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CONTENTS

Bio -prediction of body weight from zoometric traits in Sirohi goats in southern Rajasthan

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ABSTRACT: The live body weight of farm animals is a major factor in determining a number of traits that are significant economically. Birth weight, weaning weight, yearling weight, and the effectiveness of weight gains are growth parameters that are economically significant in relation to the cost of production. Data on body weight and zoometric characteristics were gathered over a 12-year period from the Sirohi goat AICRP project in Udaipur, India (2007 - 2019). The least-square means at birth to 12month of age of body height were 30.36 ± 0.288 cm to 64.00 ± 0.998 cm, body length 29.15 ± 0.321 cm to 58.89 ± 1.168 cm, body girth 30.46 ± 0.284 cm to 64.13 ± 0.995 cm, body weight 2.53 ± ± 0.034 kg to 22.38 ± 0.53 kg, respectively. At various stages of life, it was shown that there were positive, low to medium-level (0.258 to 0.762) phenotypic associations between body weight and zoometric features. The best fit regression equation was developed using a combination of body height, body length, and body girth at birth, 3, 6, and, 12 months age, based on the largest R^2 value (0.694). Result revealed that combination of body height, body length, and body girth required for best regression equation and this combination also positive association with zoometric traits.

Key words: Body measurement, body weight, goat, GDP, Sirohi

The goat (*Capra hircus*), the third-largest species of livestock, is a prominent species among small ruminants (Livestock census, 2019). One of the first farm animals that humans domesticated was the goat in Asia and Europe (Ensminger and Parker, 1986). India has the second-largest goat population in the world, with 148.88 million goats overall and 3.08 million Sirohi goats (DAHDF, 2014). In the presence of 34 breeds, India provides a significant source of goat genetic resources (NBAGR, 2020). Goats comprise roughly 19% of the nation's meat production in India (BAHFS, 2015). In the calendar year 2018–19, India exported 18425 MT of sheep and goat meat to foreign markets for a total of Rs 790.64 crores (APEDA, 2019). In terms of the nation's overall goat population, the state comes first rank with 20,84 million goats (Livestock Census, 2019). About 8% of the state's overall GDP is provided by livestock. The Sirohi goat is the most common breed of goat in Rajasthan, making over 60% of all goats in the state (Animal Husbandry Department Rajasthan, 2016). Sirohi, a district in Rajasthan, is where the breed derives its name. Most of the Aravalli hills and surrounding areas in central and southern Rajasthan are habitat to animals of this breed. The breed, which is primarily raised for meat and milk, is also known as Parbatsari, Devgarhi, and Ajmeri. The Sirohi goat is distinguished by its brilliant body colour, elegant appearance, and effective field performance. The ears are modest in size, flat, and drooping. Triplets are extremely uncommon in Sirohi goat populations; however, singles and twins are rather frequent.

The live body weight of farm animals, especially those with economic value, is a key element in determining a number of their traits. Birth weight, weaning weight, yearling weight, and weight gain effectiveness are growth characteristics that are economically significant in relation to the cost of production. The growth of kids is an indicator of its economic viability. The weaning body weight gives a fair idea about the future performance of the kid. Weight gained after birth and weight at various physiological phases of life are positively correlated.

The relationship between body weight and linear body measurements of goats is important for the estimation of the size and shape of goats suitable for breeding, slaughter and to predict body weight from linear body measurements in goats (Kamarudin *et al.,* 2011). Estimation of live weight using body measurement is a practical, faster, easier, and economical method especially in rural conditions where insufficient resources place constraints in the identification of superior animals in terms of body weight (Tyagi *et al.,* 2015). Body weight is the core economic characteristic of goats that directly affects their market value, therefore measuring zoometric traits gives farmers a gross calculation of body weight, which helps them obtain a reasonable price for the goat kids, by selling them in the market.

MATERIALS AND METHODS

Over a period of 12 years (2007 - 2019), information on Sirohi kid‘s body weight was gathered through the AICRP Project in Udaipur, India. The body weights were measured at various periods, including birth and three, six, nine, and 12 months. At different ages, including birth and three, six, nine, and twelve months, the zoometric characteristics (height, length, and girth) were also noted. Location, birth year, season, kid's sex, dam's parity, and kind of birth were used to categorise the data. Four periods were created based on the birth years. A mixed-model least-squares analysis of fitting constants was used to analyse the data (Harvey, 1990).

