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Morphological and biometric characterization on indigenous Lampuchhre sheep in Terai region of Nepal

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ABSTRACT

A comprehensive study was conducted to find out the prevailing production system of Lampuchhre Sheep (*Ovies aries*) in Western and Eastern Terai region of Nepal.Different morphological and biometric information were measured in farmer field including household survey mostly focused on sheep production in current farmers' management scenario by purposive sampling technique. Morphological and biometric parameter such as: parity, number of lambs, feeding regimes were taken according to cross- sectional household survey and focus group discussion. Moreover, the major morphological parameter namely head length, ear length, tail length, body length, neck length, fore feet, rear feet of the Lampuchhre sheep were recorded to establish a reliable regression function (equation). The multiple regression analysis provided a model equation for estimating body weight relationship among all the morphological traits. Moreover, body weight and body length had positive association with a linear functional relationship. The model equation observed was: Body weight= (-61.82)+ 0.449 (Body length)+ 0.857 (Heart Girth)+ (-0.1) Barrel height).Body length and heart girth had highly significant ($p<0.01$) relationship while the barrel height had non-significant effect ($p>0.05$) in the overall modelling. The majority of the morphological traits were found to be highly correlated in two-tailed. Body weight was correlated ($p<0.05$) with majority of the parameters except horn length, barrel height and neck length. These phenotypic information served as a basis for designing appropriate conservation and breeding strategies for sheep in the study area. However, it should be

substantiated with genetic characterization to guide the overall sheep breeding and conservation programs.

Key words: Lampuchhre sheep, modelling, characterization, potentiality

I. INTRODUCTION

Sheep generally seems to have least attention to the researcher in Nepal, despite its wide adoption in divergedagro climatic condition and widespread availability from hills to mountains. Additionally, Lampuchhre Sheep which generally found in southern part of Nepal, in warm Terai region, lags behind the research and extension program. Despite the facts, it plays a pivotal role on rural heritage and value chain due to its social values mostly among ethnic communities, which they need during the social occasions and rituals.

Sheep husbandry was carrying by the modern generation as family tradition and other ethnic communities are likely to be hesitant especially to Lampuchhre sheep, therefore it was likely that to encourage the sheep farming in Terai community would be essential.

The study of different morphological parameters of various known groups of sheep especially indigenous one which has diversified allocation in multiple environmental conditions with distinguishing characteristics is always a major concern for the animal science researcher for years. There is limited research on determining the appropriate equation/function to determine the weight of animals. The different morphological parameters of the sheep have certain level of the functional relationship with the body weight gain. The average meat production is always correlated with the body weight of the animals. The selection process of the any breeds possibly can be determined by using weight function of the animals. Identifying the major factor/parameter that have major functional relationship on the body weight might play role during selection process of animals for breed improvement program in the farm without addition of blood level of other foreign/imported breed.

Fisher (1936), Lachenbruch (1975), Krzanowski and Hand (1997), Desu and Geisser (1973) defined that discriminant analysis was extensively used in various fields where mostly linear discriminate function (LDF) was the main classification function obtained for classifying the known observations.Animal genetic resource (AnGR) characterization encompasses major activities associated with the identification, quantitative and qualitative description of breed populations and the natural habitat and production where their successful adoption may present or not (Asamoah-Boaheng and Sam, 2016). This research tries to cover upon these characterizations.

The aim of this study is to determine the major morphological parameter/physical traits including its reproductive parameters to identify variable selection criterion for developing weight gain function aiming to improve selection process. This would help on juxtaposing for breed enhancement program as well as estimation of body weight with functional equation. This will reduce the time burden for weighing sheep and arrangement of facilities for direct weight measurement process among these nomadic herder. Yanusa et al. (2013) published his paper in the International Journal of Biodiversity and Conservation, Volume 5 investigated that tail of the sheep can be most distinguishing character in his stepwise multifactorial discriminant analysis. The purpose of the discriminant analysis is to classify the observation or several observation into already known groups. (Hardel and Simar 2007).

