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Assessment of phenotype, its correlations and prediction of live body weight in goat (*Capra hircus*) raised under hot semi-arid region of India

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ABSTRACT

The present investigation was carried out on 1,070 local goats named as Udgiri goat in 242 villages from Marathwada and western Maharashtra during 2018 to 2021. The average body weight of adult Udgiri male goat is 42.77±3.94 kg while female weight is 32.98±3.44 kg and was highest than any other recognized indigenous goat breeds of Maharashtra. The average body length was 76.53±3.53 cm, height at withers was 74.65±1.65 cm, chest girth was 74.46±1.72 cm, paunch girth was 73.54±3.88 cm, tail length was 18.50±1.94 cm, horn length was 16.96±1.18 cm and ear length was 22.23±2.27 cm in male. While, in female goat, the average body length was 72.21±2.53 cm, height at withers was 68.7±2.68 cm, chest girth was 71.95±1.74 cm, paunch girth was 74.24±1.83 cm, tail length was 18.52±2.96 cm, horn length was 17.52±1.26 cm and ear length was 21.73±2.91 cm. The highest and positive significant correlation was noticed between live body weight and almost all body measurement parameters in all four age groups. The highest positive significant correlation (0.82) was found between live body weight and body length in the group of adult goat, hence, it may be used as selection criteria for goat and selection based upon these body measurements should improve the meat production. The multiple linear regression model revealed high level of coefficient of determination and low RMSE for prediction of live body weight using linear body measurements parameters.

Keywords: Body length, Body weight, Paunch girth, Marathwada, Udgiri goat

Livestock has been an important source of livelihood for small farmers of India. The rich livestock biodiversity, with goat as prime species of livelihood amongst the rural population provides availability of cast at any time, hence goat are called 'Moving ATM' or poor man's cow in rural area (Bhautik 2020). The demand for goat meat in India is increasing because of ban on the cow slaughter (Khan *et al*. 2016). Goat species are good having distinct social status, economic status, managerial and biological advantages over other livestock species for rural India. All the indigenous breeds of goat are well adapted to their local climatic conditions. They perform best in the native breeding tract and are considered as one of the hardiest animals ever to be domesticated by man; and are an important source of income and occupation to a sizeable population. However, apart from these described/recognized goat population in the country, a large number of non-descript goat population are present which are not recognized breeds. Maharashtra state is rice in livestock biodiversity with five cattle breeds, three buffalo breeds, four goat breeds, viz. Osmanabadi, Sangamneri, Konkan Kanyal and Berari (ICAR-NBAGR 2022). Higher growth rate in goat farming is very much essential for overall profitable farming, and also goats have higher production and reproduction efficiency than other species with better survivability and for faster genetic improvement as it has less generation interval and increasing replacement rate (Singh *et al.* 2009). Therefore, an investigation was undertaken to record/measure baseline data on various body phenotypic parameters and evaluate the relationship of body weight with various linear body measurement parameters and to predict the live body weight in Udgiri goat (*Capra hircus*).

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MATERIALS AND METHODS

Location of the study areas: The present study was carried out in 242 villages from total 11 districts which included seven districts from Marathwada, viz. Latur, Parbhani, Aurangabad, Nanded, Jalna, Osmanabad and Beed and four districts of western Maharashtra, viz. Ahmednagar, Satara, Solapur and Nashik. The development of the sampling frame was done by four levels of sampling in each district, 2-stage stratified sampling technique was applied, wherein all tehsil within each district and 2 villages in each tehsil were selected randomly to obtain data. Marathwada region is the most drought prone region in India and lies between 17°37' to 20°39' north latitude

and 74°33' to 78°22' east longitude. The breeding tract of Udgiri goat has typical monsoon climate, with hot, rainy and cold weather seasons (Kulkarni *et al*. 2020). Summer season is predominantly observed during March, April and May (the hottest months) and temperature vary between 22°C-39°C during this season. Winter is cool dry spell and pleasant weather prevails from November to February. Temperature varies in this season between 12°C-34°C while about 80-90% of the rainfall is concentrated in the months of June to September. The average annual rainfall in this region is 882 mm. According to the environmental conditions, the goats under the investigation are mostly (91%) reared under open grazing system where there is plenty of grass, fodder available. However, very few (9%) goats are being reared commercially under intensive or semi intensive housing system. In case of close housing, the roofs are made from grass, pasture or sometimes covered with iron sheet available in the vicinity with *kuttcha* floor mainly without electricity, water supply and drainage facilities.