Zoometric traits (body weight, body height, and length) were determined using Pearson correlation coefficients. Additionally, the correlation between body weight and zoometric traits was determined for goats in various age groups (0-3 months, 3-6 months, 6-9 months, 9-12 months, and more than 12 months). The correlation is the measure of the degree of association between the observed values of the two traits. The correlation was estimated by using the following formula:

$$r_{xy} = \frac{Cov_{x,y}}{\sqrt{(\sigma_x^2)\ (\sigma_y^2)}}$$

Where,

$Cov_{x,y} Cov_{x,y}$ = covariance between trait X and Y

$\sigma_x^2 \sigma_x^2$ and $\sigma_y^2 \sigma_y^2$ = phenotypic variance of trait X and Y

The standard error of phenotypic correlations calculated as:

$$SE\ (r) = [1 - \mathbf{r}_{(XY)}^2] / \sqrt{[N - 1]}$$

Where,

$r_{(xy)}$= correlation between trait X and Y

N-1 = Degree of freedom

The statistical significance of correlations was tested through the ‘z test.

***Regression*:**

Multiple regression analysis was carried out to develop a prediction equation for body weights on the basis of zoometric traits.

$$Y = a + \sum_{i=1}^{k} b_i x_i$$

Where,

Y = dependent variable (body weight)

a = intercept / constant

$b_1 b_1$= coefficient of regression of y on $x_1 x_1$(i=1, 2, 3)

$x_1 x_1$= Zoometric traits viz. body height, body length, body girth

Using the standard analysis of variance approach for multiple regressions, the coefficient of the determinant (R^2) was determined. $R^2$is the per centage of the sum of squares of the deviations of the Y estimate from its mean that are attributable to regression. For males, females, and overall measures, separate prediction equations were created. Using the method proposed by Di Bucchianico (2008), the coefficient of determination of each effect, which indicates the % contribution of variability, was calculated as follows:

$$R^2 = \left[1 - \frac{\text{Sum of squares of deviation due to effect}}{\text{Total sum of squares}}\right] \times 100$$

Prediction equation:

Linear regression model was arrived at, to develop a prediction equation for body weight. The following mathematical model was used for developing the prediction equation:

Table 1: Phenotypic correlation between body weight and zoometric traitsin Sirohi goats at different age

Correlation Zoometric traits /body weight	Body height	Body length	Body girth
At birth	0.278**	0.277*	0.258**
At 3months	0.739**	0.686**	0.762**
At 6months	0.723**	0.588**	0.717**
At 9months	0.741**	0.575**	0.702**
At 12months	0.696**	0.614**	0.697**

Note: * and ** indicate the Significance of values at P<0.05 and P<0.01, respectively. NS- Non-significant

Table 2:Least-squares means and S.E. for zoometric traits and body weight of Sirohi goats at different age

Traits	Age of animals				
	Birth	3 months	6 months	9 months	12 months
Body height (cm)	30.36±0.288(7814)	49.46±0.577(6828)	54.55±0.676(5067)	54.62±0.989(3920)	64.00±0.998(2690)
Body length (cm)	29.15±0.321(7814)	44.72±0.537(6828)	49.34±0.805(5067)	58.76±0.851(3920)	58.89±1.168(2690)
Body girth (cm)	30.46±0.284(7814)	49.43±0.504(6828)	55.12±0.620(5067)	59.36±0.816(3920)	64.13±0.995(2690)
Body weight (kg)	2.53±0.034(7814)	11.51±0.291(6828)	15.04±0.348(5067)	17.93±0.450(3920)	22.38±0.531(2690)

The number of observations are given in parentheses, estimates with different subscripts differ significantly. ** highly significant (p<0.01), * significant (p<0.05), NS=non- significant, SE= standard error, BH=body height, BL= body length, BG=body girth, BW= body weight

Table 3: Bio-prediction equation of body weight and coefficient of determination (R^2) at different age

Age group		**Equations pooled**	**MSE**	**Adjusted R^2**
At birth	Pooled	Y= -3.037+0.085X1+0.123X2-0.02X3	0.143	0.526
3months	Pooled	Y= -11.872+0.102X1+0.108X2+0.224X3	2.710	0.616
6months	Pooled	Y= -16.419+0.250X1-0.057X2+0.383X3	3.638	0.662
9months	Pooled	Y= -16.820+0.418X1-0.138X2+0.315X3	4.367	0.649
12months	Pooled	Y= -13.296+0.080X2+0.505X3	8.517	0.546
Age group		**Equations male**	**MSE**	**Adjusted R^2**
At birth	Male	Y= -3.571+0.095X1+0.123X2-0.014X3	0.153	0.509
3months	Male	Y= -11.800+0.105X1+0.074X2+0.313X3	2.784	0.640
6months	Male	Y= -18.325+0.300X1-0.043X2+0.358X3	4.005	0.687
9months	Male	Y= -21.012+0.453X1-0.101X2 +0.322X3	5.626	0.694
12months	Male	Y= -23.322+0.157X1+0.180X2+0.422X3	9.997	0.644
Age group		**Equations female**	**MSE**	**Adjusted R^2**
At birth	Female	Y= -3.102+ 0.061X1+0.116X2+0.009X3	0.125	0.508
3months	Female	Y= -11.083+0.094X1+0.137X2+0.248X3	2.569	0.559
6months	Female	Y= -12.765+0.183X1-0.073X2 +0.397X3	2.975	0.616
9months	Female	Y= -11.345+0.355X1-0.170X2+0.311X3	3.750	0.610
12months	Female	Y= -8.483+0.285X1-0.051X2 +0.256X3	5.701	0.522