II. METHODOLOGY

Different district of Eastern and Western Terai were selected for the study such as Sunsari, and Banke respectively. Cross sectional purposive random sampling method was used for household survey within 60 farmer / household. Lampuchree and Kage sheep growing farmers were selected for the study. Focus group discussion, face to face interview and direct farm observation was conducted to collect the data on prevailing situation within herders, farmers, wool merchants, middleman, and meat consumer. The open as well as closed type interview was scheduled to the farmers. The current populations of Kage and Lampuchhre sheep, traditional practices on rearing and other general management practices by the farmer were documented.

Breeding, health and nutritional aspects followed by farmers were categorized based on farmer's perception and secondary information. Along with this, major problems on Lampuchhre Sheep farming was investigated. Morphological/ and reproductive parameters of 60 Terai / Lampuchhre sheep was recorded in Kapilbastu district, Nepal.

Multiple regression analysis was conducted to explain the relationship between multiple independent or predictor variables and one dependent or criterion variable namely sheep body weight. A dependent variable was modeled as a function of several independent variables with corresponding coefficients, along with the constant term. The Multiple regression which requires two or more predictor variables (independent variable) to define the outcome variable (dependent variable) was used to develop the model equation.
The model equation for estimating body weight was observed within four variables namely body length, heart girth and barrel height and for female age of puberty. The regression equation for modelling was as follows.

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \mathrm{e}$$

Where
Y= body weight of sheep, α= constant, β
The multiple regression equation explained above takes the following form:
y = b1x1 + b2x2 + … + bnxn + c.
Here, bi's (i=1, 2…n) are the regression coefficients, which represent the value at which the criterion variable changes when the predictor variable changes.

Model Summary

Predictors (constant) variable were age at puberty, heart girth(cm), barrel height from the ground (cm), body length(cm). Meanwhile dependent variable was body weight (kg).

Figure1, 2: Lampuchhre Sheep in Kapilbastu, Terai, Nepal

III. RESULTS

Community involved in the household sheep production

Majority (85%) of the Lampuchhre sheep farming communities in Western Nepal were from Gaderiaethnicity as a family tradition since time immemorial. The similar scenarios were found in eastern region of Nepal where majority (89%)of Pal communities were found to be engaged. Some other highly marginalized ethnicity and some minorities group such as Muslim also had family tradition of sheep husbandry (only 4%) mainly in eastern region.

Biometric characteristics of Lampuchhre Sheep

Lampuchhre sheep also known as long tail sheep could be found different region mainly in tropical region of Nepal. It wasindigenous sheep which had its importance on rural heritage and value chain. These sheep breed was generally useful for ritual activities and social beliefs. It was also used for the fighting among each other. The owner of the victorious sheep wasrenounced as a chief who had greater knowledge on management and feeding system of the sheep and can make more robust and healthier sheep. The sheep was generally found in black and white color and sometimes in mixed colors. The average age to attain puberty was 9 month. The number of lambs in their life was 7 lambs and gives one lamb per lactation. The average birth weight of lamb was 1.2 kg with less mortality as compared to other sheep breeds with good disease resistant capacity. The average grazing hours was 12 hours per day.

Morphological information of Lampuchhre Sheep

The major morphological parameter of the male sheep namely head length, ear length, tail length, body length, neck length, fore feet, rear feet are higher as compared to female sheep of similar age. There was a large variation of body weight among female compared to male. It suggested that farmer practices selection procedures for breeding purpose and there was some uniformity in male body weight.The strong variation between the weight of female sheep within and among the herd signified that there was huge possibilities of inbreeding and meanwhile more opportunities for selection to maintain herd quality of greater performances. Uniformity need to be maintainedfor good performances on production parameters among the herd. As Singh et al (1993) described that the average body weight of Lampuchhre sheep is 30 kg which value is far below than result obtained in our study. This was may be due to variation of population from region to region.

