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Full Length Research Paper

Determination of best-fitted regression model for prediction of body weight in attappady black goats

T.V. Raja[1], R. T. Venkatachalapathy[2], A. Kannan[3] and K.A. Bindu[3]

[1]Assistant Professor and Corresponding Author; [2]Associate Professor, University Sheep and Goat Farm, Mannuthy; [3]Associate Professor, COVAS, Pookode, India.
[1,2,3]College of Veterinary and Animal Sciences, Kerala Veterinary and Animal Sciences University, Pookode- 673 576, Kerala, India.

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The present investigation was undertaken to determine the best-fitted regression model for the prediction of body weight using different linear body measurements of Attappady Black goats in Kerala, India. Data on body weight and body measurements recorded on 1412 Attappady Black goats consisting of 493 males and 919 females from its breeding tract were used for the study. The whole data was classified into five age groups *viz.,* 0-3, >3-6, >6-12, >12 and 0-12 months. The simple and multiple regression models were fitted with body weight as dependant variable and chest girth, body length and height at withers as independent variables. The correlation coefficients between body weights and body measurements at different ages were positive and strongly correlated (P<0.01) ranging from 0.509 to 0.915. The chest girth alone accounted for a maximum of 79.4 and 77.9 per cent of the total variation in body weight in males and females, respectively, signifying its importance for the prediction of body weight. Highest coefficient of determination (R^2- value) was obtained in the models when all the body measurements were included. These models also showed smaller RMSE and standard deviation ratio (SDR) thereby registering a better goodness of fit.

Key words: Body weight, correlation, prediction, regression models, Attappady Black goats.

INTRODUCTION

The Attappady Black goats, a native goat breed of Kerala state in India, are mainly known for their valuable meat and skin. They are found in Attappady, an isolated hilly region in the Palakkad district of Kerala and are exclusively reared by the tribes of this region. These goats are maintained entirely on an extensive grazing/browsing system. It is necessary to develop a formula for accurately estimating body weight from body measurements for using in the field conditions since weighing of animals using a balance is not practicable. Formula for predicting body weights from different body measurements have been developed by several authors in many breeds of Indian goats (Prasad et al., 1990; Ulaganathan et al., 1992; Singh and Mishra, 2004).
Different models might be needed to predict body weight in different environmental conditions and breeds (Enevoldsen and Kristensen, 1997). Hence, this study was undertaken to determine the best-fitted regression model for prediction of live weight of Attappady Black goats under field conditions and also to identify the criteria to be applied to investigate fitting state of simple and multiple models to actual data for estimation of body weight.

MATERIALS AND METHODOLOGY

The study was conducted in Attappady region of Kerala state in India, which is the home tract of the Attappady Black goat breed and the detailed description of the breed may be seen in Stephen et al. (2005). Data on 1412 goats, consisting of 493 males and 919 females were collected. The body weight and body measurements viz., chest girth, body length and height at withers were recorded as per Herrera et al. (1996).
Within each group, weight was regressed on body measure

*Corresponding author. E-mail:venkatesanraja09@gmail.com

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

Age group	Sex	No. of Animals	Chest Girth (cm)	Body length (cm)	Height at withers (cm)	Body weight (Kg)
0-3 Month	Male	102	40.06 ± 0.57[a]	36.91 ± 0.59[a]	40.74 ± 0.70[a]	4.80 ± 0.24[a]
	Female	93	40.47 ± 0.60[a]	37.66 ± 0.62[a]	41.76 ± 0.73[a]	5.28 ± 0.25[a]
> 3-6 Month	Male	120	49.99 ± 0.44[a]	46.38 ± 0.43[a]	51.05 ± 0.46[a]	10.14 ± 0.28[a]
	Female	134	49.47 ± 0.42[a]	46.46 ± 0.41[b]	50.62 ± 0.43[a]	9.82 ± 0.26[a]
> 6-12 Month	Male	148	58.21 ± 0.39[a]	53.84 ± 0.42[a]	58.34 ± 0.39[a]	15.68 ± 0.29[a]
	Female	227	57.80 ± 0.32[a]	53.54 ± 0.34[a]	57.72 ± 0.32[a]	14.61 ± 0.23[b]
> 12 Month	Male	123	69.54 ± 0.54[a]	63.84 ± 0.53[a]	68.81 ± 0.47[a]	26.17 ± 0.54[a]
	Female	465	67.29 ± 0.28[b]	61.33 ± 0.27[b]	65.49 ± 0.24[b]	23.05 ± 0.28[b]