NOTE: Y= body weight, X1=body height, X2= body length and X3= body girth

$Y = a+b_1x_1+b_2x_2+b_3x_3$

Where,

Y is the body weight

$b_1, b_2 b_1, b_2$ and $b_3 b_3$ are the partial regression coefficients

x_1, x_2 x_1, x_2 and are the body height, body girth and body length respectively.

RESULTS AND DISCUSSION

Phenotypic correlations

Body weight with zoometric traits at different ages

Phenotypic correlations of body weight with height at birth, 3, 6, 9, and 12months of age were observed 0.278, 0.739, 0.723, 0.741, and 0.696, respectively (Table 1). Lower phenotypic correlations were reported by Chauhan (2018) in Marwari goats at birth, 6, 9, and 12months of age. Whereas, higher estimates of phenotypic correlation were reported by Alex *et al.* (2010) in Malabari goats at birth and 3 months of age.

Table 4: Actual body weight (kg) and predicated body weight (kg) of Sirohi goats at different age

Age group		Equations pooled	Predicted body weight	Actual body weight	Significance
At birth	Pooled	Y= - 1.176+0.133X1	3.07	2.54	*
		Y= -2.021+0.157X2	2.53	2.54	NS
		Y= -1.963+0.142X3	2.53	2.54	NS
		Y= -3.645+0.083X1+0.122X2	2.54	2.54	NS
		Y= -2.503+0.073X1+0.085X3	2.51	2.54	*
		Y= -2.961+0.117X2+0.067X3	2.55	2.54	*
		Y= -3.037+0.085X1+0.123X2-0.02 X3	2.60	2.54	*
	Male	Y= -1.559+0.131X1	2.67	2.68	NS
		Y= -1.814+0.153X2	2.68	2.68	NS
		Y= -1.640+0.135X3	2.68	2.68	NS
		Y= -3.612+0.088X1+0.118X2	2.69	2.68	NS
		Y= -2.237+0.080X1+0.073X3	2.68	2.68	NS
		Y= -2.777+0.114X2+0.066X3	2.68	2.68	NS
		Y= -3.571+0.095X1+0.123X2-0.014 X3	2.66	2.68	*
	Female	Y= -1.417+0.121X1	2.39	2.39	NS
		Y= -1.862+0.149X2	2.38	2.39	NS
		Y=-1.846+0.135X3	2.38	2.39	NS
		Y= -3.230+0.070X1+0.119X2	2.37	2.39	NS
		Y= -2.297+0.057X1+0.092X3	2.39	2.39	*
		Y= -2.711+0.112X2+0.061X3	2.39	2.39	NS
		Y= - 3.102+0.061X1+0.116X2+0.009X3	2.41	2.39	*
3 months	Pooled	Y= - 9.227+0.430X1	13.04	13.4	NS
		Y= -7.589+0.450X2	13.04	13.4	NS
		Y= -10.775+0.461X3	13.07	13.4	NS
		Y= -10.662+0.300X1+0.178X2	13.03	13.4	NS
		Y= -11.273+0.143X1+0.327X3	13.03	13.4	NS
		Y= -11.694+0.134X2 +0.360X3	13.05	13.4	NS
		Y=-11.872+0.102X1+0.108X2+0.224X3	13.24	13.4	NS
	Male	Y= -9.328+0.435X1	13.53	13.55	NS
		Y= -7.565+0.454X2	13.56	13.55	NS
		Y= -10.974+0.468X3	13.56	13.55	NS
		Y= -10.558+0.323X1+0.154X2	13.58	13.55	NS
		Y= -11.390+0.132X1+0.343X3	13.52	13.55	NS
		Y= -11.648+0.100X2+0.392X3	13.55	13.55	NS
		Y=-11.800+0.105X1+0.074X2+0.313X3	13.57	13.55	NS
	Female	Y= -8.164+0.405X1	12.49	12.51	NS
		Y= -6.641+0.424X2	12.50	12.51	NS
		Y= -9.614+0.434X3	12.48	12.51	NS
		Y= -9.882+0.266X1+0.196X2	12.53	12.51	NS
		Y= -10.245+0.146X1+0.301X3	12.52	12.51	NS
		Y= -10.857+0.160X2+0.317X3	12.50	12.51	NS
		Y=-11.083+0.094X1+0.137X2+0.248X3	12.52	12.51	NS
6 months	Pooled	Y= - 14.642+0.551X1	17.22	17.25	NS
		Y= -6.516+0.460X2	17.23	17.25	NS
		Y= -14.779+0.555X3	17.26	17.25	NS
		Y= -14.845+0.487X1+ 0.077X2	17.29	17.25	NS
		Y= -16.397+0.234X1+0.349X3	17.28	17.25	NS
		Y= -14.766-0.008X2+0.562X3	17.26	17.25	NS
		Y= -16.419+0.250X1-0.057X2+0.383X3	17.20	17.25	NS
	Male	Y= -16.71+0.592X1	17.99	17.98	NS
		Y= -8.764+0.511X2	17.99	17.98	NS
		Y= -16.50+0.590X3	18.01	17.98	NS
		Y= -16.91+0.521X1+0.083X2	17.97	17.98	NS