Table1. Morphological and biometric parameters of Lampuchhre Sheep breed in Terai

Parameters	Male (n=30)	Female (n=30)	Total (60)
Head Length (cm)	24.80±0.83	23.27±0.75	23.53±0.95
Ear Length (cm)	16.40±0.96	14.37±3.74	14.72±3.50
Tail Length(cm)	38.90±1.52	35.29±2.77	35.91±2.92
Body Length(cm)	74.40±3.05	68.41±4.46	69.44±4.79
Heart Girth(cm)	80.60±2.19	73.85±2.83	75.02±3.74
Barrel height from the ground (cm)	34.50±1.58	31.71±1.52	32.19±1.84
Neck Length(cm)	24.50±1.58	23.56±1.34	23.72±1.39
Fore feet above knee (cm)	23.50±.50	21.78±0.79	22.07±0.99
Fore feet below knee (cm)	24.30±1.56	22.10±1.25	22.48±1.53
Rear feet above hock (cm)	27.50±1.00	25.43±0.88	25.79±1.18
Rear feet below hock (cm)	28.80±0.75	27.37±0.72	27.62±.90
Horn Length (cm)	27.80±16.66	.416±2.04	5.14±12.41
Body Weight (kg)	40.32±3.15	31.17±3.48	32.75±4.87
Age at puberty		6.79±.29	6.79±.29
lambing interval (days)		365.00	365.00
Average age in years	3.00±.71	3.71±1.45	3.59±1.37

Independent sample t test of Phenotypical (morphological) traits

Most of the morphological parameters were significantly correlated with the body weight of the animals. The barrel height had non-significant effect (p>0.05) in the overall modelling while body length and heart girth had highly significant (p<0.01) relationship. The majority of the morphological traits were found to be highly correlated in two-tailed. Meanwhile, horn length was also significantly correlated (p<0.01) with head length, body weight, and heart girth, both feet height above knee and above hock. Furthermore, neck length was significantly correlated with only heart girth and non-significant with all other morphological character measured under this study. Besides these, heart girth was significantly correlated with all parameter except ear length. In case of body weight, it was correlated (p<0.05) with majority of the parameters except horn length, barrel height and neck length. Similarly, rear and fore feet height below knee was significantly co-related with all parameters except ear length.

Table 2.F test of physical traits

Parameters		Levene's Test for Equality of Variances		t-test for Equality of Means			Confidence level	
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**
Head Length in cm	E. V. assumed	.029	0.867	4.068	27	.000	1.52	0.3759
	E. V. not assumed			3.781	5.431	0.011	1.529	0.404
Horn Length in cm	E. V. assumed	36.218	0.000	8.331	27	0.000	27.383	3.287
	E variances not assumed			3.668	4.025	.021	27.383	7.465
Ear Length (cm)	Equal variances assumed	6.066	.020	1.185	27	.246	2.025	1.709
	Equal variances not assumed			2.309	25.293	.029	2.025	0.87719
Tail Length(cm)	Equal variances assumed	.757	.392	2.795	27	.009	3.608	1.290
	Equal variances not assumed			4.084	10.621	.002	3.608	0.883
Body	Equal variances	.015	.902	2.842	27	.008	5.983	2.10496

Length(cm)	assumed							
	Equal variances not assumed			3.649	8.083	.006	5.983	1.639
Body Weight (kg)	Equal variances assumed	.073	.789	5.420	27	.000	9.149	1.688
	Equal variances not assumed			5.805	6.231	.001	9.149	1.576
Heart Girth (cm)	Equal variances assumed	1.100	.304	4.993	27	.000	6.745	1.351
	Equal variances not assumed			5.929	7.124	.001	6.745	1.137
Barrel height from the ground (cm)	Equal variances assumed	.060	.809	3.719	27	.001	2.791	.750
	Equal variances not assumed			3.616	5.646	.012	2.791	.771
Neck Length(cm)	Equal variances assumed	.233	.633	1.385	27	.177	.937	.676
	Equal variances not assumed			1.237	5.262	.268	.937	.758
Fore feet above knee (cm)	Equal variances assumed	1.038	.317	4.644	27	.000	1.729	.372
	Equal variances not assumed			6.262	8.877	.000	1.729	.276
Fore feet below knee (cm)	Equal variances assumed	.601	.445	3.430	27	.002	2.195	.640
	Equal variances not assumed			2.947	5.120	.031	2.195	.745
Rear feet above hock (cm)	Equal variances assumed	.199	.659	4.685	27	.000	2.062	.440
	Equal variances not assumed			4.282	5.358	.007	2.062	.481
Rear feet below hock	Equal variances assumed	.000	.991	3.966	27	.000	1.425	.359

