DETERMINANTS OF MAJOR BODY MORPHOMETRIC TRAITS OF KHARI GOAT KIDS (*Capra hircus* L.) IN NAWALPUR DISTRICT, NEPAL

N. Bhattarai*
Department of Animal Breeding and Biotechnology, Agriculture and Forestry University, Rampur, Chitwan, Bagmati, Nepal
*nbhattarai@afu.edu.np

ABSTRACT

This study was carried out aiming at studying the non-genetic determinants affecting three major body morphological traits of *Khari* goats in Nawalparasi, Nepal. Body length, wither height and heart girth at the age of birth, weaning, nine months and fifteen months of 1260 kids born from 1005 does were measured and analyzed using fixed effect Least Square Mixed Model and Maximum Likelihood Computer Program (LSMMML PC-2). Significantly different means of body length, wither height and heart girth were between different sub-classes of non-genetic factors compared using Duncan's Multiple Range Test (DMRT) computer software. Findings revealed that overall mean wither height of kids ranged from 28.84±0.59 cm at birth to 61.95±1.03 cm at fifteen months, respectively. Similarly, overall mean hearth girth of kids varied from 29.62±0.58 cm at to 65.04±1.17 cm at fifteen months' age, respectively. Overall mean body length of *Khari* goat kids was at birth, weaning, nine months and fifteen months' age was determined 28.09±0.67 cm at birth and reached to 59.96±0.98 cm at fifteen months' age. Altitude, coat color, kidding season, dam's parity, dam's size, sex and birth type of kids were the important sources of variation ($p<0.05$ to <0.001) with respect to wither height, hearth girth and body length of kids at most of the stages of growth in case Nepalese hill goats. Thus, the results of present study help describe indigenous *Khari* goat breed using the phenotypic values of morphometric traits such as body length, heart girth and wither height which may be useful to estimate the phenological variations within breed.

Keywords: *birth type, body length, heart girth, parity, wither height*

INTRODUCTION

Goats (*Capra hircus* L.) are multipurpose small ruminants and significantly contribute in the nutrition and socio-economic security of rural, landless and marginal farmers in Nepal (Bhattarai et al., 2019). Goat farming is a rapidly increasing enterprise among the youth entrepreneurs in recent years. Goat contributes about 4 percent to the total GDP and about 20 percent to the total meat production, ranks second after buffalo (MoALD, 2019). Goats can efficiently survive on available shrubs and trees in adverse harsh environment in low fertility lands where no other crop can be grown (Hagan et al., 2012). There are four prominent indigenous genetic resources of goats in Nepal viz. Chyangra, Sinhal, Khari and Terai (Neopane, 1997). Khari goat is one of the most populated and widely preferred goats covering more than 50 percent of small ruminant population in Nepal (Bhattarai et al., 2019 & Poudel, 2020).

Khari goats have the broad genetic variability among this species in Nepal with wider variation in growth, reproductive and morphological variation. They have small body size ranging from 25 to 30 kg males and 20-25 kg females with low to medium body length, wither height and heart girth that enables it to survive under stressful environmental conditions, high disease incidence, and low input requiring (Neopane, 1997 & Kolachhapati, 2006). Characterization is one of the primary process of identifying distinct breed population and explaining the morphological and growth parameters in a particular environment and habitat taking into account the socio-economic factors that affect them (FAO, 2020). Khari goat has

been scarcely described with respect to their linear body measurements i.e. morphological traits that are considered to be the important selection criteria of within breed selection for genetic improvement (Hagan et al., 2012; Salako & Ngere, 2002). In this reference, current study therefore sought to investigate the major morphological characteristics of Nepalese indigenous Khari goats in the mid-hills of Nawalpur district, Gandaki Province, Nepal. Thus, present study was mainly focused on determining the baseline values of major body morphological traits of Khari goats and the determining factors associated to bring phenotypic variation among these traits.

MATERIALS AND METHODS

This study was carried out in the native goat flocks of Hupsekot Rural Municipality (former Deurali VDC), Nawalparasi, Nepal from February, 2012 to January 2015 representing two agro-ecological domains i.e. Inner Terai (lower altitude, ranging 300-700 masl) and hill (upper altitude, ranging 700-1100 masl). The experimental goats were commonly reared under semi-intensive system of management with 4 to 6 hours grazing supplied with *ad-lib* water, minerals and concentrates. The animals were regularly vaccinated for PPR and drenched/dewormed for round worms and liver flukes. Altogether 1260 kids including 696 males and 564 females were considered for this study. There were altogether seven non-genetic factors considered in this study. Accordingly, the altitude being grouped into 2 sub-classes i.e. lower and upper; color into five sub-classes i.e. black, black and white, brown, mixed and white; season of kidding into four sub-classes i.e. Spring (February/March to April/May), Rainy (May/June to July/August), Autumn (August/September to October/November) and Winter (November/December to January/February); dam's parity into three sub-classes i.e. early (1st and 2nd parity), mid (3rd to 6th parity) and late (7th and above parity) as suggested by Neopane (1997), size of dams into three sub-classes i.e. small (≤22 kg live body weight), medium (>22 to ≥32 kg live body weight) and large (>32 kg live body weight); and birth type in to three sub-classes i.e. single (does having 1 kid at time), twins (does having 2 kids at a time) and triplet (does having 3 kids at a time). Measurements on three important body morphological traits including wither height, heart girth and body length of kids were recorded (in cm) at the age of birth, weaning (4 months), nine months and fifteen months considering above mentioned determinants (non-genetic factors).