Collection of data: The data were collected as per norms and guidelines laid down by ICAR-National Bureau of Animal genetic Resources (ICAR-NBAGR), Karnal, India which is a nodal institute for livestock breeds recognition. The investigation was carried out for four years during 2018 to 2021. Total 1,070 local goats were surveyed which included 389 male and 681 female animals. The animals were divided in four age groups, i.e. 3 months (consisted of 53 males and 91 females), 6 months (consisted of 62 males and 149 females), 9 months (consisted of 129 males and 204 females), and adult >15 months (consisted of 145 males and 237 females). The linear dimensions measured in centimeters which included eight linear body measurements parameters such as body weight, body length, height at withers, chest girth, paunch girth, tail length, horn length and ear length. The live body weight was recorded in kilograms with the help of 100 kg spring balance fixed to the support by hanging the goat in a fold of gunny bag attached to the ropes early in the morning before the animals were fed.

Statistical analyses: The statistical analysis was made using the program SPSS-28 (2022) statistical package designed for windows. Relationships between the several body measurement parameters were calculated by Pearson correlations. The multiple linear regression (MLR) analysis was performed to study the relationship between several independent or predictor variables, viz. body length, height at withers, chest girth, paunch girth, tail length, horn length and ear length and a dependent or criterion variables, viz. live body weight of goat. The assumption of the model is that the relationship between the dependent variable Y_i and the β vector of regressors X_k is linear. The following represents a MLR equation (Pedhazur 1982):

$$\hat{Y} = a + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots + \beta_k X_k$$

Where, a is the intercept, β is the slope or coefficient, and k is the number of observations. For prediction purposes, the linear regression equation was fitted a forecasting model to an observed data set of Y and X values. The fitted model can be used to make a forecast of the value of Y with new additional observed values of X.

The coefficient of determination (R^2) and root mean square error were used as measure to assess the accuracy of prediction equations.

RESULTS AND DISCUSSION

Body measurement parameters and body weight: These observations were recorded for the first time on Udgiri goat which is proposed as new goat breed in India. These are baseline data generated/recorded from breeding tract of the goat. It was observed that, the average body weight of adult Udgiri male goat is 42.77±3.94 kg while female weight is 32.98±3.44 kg. However, the average body weight of male at 3 months, 6 months and 9 months was 13.57±1.12 kg, 19.9±3.14 kg and 22.86±22.96 kg, respectively, while in female, it was 13.13±1.12 kg, 17.47±3.22 kg and 20.22±2.55 kg, respectively. Verma *et al*. (2011) reported lower body weight as 35.26±1.75 kg and 29.64±0.45 kg in male and female, respectively for adult Konkan Kanyal goat breed. Similarly, Verma *et al*. (2012) also reported body weight, i.e. 42.00±11.00 kg and 29.61±0.71 kg in male and female, respectively in Berari goat. To sum up, the average body weight of adult Udgiri male as well as female goat is highest than other recognized indigenous

Table 1. Overall body measurement (cm) & body weight (kg) of Udgiri goat (Mean±SE)

Age group	3 Months		6 Months		9 Months		Adult (> 15 Months)	
N	53	91	62	149	129	204	145	237
Sex	Male	Female	Male	Female	Male	Female	Male	Female
BW	13.57±1.12	13.13±1.12	19.9±3.14	17.47±3.22	22.86±22.96	20.22±2.55	42.77±3.94	32.98±3.44
BL	47.94±1.23	46.39±1.44	53.98±2.67	55.69±2.52	64.89±1.92	63.79±2.63	76.53±3.53	72.21±2.53
HW	43.93±1.24	43.72±1.18	53.45±2.19	47.66±2.82	65.04±1.78	63.71±1.78	74.65±1.65	68.70±2.68
CG	52.23±2.16	51.44±1.21	62.52±2.91	56.35±0.19	64.95±1.42	63.67±1.82	74.46±1.72	71.95±1.74
PG	51.84±2.67	48.61±1.11	54.55±2.32	65.30±0.25	64.93±1.11	65.3±1.38	73.54±3.88	74.24±1.83
TL	11.45±0.13	11.8±1.28	13.68±1.37	25.51±0.17	16.47±1.15	17.21±1.24	18.50±1.94	18.52±2.96
HL	7.91±1.79	7.11±1.37	8.78±2.63	22.41±0.03	15.66±1.36	14.97±1.73	16.96±1.18	17.52±1.26
EL	11.82±1.15	13.46±1.79	15.17±2.55	17.6±1.27	16.03±1.14	17.71±1.53	22.23±2.27	21.73±2.91

Note: BW, Body weight; BL, body length; HW, height at withers; CG, chest girth; PG, paunch girth; TL, tail length; HL, horn length; EL, ear length; N, number of observations.

goat breeds of Maharashtra state of India (Table 1).