		Y= -18.305+0.287X1+0.333X3	18.00	17.98	NS
		Y= -16.538+0.020X2+0.572X3	17.97	17.98	NS
		Y= -18.325+0.300X1-0.043X2+0.358 X3	17.94	17.98	NS
	Female	Y= -10.776+0.479X1	16.58	16.57	NS
		Y=-2.696+0.378X2	16.56	16.57	NS
		Y= -11.441+0.491X3	16.55	16.57	NS
		Y= -10.983+0.427X1+0.062X2	16.56	16.57	NS
		Y= -12.757+0.162X1+0.352X3	16.56	16.57	NS
		Y= -11.353-0.041X2+0.527X3	16.59	16.57	NS
		Y=-12.765+0.183X1-0.073X2 +0.397 X3	16.59	16.57	NS
9 months	Pooled	Y= -15.897+0.593X1	20.78	20.82	NS
		Y= -5.378+0.470X2	20.84	20.82	NS
		Y= -14.510+0.572X3	20.83	20.82	NS
		Y= -15.854+0.637X1-0.049X2	20.82	20.82	NS
		Y= -16.677+0.370X1+0.238X3	20.92	20.82	NS
		Y= -14.450-0.062X2+0.627X3	20.83	20.82	NS
		Y=-16.820+0.418X1-0.138X2+ 0.315 X3	20.80	20.82	NS
	Male	Y= -19.942+0.666X1	21.72	21.75	NS
		Y= -9.753+0.558X2	21.76	21.75	NS
		Y= -18.872+0.650X3	21.74	21.75	NS
		Y= -19.920+0.677X1-0.012X2	21.76	21.75	NS
		Y= -20.979+0.416X1+0.286X3	22.92	21.75	*
		Y= -18.857-0.009X2+0.658X3	21.75	21.75	NS
		Y=-21.012+0.453X1-0.101X2 +0.322 X3	21.74	21.75	NS
	Female	Y= -10.491+0.499X1	20.10	20.08	NS
		Y= -0.194+0.367X2	20.07	20.08	NS
		Y= -9.067+0.476X3	20.07	20.08	NS
		Y= -10.471+0.571X1-0.080X2	20.11	20.08	NS
		Y= -11.092+0.301X1+0.208X3	20.10	20.08	NS
		Y= -8.992-0.112X2+0.576X3	20.09	20.08	NS
		Y= -11.345+0.355X1-0.170X2+0.311 X3	20.07	20.08	NS
12 months	Pooled	Y= - 13.955+0.527X1	20.73	24.72	*
		Y= -5.694+0.510X2	24.70	24.72	NS
		Y= -13.223+0.576X3	24.70	24.72	NS
		Y= -13.954+0.479X1+0.119X2	24.70	24.72	NS
		Y= -15.315+0.275X1+0.333X3	24.73	24.72	NS
		Y= -13.296+0.080X2+0.505X3	24.72	24.72	NS
		Y= -18.31+0.518X1-0.319X2+0.425 X3	24.80	24.72	NS
	Male	Y= -20.265+0.697X1	26.50	26.48	NS
		Y= -15.013+0.685X2	26.49	26.48	NS
		Y= -21.813+0.721X3	26.49	26.48	NS
		Y= -21.402+0.408X1+0.338X2	26.45	26.48	NS
		Y= -23.308+0.218X1+0.525X3	26.49	26.48	NS
		Y= -22.339+0.220X2+0.529X3	26.43	26.48	NS
		Y=-23.322+0.157X1+0.180X2+0.422X3	26.38	26.48	NS
	Female	Y= -7.578+0.481X1	23.84	23.86	NS
		Y= -0.924+0.417X2	23.72	23.86	NS
		Y= -6.075+0.458X3	23.81	23.86	NS
		Y= -7.515+0.451X1+0.027X2	23.54	23.86	*
		Y= -8.285+0.262X1+0.230X3	23.83	23.86	NS
		Y= -6.075+0.024X2+0.436X3	23.80	23.86	NS
		Y= -8.483+0.285X1-0.051X2 +0.256 X3	23.82	23.86	NS