Data were analyzed by 'Least Square Mixed Model and Maximum Likelihood Computer Program (LSMMML PC-2)' (Harvey, 1990). Least Square mean (LSM) and standard error of the mean (SEM) of each body morphological traits were determined using the following statistical model given by Henderson (1953). Significantly different means of WH, HG and BL with respect to various determinants were compared using Duncan's Multiple Range Test (DMRT) computer software (Duncan, 1955).

$$\boldsymbol{Y_{ijklmno} = \mu + a_i + b_j + c_k + d_l + f_m + g_n + h_o + e_{ijklmnop}}$$

Where, $Y_{ijklmno}$ = adjusted mean for body morphological traits.

μ = Pooled/overall mean

a_i is the effect of i^{th} altitude (i =1,2): lower and upper.

b_j is the effect of j^{th} coat color of kids (j= 1,2,3,4,5); black, black and white, brown, mixed and white.

c_k is the effect of k^{th} season of kidding (k= 1,2,3,4); spring, rainy, autumn and winter.

d_l is the effect of l^{th} number of parity of dams (m = 1,2,3); early, middle and late.

f_m is the effect of m^{th} size of dams (n = 1,2,3); small, medium and large.

g_n is the effect of n^{th} sex of kids (o= 1,2); male and female.
h_o is the effect of o^{th} type of birth (p= 1,2,3); single, twins and triplets.
$e_{ijklmnop}$= is the random element (residual effect) assumed to be normally and independently distributed.

RESULTS AND DISCUSSION

Wither height

Overall mean wither height of the kids under this study was determined 28.84±0.59 cm and reached to 46.29±1.09 cm at the age of weaning and 61.95±1.03 cm at 15 months with the linear increment rate of 2.21 cm per month (Table 1). Sapkota (2007) reported in accordance with the findings of present study confirming the wither height of goats in Nepal ranging from 29.47 cm at birth, 41.01 cm at pre-weaning (two months), 46.93 cm at weaning, 50.92 cm at post weaning (six months) and 54.11 cm at post weaning (eight months) age of kids. Moreover, Bhattarai (2007) reported the overall mean height at withers of local Terai goats in Siraha, Nepal as 38.87 cm at birth and that at post-weaning age of eight months as 57.50 cm, respectively showing greater height of Terai goat than hill goat considered in this study. Similar value of average wither height (i.e. 51.5 cm and 55.6 cm at 4-6 and 6-12 months age, respectively) was also reported by Neopane (2000) in case of central Terai goats in Nepal. Furthermore, Ray et. al. (2015) and Tudu et. al. (2015) studied the effect of non-genetic effect on wither height of indigenous goats at different stages of growth in north central plateau climatic zone of Odisha, India and Bengal goats at their home tract, and reported the significantly lower values of wither height at almost all stages of growth that was not in accordance with the findings of present study. In addition, wither heights of goat kids of different genotypes at 90 and 180 days of age reported by Yilmaz et. al. (2013), Bolacali (2010) and Simsek and Bayraktar (2006) have been observed to be higher than the findings of present research. Wither height of the kids was observed to be varied differently at different stages of growth with respect to various types of non-genetic factors including altitude, coat color of the kids, season of conception, season of kidding, dam's parity, size of dams, sex of kids and type of birth of the kids.

Effect of altitude

Altitude was not an important source of variation with respect to the wither height of Khari kids at birth (Table 1). However, the results of present study revealed that altitude had a significant influence (except at the time of birth) on the wither height of Khari goat kids at pre-weaning ($p<0.001$), weaning ($p<0.001$), six months ($p<0.01$), nine months ($p<0.01$), twelve months ($p<0.01$) and fifteen months of age ($p<0.01$). Accordingly, wither height of the *Khari* goat kids under this study was observed higher for the kids of lower altitude at all the stages of growth as compared to those of upper altitude. Sapkota (2007) also confirmed the significant influence ($p<0.001$) of location (representing varying altitudes) on wither height of goat kids at all stages of growth considered under present study.