The average body length (cm) of adult Udgiri male goat was 76.53±3.53 cm and 72.21±2.53 cm for female. Height at withers of male was 74.65±1.65 cm; female was 68.7±2.68 cm. Chest girth of male was 74.46±1.72 cm; female was 71.95±1.74 cm. Paunch girth of male was 73.54±3.88 cm; female was 74.24±1.83 cm. Tail length of male was 18.50±1.94 cm; female was 18.52±2.96 cm. Horn length of male was 16.96±1.18 cm; female was 17.52±1.26 cm and ear length of male was 22.23±2.27 cm while female was 21.73±2.91 cm (Table 1). Similar results were reported by Raskar *et al*. (2018) for height at withers, heart girth, body length, ear length, horn length and body weight for 3 months of age as 40.69±0.55 cm, 37.61±0.54cm,32.08±0.55cm,11.69±0.27cm,0.39±0.15cm and 6.29±0.35 kg, respectively, in Osmanabadi goats.

Pearson correlations between body measurements parameters and live body weight: Pearson correlation coefficient was retrieved for various body measurement parameters across different age groups in Udgiri goat. The highest and positive significant correlation was observed amongst body weight and almost all body measurement parameters in all age groups. The highest significant correlation (0.70) was indicated amongst body weight and

Table 2. Pearson correlations between body measurements in Udgiri goats at different age

Variable	BW	BL	HW	CG	PG	TL	HL	EL
				3 Months (n=144)				
BW	01	0.70**	0.67**	0.69**	0.47*	0.39*	0.49*	0.50*
BL	-	01	0.69*	0.48*	0.35^{NS}	0.40*	0.23^{NS}	0.37*
HW	-	-	01	0.69*	0.76**	0.20^{NS}	0.19^{NS}	0.39*
CG	-	-	-	01	0.69**	0.39*	0.39*	0.29^{NS}
PG	-	-	-	-	01	0.39*	0.40*	0.49**
TL	-	-	-	-	-	01	0.25^{NS}	0.29^{NS}
HL	-	-	-	-	-	-	01	0.28^{NS}
EL	-	-	-	-	-	-	-	01
				6 Months (n=211)				
	BW	BL	HW	CG	PG	TL	HL	EL
BW	01	0.75**	0.68**	0.79**	0.49*	0.57*	0.59*	0.57*
BL	-	01	0.72**	0.36*	0.31^{NS}	0.45*	0.67*	0.44*
HW	-	-	01	0.67*	0.43^{NS}	0.65*	0.25^{NS}	0.29^{NS}
CG	-	-	-	01	0.69**	0.36^{NS}	0.39*	0.33^{NS}
PG	-	-	-	-	01	0.38*	0.45*	0.49*
TL	-	-	-	-	-	01	0.23	0.22^{NS}
HL	-	-	-	-	-	-	01	0.21^{NS}
EL	-	-	-	-	-	-	-	01
				9 Months (n=333)				
	BW	BL	HW	CG	PG	TL	HL	EL
BW	01	0.79**	0.80**	0.65*	0.66**	0.37*	0.29*	0.33^{NS}
BL	-	01	0.72**	0.46*	0.37*	0.22^{NS}	0.27^{NS}	0.47*
HW	-	-	01	0.62*	0.73**	0.17^{NS}	0.27^{NS}	0.66**
CG	-	-	-	01	0.69**	0.23^{NS}	0.47^{*NS}	0.46*
PG	-	-	-	-	01	0.19^{NS}	0.22	0.55*
TL	-	-	-	-	-	01	0.38*	0.48*
HL	-	-	-	-	-	-	01	0.49*
EL	-	-	-	-	-	-	-	01
				Adult > 15 Months (n=382)				
	BW	BL	HW	CG	PG	TL	HL	EL
BW	01	0.82**	0.81**	0.78**	0.53*	0.56**	0.41*	0.27^{NS}
BL	-	01	0.71**	0.54**	0.73**	0.33^{NS}	0.56**	0.18^{NS}
HW	-	-	01	0.77**	0.72**	0.24^{NS}	0.19^{NS}	0.17^{NS}
CG	-	-	-	01	0.71**	0.29^{NS}	0.19^{NS}	0.22^{NS}
PG	-	-	-	-	01	0.49*	0.26^{NS}	0.21^{NS}
TL	-	-	-	-	-	01	0.18^{NS}	0.31*
HL	-	-	-	-	-	-	01	0.23^{NS}
EL	-	-	-	-	-	-	-	01