(cm)	Equal variances not assumed			3.850	5.638	.010	1.425	.370
Age in years	Equal variances assumed	2.165	.153	-1.049	27	.304	-.708	.675
	Equal variances not assumed			-1.631	12.528	.128	-.708	.434

Most of the morphological parameters weresignificantlycorrelated with the body weight of the animals.

Partial regression of body weight and body length

Body weight and body length had linear relationship. As body length progress, the body weight also increased.

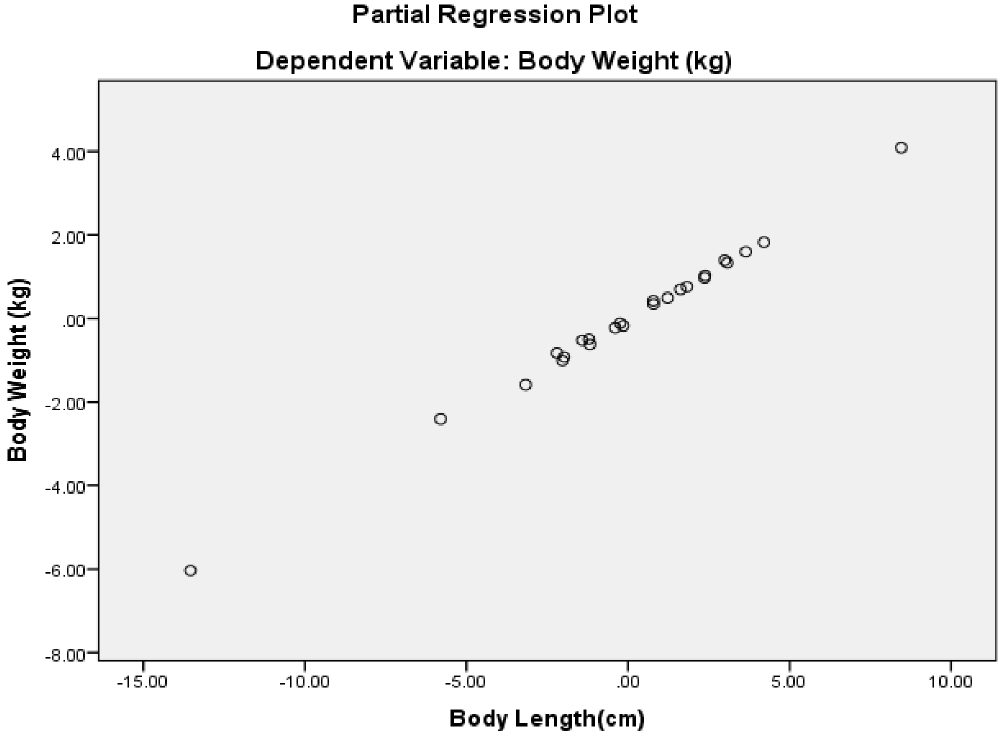

Figure: 3Partial regression of body weight and body length

Fitting of the model

P-P plot of regression standardized residual and dependent variable was measured and the relation was found to be directly correlated which signified that the modelling of the weight measurement wascoincided from each other value. This coincident validated the regression modeling equation of the morphological parameters.

A P-P plot compared the empirical cumulative distribution function of a data set with a specified theoretical cumulative distribution function. The plot showed that our observed value closely lied within the expected line. The majority of the observed value concentrated towards the straight line of the expected value with minimum scatterings of the data. The normal P-P plots of body weight of Lampuchhre sheep showed that the regression equation had a significant result on the hypothesis that, body weight of the sheep could be simulated by regression equation in very efficient way.