Means bearing same superscript don not differ significantly between sexes

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

Age	Sex	No. of observations	Chest girth	Body length	Height at withers
0-3 months	Male	102	0.891**	0.871**	0.874**
	Female	93	0.882**	0.872**	0.849**
>3-6 months	Male	120	0.806**	0.660**	0.663**
	Female	134	0.718**	0.695**	0.779**
>6-12 months	Male	148	0.676**	0.611**	0.670**
	Female	227	0.707**	0.509**	0.538**
Above 12 months	Male	123	0.821**	0.752**	0.700**
	Female	465	0.798**	0.593**	0.652**
0-12 months	Male	370	0.915**	0.881**	0.880**
	Female	454	0.894**	0.841**	0.851**

** Highly significant (P<0.01)

Within each group, weight was regressed on body measurements by stepwise regression analysis as described by Sharaby and Suleiman (1987), to determine the combination of body dimensions for each sex that explains variation in the dependent variable. Separate prediction equations were developed for male and female goats. Pearson's correlation coefficients were estimated between body weight and all body measurements. For evaluating and comparing different regressions models to determine the best-fitted equation the criteria viz., coefficient of determination (R^2), residual mean square error (RMSE) and SDR were used.

RESULTS AND DISCUSSION

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 the highest followed by the chest girth and body length. This trend was noticed till 12 months of age and in goats above 12 months the chest girth was maximum followed by height at withers and body length. Generally males had higher values than females except for the group 0-3 months. This male advantage was more conspicuous and statistically highly significant at above 12 months of age (P<0.01). Raghavan and Raja (2004) have reported the overall average body length, height at withers and chest girth of Malabari goats of one year of age reared by the farmers as 61, 60, and 69cm, respectively. The comparison of the measurements of these two Keralan breeds shows that Attappady Black is taller than the Malabari breed.

Correlation coefficient

The correlation coefficients between body weight and body

Table 3. Prediction equations and coefficient of determination (R^2) at different age groups in Attappady Black goats.

Age group	Male	R^2 value	Female	R^2 value
0-3 months	$Y = -9.70 + 0.1804 X_1 + 0.0793 X_2 - 0.1067 X_3$	0.833	$Y = -9.40 + 0.2212 X_1 + 0.1540 X_2 - 0.0017 X_3$	0.798
	$Y = -9.95 + 0.2368 X_1 + 0.1426 X_2$	0.816	$Y = -9.39 + 0.2199 X_1 + 0.1533 X_2$	0.798
	$Y = -10.03 + 0.3702 X_1$	0.794	$Y = -9.60 + 0.3675 X_1$	0.779
	$Y = -8.43 + 0.1805 X_2 + 0.1612 X_3$	0.805	$Y = -8.03 + 0.2406 X_2 + 0.1017 X_3$	0.774
	$Y = -8.16 + 0.3511 X_2$	0.759	$Y = -7.93 + 0.3507 X_2$	0.761
	$Y = -7.29 + 0.2967 X_3$	0.764	$Y = -6.88 + 0.2911 X_3$	0.721
> 3-6 months	$Y = -9.67 + 0.2252 X_1 + 0.1338 X_3$	0.827	$Y = -9.35 + 0.3071 X_1 + 0.0528 X_3$	0.781
	$Y = -17.85 + 0.4779 X_1 + 0.0008 X_2 + 0.0796 X_3$	0.659	$Y = -17.79 + 0.1607 X_1 + 0.0858 X_2 + 0.3095 X_3$	0.652
	$Y = -17.50 + 0.5198 X_1 + 0.0356 X_2$	0.651	$Y = -14.87 + 0.2699 X_1 + 0.2438 X_2$	0.588
	$Y = -17.35 + 0.5498 X_1$	0.650	$Y = -11.27 + 0.4263 X_1$	0.516
	$Y = -12.27 + 0.2413 X_2 + 0.2198 X_3$	0.505	$Y = -16.92 + 0.1341 X_2 + 0.4052 X_3$	0.623
	$Y = -9.51 + 0.4237 X_2$	0.436	$Y = -11.10 + 0.4503 X_2$	0.482
	$Y = -9.08 + 0.3766 X_3$	0.440	$Y = -16.16 + 0.5132 X_3$	0.607
> 6-12 months	$Y = -17.85 + 0.4784 X_1 + 0.0798 X_3$	0.659	$Y = -17.43 + 0.1794 X_1 + 0.3630 X_3$	0.646
	$Y = -19.60 + 0.2549 X_1 + 0.1362 X_2 + 0.2247 X_3$	0.536	$Y = -16.81 + 0.3838 X_1 + 0.0591 X_2 + 0.1052 X_3$	0.523
	$Y = -17.63 + 0.3858 X_1 + 0.2014 X_2$	0.500	$Y = -14.75 + 0.4287 X_1 + 0.0856 X_2$	0.510
	$Y = -15.62 + 0.5376 X_1$	0.457	$Y = -13.23 + 0.4817 X_1$	0.500
	$Y = -16.13 + 0.2110 X_2 + 0.3505 X_3$	0.496	$Y = -11.62 + 0.2060 X_2 + 0.2634 X_3$	0.357
	$Y = -7.90 + 0.4378 X_2$	0.373	$Y = -3.51 + 0.3386 X_2$	0.259
	$Y = -13.29 + 0.4965 X_3$	0.449	$Y = -7.39 + 0.3813 X_3$	0.289
	$Y = -18.85 + 0.3163 X_1 + 0.2762 X_3$	0.519	$Y = -16.17 + 0.4105 X_1 + 0.1222 X_3$	0.519