NOTE: Y= body weight, X1=body height, X2= body length and X3= body girth

Phenotypic correlations of body weight with length at birth, 3, 6, 9, and 12months of age were observed 0.277, 0.686, 0.588, 0.575, and 0.614, respectively (Table 1). Lower phenotypic correlations were reported by Chauhan (2018) in Marwari goats at birth, 6, 9, and 12months of age. Whereas, higher estimates of phenotypic correlation were reported by Alex *et al.* (2010) in Malabari goats at birth.

Phenotypic correlations of body weight with body girth at birth, 3, 6, 9, and 12months of age were observed 0.258, 0.762, 0.717, 0.702, and 0.697, respectively (Table 1). Lower phenotypic correlations were reported by Chauhan (2018) in Marwari goats at birth, 3, 6, and 12months of age. Whereas, higher estimates of phenotypic correlation were reported by Alex *et al.* (2010) in Malabari goats at birth, 3, 6, 9, and 12months of age.

A positive and significant phenotypic correlation was observed between different zoometric traits (body height, body girth, and body length) and body weight. Among all zoometric traits (body height, body girth, and body length), the maximum correlation was obtained between body height and body weight at birth, 6 and 9months (0.278, 0.723, and 0.741) while the correlation between body weight and body girth was maximum 0.762 and 0.697 at 3 and 12months age respectively (Table 1).

Among all body measurements, body girth had a maximum correlation with bodyweight followed by height and length. It was concluded that body girth is to be a fair prediction of body weight. The variation of body weight due to body measurements differed between the age group. The association of body weights with body measurements (zoometric traits) was of course due to contribution in body weight by the body measurements. The prediction of body weight also uses the correlation of zoometric traits in each group.

Bio-prediction equations of body weight and coefficient of determination (R^2)

The overall, least-squares means of body weight and zoometric traits of the different age groups of Sirohi goats are given in Table 2 Among the different prediction, equations developed from zoometric traits, the prediction equation for combination with body height, body length, and body girth was observed to be most fit based on R^2 values and this trend was noticed up to 12months of age (Table 3). Thus, different prediction equations were developed to provide a good estimate for the prediction of live weight in Sirohi goat keeping in view the high correlation observed in the present study. The different regression equations for the prediction of body weight based on different zoometric traits (body height, body girth, and body length) and coefficient of determination are presented in Table 3. The correspondence of actual body weight and predicted body weight was statistically analysed for different groups and traits and is presented in Table 4.

The combination of body height, body length, and body girth were found to be the most suitable to predict the body weight based on R^2 values in pooled groups, males, and females respectively at birth, 3, 6, 9, and 12months of age (Table 3). Similar report with the combination of body height, body length, and body girth as most suitable for prediction of body weight observed by Tyagi *et al.* (2013) in Surti goat and Dudhe *et al.* (2015) in Sirohi goats at birth, 3, 6, 9 months of age.

It was clear that the maximum value of R^2 was obtained for a combination of more than one estimate of zoometric traits so this indicated that body weight can be predicted more accurately by the combination of two or more than two factors than only one factor. The variation of body weight due to body measurements differed between the age group. The association of body weights with body measurements was of course due to contribution in body weight by the body measurements.

Actual body weight (kg) and predicated body weight (kg) of Sirohi goats at different age

In most of all the age groups, there was no significant difference between actual body weight and predicted body weight by Z-test (table IV). Similar reports at non-significant differences were also found between predicated body weight and actual body weight in pooled, male, and female groups by Chauhan *et al.*(2018) in Marwari goat.

CONCLUSION

In the present study, it was concluded that regression equations having zoometric traits as the independent variable may be a reliable method for the prediction of body weight, and the combination of body height, body length, and body girth offers the best-fitted equation. It is hereby, recommended that a combination of body height, body length, and body girth measurement would be the best to estimate the body weight of Sirohi goats.

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