The residual probability was coincided with expected probability which signified the fitting of the model coincided with actual value.

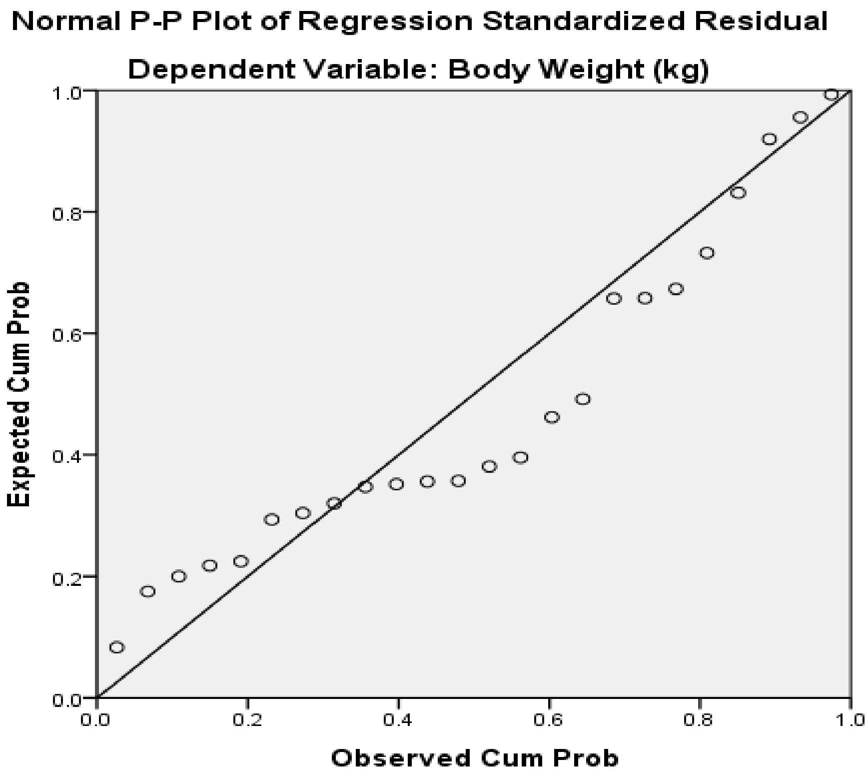

Figure 4.P-P plot of observed and expected probability

Body weight characterizations

To construct a P-P plot, the n non-missing values are first sorted in increasing order: x(1) x(2) x(n) Then the ith ordered value x(i) was represented on the plot by the point whose X coordinate is E (x) and whose y-coordinate was O (y) . Like Q-Q plots and probability plots, P-P plots was used to determine how well a theoretical distribution models of a data distribution. If the theoretical reasonably models in all respects, including location and scale, the point pattern on the P-P plot was linear through the origin and had almost unit slope.

The model equation for estimating body weight was observed within four variables namely body length, heart girth and barrel height and for female age of puberty. The barrel height and age at puberty had non-significant effect (p>0.05) in the overall modelling while body length and heart girth had highly significant (p<0.01) relationship. The regression equation for modelling was as follows.

$$\boldsymbol{Y = a + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \ e_{ijk}}$$

$Bodyweight = (-62.73) + 0.449\ (BodyLenght) + 0.857(HeartGirth) + (-0.1)(Barrelheight) + 0.911$ (Constant)

Table 3. Modelling for the body weight gain of the Lampuchhre Sheep

Parameters	Unstandardized Coefficients		Standardized Coefficients	t values	Significant level
	B	Std. Error	Beta		
(Constant)	-62.731	.911		-68.842	.000
Body Length(cm)	.449	.006	.576	75.384	.000
Heart Girth(cm)	.857	.009	.698	94.482	.000
Barrel height from the ground (cm)	-.010	.017	-.004	-.594	.560

Age at puberty	.023	.088	.002	.259	.799

Fitting of the model on histogram

The histogram followed the normality curve and complemented the finding of the model equation showing body weight (kg) as dependent variable:

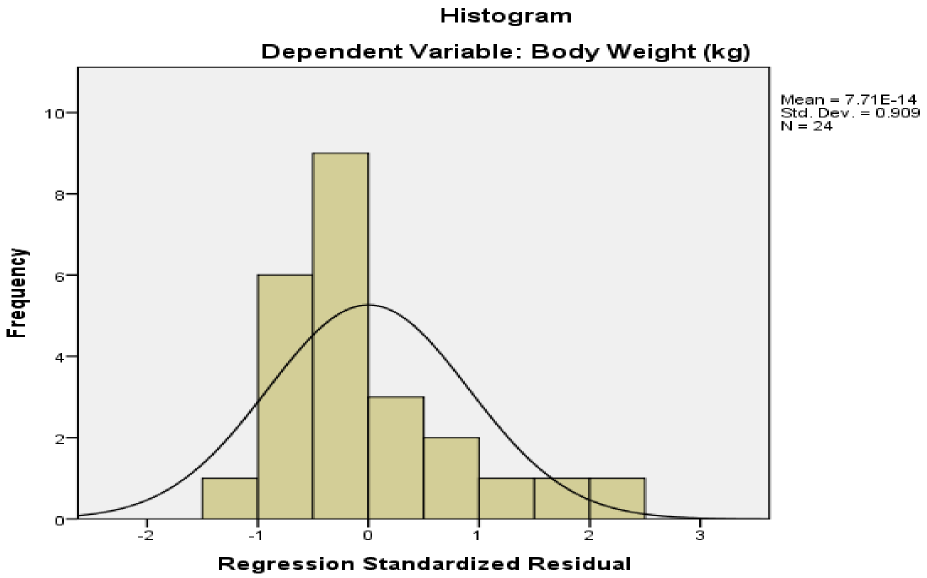

Figure 5.Histogram showing normality of the standardized residuals

Analysis of variance

The ANOVA results showed that the regression equation was highly significant and the model formulated had accuracy at 99% confidence interval. Therefore, we concluded that the predictor of this model can be used at farm and field level for the weight gainfunction of the Lampuchhre sheep.

Table 4. ANOVA of physical traits

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	278.533	4	69.633	5076.465	0.000
Residual	.261	19	.014		
Total	278.793	23			

Correlation of different physical traits of the Lampuchhre Sheep

Dependent Variable was body weight (kg) and predictors (constant) were age at puberty (for femaleonly), heart girth (cm), barrel height from the ground (cm), and body length (from neck bone to tail bone (cm)

Table 5. Correlation matrix of association between different physical traits

Pearson Correlations (2-tailed)		Head Length in cm	Horn Length in cm	Ear Length (cm)	Tail Length (cm)	Body Length (cm)	Body Weight (kg)	Heart Girth(cm)	Barrel height from the ground (cm)	Neck Length(cm)	Fore feet above knee (cm)	Fore feet below knee (cm)	Rear feet above hock (cm)	Rear feet below hock (cm)
Head Length in cm	Pearson Correlation	1												
	Sig. (2-tailed)													
Horn Length in cm	Pearson Correlation	.519**	1											
	Sig. (2-tailed)	.004												
Ear Length (cm)	Pearson Correlation	.201	.140	1										
	Sig. (2-tailed)	.296	.470											
Tail Length(cm)	Pearson Correlation	.465*	.297	.067	1									
	Sig. (2-tailed)	.011	.117	.729										
Body Length(cm)	Pearson Correlation	.606**	.228	.476**	.530**	1								
	Sig. (2-tailed)	.000	.234	.009	.003									
Body Weight (kg)	Pearson Correlation	.706**	.519**	.380*	.620**	.792**	1							
	Sig. (2-tailed)	.000	.004	.042	.000	.000								
Heart Girth(cm)	Pearson Correlation	.598**	.580**	.239	.548**	.479**	.914**	1						
	Sig. (2-tailed)	.001	.001	.212	.002	.009	.000							
Barrel height from the ground (cm)	Pearson Correlation	.133	.566**	.047	.364	.101	.363	.454*	1					
	Sig. (2-tailed)	.491	.001	.808	.052	.602	.053	.013						
Neck Length(cm)	Pearson Correlation	.007	.091	.011	.360	.038	.348	.463*	.236	1				
	Sig. (2-tailed)	.970	.640	.954	.055	.846	.064	.011	.219					
Fore feet above knee (cm)	Pearson Correlation	.551**	.485**	.031	.436*	.509**	.693**	.650**	.342	.244	1			
	Sig. (2-tailed)	.002	.008	.872	.018	.005	.000	.000	.069	.201				
Fore feet below knee (cm)	Pearson Correlation	.446*	.582**	.189	.481**	.507**	.593**	.520**	.263	-.069	.544**	1		
	Sig. (2-tailed)	.015	.001	.327	.008	.005	.001	.004	.167	.722	.002			
Rear feet above hock (cm)	Pearson Correlation	.457*	.533**	.266	.378*	.429*	.543**	.472**	.297	.191	.511**	.392*	1	
	Sig. (2-tailed)	.013	.003	.164	.043	.020	.002	.010	.118	.322	.005	.036		
Rear feet below hock (cm)	Pearson Correlation	.513**	.570**	.192	.362	.272	.507**	.533**	.340	.218	.417*	.576**	.567**	1
	Sig. (2-tailed)	.004	.001	.319	.054	.154	.005	.003	.071	.256	.025	.001	.001	
	N	60	60	60	60	60	60	60	60	60	60	60	60	60