measurements for males and females are presented in Table 2. In all the age groups in both sexes positive and highly significant ($P<0.01$) correlations were observed. This was comparable to the earlier reported values (Mukherjee et al.,1986; Singh et al., 1987; Das and Sharma, 1994; Topal et al., 2003; Topal and Macit, 2004 and Thiruvenkadan, 2005). The high correlation coefficients between body weight and body measurements for all age groups suggest that either of these variables or their combination could provide a good estimate for predicting live weight of Attappady Black goats. Among these three body measurements, chest girth had the highest correlation coefficient in males and females at 0-3 months and in both sexes at 0-12 month age groups. The height at withers had high correlation with body weight in 0-3 months in both the sexes. The correlations between body weights and body measurements in pooled data from 0-12 months of age were higher than those at different age groups. This might be due to more or less similar environmental influence at different age groups. Since body measurements had high correlation with body weight, this

Table 3. Cont.

Age group	Male	R^2 value	Female	R^2 value
> 12 Months	$Y = -42.07 + 0.6041 X_1 + 0.3229 X_2 + 0.0817 X_3$	0.712	$Y = -33.77 + 0.5847 X_1 + 0.1663 X_2 + 0.1110 X_3$	0.659
	$Y = -41.11 + 0.6509 X_1 + 0.3449 X_2$	0.710	$Y = -31.37 + 0.6367 X_1 + 0.1888 X_2$	0.655
	$Y = -36.51 + 0.9014 X_1$	0.674	$Y = -28.96 + 0.7729 X_1$	0.636
	$Y = -37.83 + 0.5961 X_2 + 0.3770 X_3$	0.622	$Y = -30.87 + 0.4105 X_2 + 0.4388 X_3$	0.529
	$Y = -29.54 + 0.8726 X_2$	0.562	$Y = -16.64 + 0.6471 X_2$	0.447
	$Y = -27.73 + 0.7832 X_3$	0.490	$Y = -26.69 + 0.7594 X_3$	0.425
0-12 Months	$Y = -39.08 + 0.7729 X_1 + 0.1672 X_3$	0.682	$Y = -32.89 + 0.6732 X_1 + 0.1624 X_3$	0.645
	$Y = -17.87 + 0.3709 X_1 + 0.1016 X_2 + 0.1030 X_3$	0.848	$Y = -16.21 + 0.3376 X_1 + 0.0871 X_2 + 0.1111 X_3$	0.816
	$Y = -17.64 + 0.4319 X_1 + 0.1431 X_2$	0.844	$Y = -15.53 + 0.3943 X_1 + 0.1326 X_2$	0.810
	$Y = -17.50 + 0.5615 X_1$	0.837	$Y = -14.88 + 0.5052 X_1$	0.800
	$Y = -16.61 + 0.2915 X_2 + 0.2713 X_3$	0.811	$Y = -15.80 + 0.2427 X_2 + 0.2939 X_3$	0.761
	$Y = -15.01 + 0.5538 X_2$	0.776	$Y = -13.04 + 0.5047 X_2$	0.707
	$Y = -15.80 + 0.5219 X_3$	0.775	$Y = -15.22 + 0.5063 X_3$	0.725
	$Y = -17.87 + 0.4292 X_1 + 0.1382 X_3$	0.845	$Y = -16.10 + 0.3779 X_1 + 0.1492 X_3$	0.812

