 3).

The model which gave maximum R^2 value with smallest RMS and SD ratio was considered to be better for prediction and the results obtained in the present study revealed that in all the age groups, the ANN model gave more accurate prediction of body weight than MRA models.

5. CONCLUSION

In the present study it was found that the accuracy of prediction of body weight from ANNs analysis was higher with lower estimates of root mean square errors and SD ratio in comparison to MRA. The results showed that the predicted body weights by both ANN and MRA models are perfectly acceptable when compared to the actual body weights. However, the ANN models were comparatively more efficient to predict the body weight using body measurements in Attappady Black goats. Hence it was concluded that artificial neural network (ANN) models could be used as an alternative to traditional methods for estimating the live weight using linear body measurements.

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