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

IV. DICUSSION

The major communities involved in Local Lampuchhre sheep farming wasGaderia and Pal communities. They were used to on keeping sheep since the time immemorial. These sheep might be consider as rural heritage. These sheep were most common among minorities group or within some ethnic groups. The stronger the sheep they have, the greater their social status considered among the villager and farmer. They had weekly customs of allowing the animals for fighting so the winner was mostly used for the breeding purpose for that week. If during the second week, the next animals won the race, whichultimately would get the opportunities for breeding among all the sheep that come heat during that period. This tradition had some advantage for selection of breeding ram in the village and perpetually reduces the chances of inbreeding also. It wasbecause the younger one has greater chance to win, and as the time progress, these were possibilities for other breeding ram in the village to win. The most robust one which had most important vigor and body size with strong body probably would get the chances of their traits to be transferred to their offspring.

Sexual dimorphism was observed among male and female sheep. Due to small number of male sheep taken, the equation was made for the average of male and female sheep. The majority of the morphological traits were found to be highly correlated in two-tailed. The correlation of head length, horn length, tail length, body length heart girth, and knee height of both feet, rear feet above hock were interestingly non-significant ($p>0.05$) to the barrel height from the ground and neck length. Meanwhile, horn length was also significantly correlated ($p<0.05$) with head length, body weight, and heart girth, both feet height above knee and above hock. Furthermore, neck length was significantly correlated ($p<0.05$) with only heart girth and non-significant with all other morphological character measured under this study. Besides these, heart girth was significantly correlated with all parameter except ear length. In case of body weight, it was highly correlated with majority of the parameters except horn length, barrel height and neck length. Similarly, rear and fore feet height below knee was significantly co-related with all parameters except ear length. More interestingly, rear feet above hock was correlated with tail length while rear feet below hock was not correlated.Multivariate analysis was a strong tool for characterizations of physical traits of small ruminants(Traore et al., 2008).Traore et al. (2008) investigation published in Small Ruminant ResearchVolume 80, Issues 1–3 also characterized morphological traits in Burkina Faso's sheep by multivariate analysis.In the similar way, the multivariate analysis of small ruminant was also conducted by Mohammed et al 2016 specifically on morphological characterizationsof goats of Ethiopia.Carneiro et al (2010) described that phenotypic information can be used initially used in mass selection, whereby individuals with better trait values can be chosen to be parents of the next generation (Carneiro et al. 2010).