X_1 = Chest girth X_2 = Body length X_3 = Height at withers Y = Body weight

may be used as selection criteria. Bhattacharya et al. (1984) and Bose and Basu (1984) also reported that selection based on body measurements should improve meat production in goats.

Fitted regressions

Table 3 gives the regression equations developed for different age groups of both sexes along with the coefficient of determinations. At the age of 0-3 months maximum R^2 per cent (83.3 in male and 79.8 in female) was obtained for the equations incorporating all the three measurements. Individually the chest girth alone accounted for maximum of 79.4 and 77.9 per cent of total vaiation in body weight in males and females, respectively, together with ease of measurement, justifies the use of chest girth as a foremost weight predictor. This finding is in agreement with the results reported by Mohammed and Amin (1996), Topal et al. (2003) and Thiruvenkadan (2005).

In all the age groups chest girth was most reliable in predicting the body weight since maximum coefficient of determination was obtained for the equations incorporating chest girth alone. The higher association of body weight with chest girth might be due to relatively larger contribution in body weight by chest girth (consisting of bones, muscles and viscera). However, highest variation of body weight was accounted for by the combination of chest girth, body length and height at withers than each individually of all the age groups in both sexes. These results are also supported by Bose and Basu (1984); Bhattacharya et al. (1984); Prasad et al. (1990); Das and Sharma (1994); Topal et al. (2003) and Topal and Macit (2004). Since in all the age groups the highest R^2 was obtained when all the body measurements were included in the regression equations, this suggests that weight could be estimated more accurately by combination of two or more measurements than by chest girth alone.

The coefficient of determination was highest (84.8 per cent in males and 81.6 per cent in females) in a regression model constructed using pooled data, within sexes from 0-12 months of age, when compared to equations constructed at different age groups. When the

Table 4. Statistical parameters for different equations.

Age group	Equation	Male					Female				
		F	RMSE	SDR	CV	R^2	F	RMSE	SDR	CV	R^2
0-3 months	A	162.59	1.009	0.409	21.12	0.833	117.49	1.037	0.449	19.75	0.798
	B	219.03	1.059	0.429	22.17	0.816	178.21	1.037	0.449	19.75	0.798
	C	384.70	1.120	0.454	23.45	0.794	320.31	1.086	0.470	20.69	0.779
	D	204.14	1.089	0.442	22.81	0.805	153.92	1.099	0.476	20.92	0.773
	E	314.20	1.212	0.491	25.37	0.759	289.32	1.130	0.489	21.52	0.761
	F	323.23	1.199	0.486	25.10	0.764	234.79	1.221	0.529	23.25	0.721
	G	237.09	1.025	0.416	21.46	0.827	160.86	1.080	0.468	20.56	0.781
>3-6 months	A	74.58	1.781	0.584	17.63	0.659	81.34	1.781	0.590	18.21	0.652
	B	109.08	1.801	0.591	17.83	0.651	93.33	1.939	0.642	19.83	0.588
	C	218.91	1.804	0.591	17.86	0.650	140.48	2.102	0.696	21.49	0.516
	D	59.67	2.144	0.704	21.23	0.505	108.20	1.855	0.614	18.96	0.623
	E	91.21	2.289	0.751	22.66	0.436	123.00	2.173	0.719	22.22	0.482
	F	92.65	2.281	0.748	22.59	0.440	203.90	1.893	0.627	19.36	0.607
	G	112.83	1.781	0.584	17.63	0.659	119.70	1.796	0.595	18.36	0.646
>6-12 months	A	55.42	2.484	0.681	15.90	0.536	81.57	2.303	0.690	15.80	0.523
	B	72.42	2.579	0.707	16.51	0.500	116.71	2.334	0.700	16.01	0.510
	C	123.01	2.686	0.737	17.20	0.457	224.82	2.359	0.707	16.18	0.500
	D	71.49	2.588	0.710	16.56	0.496	62.23	2.675	0.802	18.34	0.357
	E	86.87	2.887	0.792	18.48	0.373	78.66	2.871	0.861	19.69	0.259
	F	118.81	2.708	0.743	17.33	0.449	91.43	2.813	0.843	19.29	0.289
	G	78.10	2.530	0.694	16.19	0.519	120.64	2.315	0.694	15.87	0.519
>12 months	A	97.98	4.210	0.537	16.15	0.712	296.38	3.186	0.584	13.84	0.659
	B	146.83	4.224	0.539	16.21	0.710	437.92	3.204	0.588	13.91	0.655
	C	249.70	4.481	0.571	17.19	0.674	810.30	3.288	0.603	14.28	0.636
	D	98.87	4.820	0.615	18.49	0.622	259.89	3.740	0.686	16.24	0.529
	E	157.48	5.170	0.659	19.83	0.565	374.56	4.054	0.744	17.61	0.447
	F	116.42	5.599	0.714	21.48	0.490	342.50	4.134	0.758	17.95	0.425
	G	128.83	4.421	0.564	16.96	0.682	420.15	3.247	0.596	14.10	0.645
0-12 months	A	681.32	2.119	0.390	19.50	0.848	663.48	2.056	0.429	18.23	0.816
	B	995.88	2.145	0.394	19.74	0.844	961.61	2.086	0.436	18.51	0.810
	C	1892.89	2.194	0.403	20.19	0.837	1805.16	2.142	0.447	19.00	0.800
	D	788.23	2.363	0.435	21.75	0.811	718.64	2.339	0.489	20.75	0.761
	E	1273.62	2.574	0.473	23.69	0.776	1092.79	2.589	0.541	22.97	0.707
	F	1266.76	2.580	0.474	23.74	0.775	1192.63	2.510	0.524	22.26	0.725
	G	1000.52	2.140	0.394	19.70	0.845	973.74	2.076	0.434	18.41	0.812