Note: BW, Body weight; BL, body length; HW, height at withers; CG, chest girth; PG, paunch girth; TL, tail length; HL, horn length; EL, ear length. **P<0.01; * P<0.05; NS, Non-significant; n, number of observations.

body length, while lowest correlation (0.19) was found between height at withers and horn length in 3 months age group. Similarly, for 6 months age group, highest significant correlation (0.79) was observed amongst body weight and chest girth, while lowest (0.21) was observed amongst ear length and horn length. However, highest significant correlation (0.80) of body weight was found with height at withers and lowest (0.17) amongst tail length and height at withers in 9 months age group. In adult group above 15 months, the highest significant correlation (0.82) was found between body weight and body length while lowest (0.17) between ear length and height at withers (Table 2). These results are in agreement with Shinde (2000), Mandakmale (2002), Motghare *et al*. (2006) and Mule *et al*. (2014) in different goat breeds.

Prediction of live body weight using multiple linear regression method: In present study, estimations were made by regressing the live weight on measurements of seven traits, viz. body length, height at withers, chest girth, paunch girth, tail length, horn length and ear length. The regression coefficients of live body weight on those linear measurements are shown in Table 3.

Table 3. Multiple linear regression equation for prediction of live body weight in Udgiri goat

Multiple linear regression equation	R^2 value	RMSE
$\hat{Y} = 36.48 + 0.36^{*}a + 0.10^{*}b + 0.749^{*}c + 0.073^{*}d + 0.064^{*}e + 0.011^{*}f + 0.008^{*}g$	0.95	0.0817

Note: a, body length; b, height at withers; c, chest girth; d, paunch girth; e, tail length; f, horn length; g, ear length; R^2, Coefficient of determination; RMSE, Root mean square error.

The high level of coefficient of determination (R^2=0.95) and low root mean square error (0.081) was observed for prediction of live body weight of Udgiri goat for linear body measurements parameters using multiple linear regression model. It was inferred that, chest girth, body length and height at withers have highest coefficients and are major contributors in the equation. Further, it was depicted from the regression plot that, actual and predicted body weight are almost overlapping on each other due to high R^2 value (Fig. 1). The findings of this study are consistent with those reported by Ojedapo *et al.* (2007) and Samuel and Salako (2008) that live body were highly correlated with linear body measurements of goat.

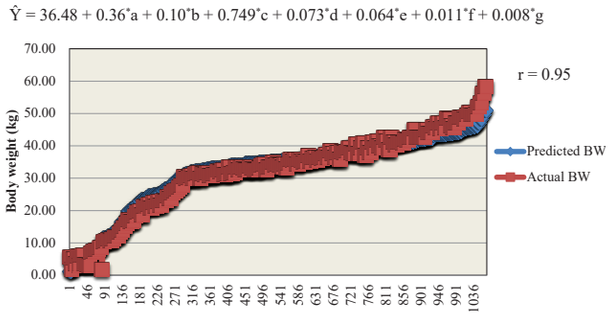

Fig. 1. Regression plot for prediction vs actual of live body weight using multiple linear regression in Udgiri goat.

The present investigation proves that the live bodyweight of the goat is most dependent trait on the three main body measurements parameters, viz. body length, chest girth and height at wither as compared to other traits. The correlation between live body weight and almost all body measurements were positive and highly significant at all the ages groups studied, therefore it is inferred that the early selection based on any higher body measurements is likely to result in higher body weights at subsequent age. Since, the body measurement had high correlation with body weight, this may be used as selection criteria for goat and selection based upon these body measurements should improve the meat production. The high level of accuracy of prediction of live body weight with low root mean square error was observed using linear body measurements parameters; therefore, multiple linear regression equation was sufficient to be used in the estimation of live weight from linear body measurements in goat. However, more investigation is needed in this field of research so as to confirm this statement.

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