The weight measure function was easy ways to measure the body weight when carrying weigh balance is not feasible. On the other hand, there wasdifferent weigh equation for different type of sheep. The carcass weight of the sheep would have always dependent on the flesh amount in different body parts of the animals. During the selection and breeding program of the sheep, there was always problems on which part of the animal has the major functional relationship for body weight/carcass weight of the animals. In this scenarios, heart girth had major functional relationship for body mass index of the animals. Therefore there was high possibility of getting more advantage and success in case we select the animals which has most prominent heart girth for better size and growth rate of offspring during the days to come. This would be equally applicable in selecting the ram which had larger heart girth and the longer body length.

The characterizations of sheep in this study will be helpful to livestock farmers and researchers in preserving the genetic resources of some of the indigenous Nepali sheep breeds, as well as to farmers and dealers in livestock products in the production, processing and marketing of livestock and livestock products. However, whether the variations in these morphological traits are caused by adaptive or non-adaptive sources needs to be further verified by comparing between relative levels of population divergence in quantitative traits and neutral DNA markers.

CONCLUSION

Different morphological parameters of the sheep was directly related to the body weight of the sheep. In the nut shell, different morphological parameter of the Lampuchhre sheep was also correlated to each other. Therefore besides body weight, other physical traits could be also considered as a major functional parameters during any kind if genetic improvement program. Moreover the strong variation between the weightsof female sheep within the herd signifies that there was huge possibilities of inbreeding and meanwhile, more opportunities for selection to maintain herd quality of greater performances. This studied tried to open the pathways for studying impact of genotype and manage mental environment on morphological and reproductive parameter of indigenous Lampuchhre sheep within the days to come. Further genetic study may be needed to fully describe this unique sheep population and its genotypic features. The present information when complemented with DNA microsatellites may help in management and in situ conservation of this indigenous Lampuchhre sheep specifically in Terai region of Nepal.

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REFERENCES

[1.] Traore A,IAlvarez,HH Tamboura,I Fernandez Kabore,B Royo , JP Gutierrez, M Sangare , Ouedraogo-Sanou e , A Toguyeni L Sawadogo, F GoyachGenetic characterisation of Burkina Faso goats using microsatellite polymorphism (2008).

[2.] Asamoah-Boaheng M, & EK Sam. Morphological characterization of breeds of sheep: a discriminant analysis approach. Springer Plus,(2016). 5, 69. Doi: 10.1186/s40064-016-1669-8.

[3.] Desu MM, SGeisser .Methods and applications of equal-mean discrimination. In: Cacoullos T, editor. Discriminant analysis and applications. (1973). New York: Academic Press; 1973. pp. 139–161. [Google Scholar] [Ref list].

[4.] Fisher RA. The use of multiple measurements in taxonomic problems. Annal Eugen. 1936;7:179–188. doi: 10.1111/j.1469-1809.1936.tb02137.x. [CrossRef] [Google Scholar][Ref list].

[5.] Hardel WK, Simar L. Applied multivariate statistical analysis. Heidelberg: Springer; 2007. [Google Scholar] [Ref list].

[6.] Krzanowski WJ and Hand DJ. Assessing error rate estimators: the leave-one-out reconsidered. (2007).Aust J Stat. 1997;39(1):35–46. doi: 10.1111/j.1467-842X.1997.tb00521.x.[CrossRef] [Google Scholar][Ref list].

[7.] Lachenbruch PA.Zero-mean difference discrimination and the absolute linear discriminant function. Biometrika. 1975;62(2):397–401.doi:10.1093/biomet/62.2.397. [CrossRef] [Google Scholar][Ref list].

[8.] Mohammed, Ahmed & Kefelegn, Kebede & Effa, Kefena. Morphological characterization of indigenous goats in Western Ethiopia: implication for community-based breeding programmes.

Animal Genetic Resources/Ressources génétiques animales/Recursos genéticos animales(2016). Retrieved from 1. 1-10. 10.1017/S2078633616000047.

[9.] Lachenbruch PA Some Unsolved Practical Problems in Discriminant Analysis by Department of Biostatistics University of North Carolina at Chapel Hill Institute of Statistics (1975). 1imeo Series No. 1050.