$A = a + b_1 X_1 + b_2 X_2 + b_3 X_3$; $B = a + b_1 X_1 + b_2 X_2$; $C = a + b_1 X_1$; $D = a + b_2 X_2 + b_3 X_3$; $E = a + b_2 X_2$; $F = a + b_3 X_3$; $G = a + b_1 X_1 + b_3 X_3$;

X_1= Chest girth, X_2 = Body length, X_3= Height at withers Y= Body weight

chest girth alone is used for prediction the R^2 values were 83.7 and 80.0 per cent in males and females, respectively. Hence, this regression equation alone may be used to predict the body weight of Attappady Black goats at different age groups. This finding supports the earlier reports of Mayaka et al. (1995) and Thiruvenkadan (2005).

Prediction accuracy

The statistical parameters viz., R^2 value, RMSE, SDR, C.V% and F value are given in Table 4. The R^2 - value indicated that the body measurements included in the prediction were able to describe more variation in live weight. From the above table it may be seen that the R^2 value always increased, as more independent variables were included to the regression. Hence, the criterion that was free from this advantage viz., residual mean square (RMSE) was used to estimate the prediction accuracy of the equations developed. Considering the RMSE value and SDR in addition to the R^2 value, the equation, which gave

maximum R^2 value with the smallest RMSE and SDR was considered as most accurate model in prediction of body weight. Based on this criterion at all the age groups, prediction equations using all the three measurements were found to be the best for estimating the body weights. Chest girth is the most important single measurement for prediction body weight. Inclusion of measurements such as body height and body length in the prediction equation along with the chest girth increased the accuracy of estimation of body weight.

The coefficient of variation for males (residual standard deviation/ mean of the dependent variable) was 15.90 to 25.37 per cent for males and 13.84 to 23.25 per cent for females. The F values were highly significant in both males and females of all age groups. These results are similar to the reports of Bhattacharya et al. (1984) and Thiruvenkadan (2005).

CONCLUSION

The body weight and different body measurements were significantly correlated with each other. Body weight had higher association with heart girth than with length and height. The chest girth alone or in combination with other two measurements can be used for prediction of body weight with better accuracy. For prediction of body weight at different age groups the equations with all the three variables can be used separately since they gave maximum R^2 value and minimum RMSE and SDR. Due to the flexibility in prediction of body weight for different age groups the regression equations of 0-12 months may be used for predicting the body weight of Attappady Black goats.

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