Effect of coat color

Results of this study revealed that coat color of the kids was an important source of variation with respect to wither height of kids at birth ($p<0.01$), weaning ($p<0.01$) and six months age ($p<0.05$). Whereas, wither height of the *Khari* goat kids under this study was observed higher for the kids of black coat color at birth, white at pre-weaning and weaning

and in the kids of mixed coat color at rest of the age categories. At the meantime, coat color of the kids was not an important source of variation with respect to the wither height of kids at pre-weaning, nine months, twelve months and fifteen months age (Table 1). Tudu et. al. (2015) reported significant ($p< 0.05$) difference in wither height with respect to three color varieties of Bengal goats at all stages of growth confirming the higher value of wither height of White Bengal goats followed by Brown Bengal and Black Bengal goats.

Effect of season of kidding

Season of kidding had significant influence on wither height of *Khari* goat kids at birth ($p<0.05$), pre-weaning ($p<0.001$), weaning ($p<0.001$), six months ($p<0.05$), twelve months ($p<0.05$) and fifteen months ($p<0.01$) and had no significant effect on wither height of kids at nine months age. Accordingly, wither heights of the Khari goat kids in this study were reported to be higher for the kids born in rainy season at all stages of growth except birth and pre-weaning age as compared to the contemporary kids born to the dams conceived in other seasons. Wither height at birth was observed to be higher for the kids born in autumn season as compared to the contemporary kids born in other seasons. Sapkota (2007) compared the performance of goats representing eastern, central and western region of Nepal and reported the significant effect of season of kidding on wither height of kids at two months pre-weaning ($p<0.001$), weaning ($p<0.001$) and eight months post weaning ($p<0.001$) ages except at birth and six months post weaning.

Effect of parity

Results of this study reflected that parity of dams had significant influence on wither height of Khari goat kids at pre-weaning ($p<0.05$), weaning ($p<0.001$), and six months ($p<0.01$) age (Table 1). Whereas, wither height was not significantly influenced by the effect of dams parity at birth, nine months, twelve months and fifteen months age of kids ($p>0.05$). Accordingly, wither heights of the Khari goat kids attributed in present study were reported to be higher for the kids born to the does of late parity at birth and at rest of the ages the trait was higher for the kids born to the does of middle parity as compared to those born from the does of early parity. Similarly, Yilmaz et. al. (2013) investigated the survival rate, growth performance and some body measurements of Saanen and its crosses with Hair-goats and reported the significant effect of dams' age on wither height of kids only at the post weaning age of six months confirming the taller height of kids born to the older does as compared to those of younger ones. In contrast to the findings of this study, Sapkota (2007) reported non-significant influence of dams' parity on withers height of goat kids at all stages of growth.

Effect of size of dam

Wither height of Khari goat kids in this study was significantly ($p<0.05$) affected by the size of dams at birth, weaning and six months age (Table 1). Whereas, the trait was not significantly influenced by the effect of dam's size at pre-weaning, nine months, twelve months and fifteen months age of kids ($p>0.05$). Accordingly, results reflected that, wither heights of the kids at all stages of growth were determined to be higher for the kids born to larger dams as compared to those born to medium and smaller dams. Similarly, Yilmaz et. al. (2013) reported the significant effect of dam's weight/size on wither height of Saanen and its crosses with Hair-goats at the age of six months. However, wither height at birth and three months age of kids was not affected by the weight of dams.

Effect of sex of kids

Results of present study revealed that sex of kids had significant influence on the wither height of kids at birth ($p<0.01$), pre-weaning ($p<0.05$), weaning ($p<0.05$), twelve months ($p<0.05$), and fifteen months age ($p<0.01$) except at six months and nine months age ($p>0.05$). Sapkota (2007) working in the goats of eastern, central and western region of Nepal reported significant effect of sex on wither height at two months pre-weaning, weaning ($p<0.05$), six months post weaning ($p<0.01$) age of kids. Bhattarai (2007) on the other hand also reported in accordance with the findings of this study indicating higher wither height of male kids as compared that of contemporary female kids. Yilmaz et. al. (2013) working in Saanen and its crosses with Hair-goats reported the significant effect ($p<0.05$) of sex on wither height of kids at weaning, however the trait was not significantly differed with respect to sex of kids at birth and six months age. Similarly, the wither height was statistically significant ($p<0.05$) between the male and female in all age groups of Bengal goats where males showed higher measurements than their female counterparts (Tudu et al., 2015). Results of present study was also supported by Kurnianto et. Al. (2013) and Gyaneshwari et. al. (2007) working on local goats (Kejobong and Etawa Grade) in Central Java, Indonesia and Black Bengal goats in India, respectively. Furthermore, Elmaz et. al. (2012) determined some morphological characteristics of Honamli goat and kids, a newly defined Indigenius goat breed of Turkey and reported significant influence ($p<0.05$) of sex on wither height at one month and 3 months age of kids. On the other hand, Ray et al. (2015) and Patro and Mishra (1987) had confirmed the significantly ($P<0.05$) higher wither height of males as compared to that of females at birth, three months, six months, nine months and twelve months age of kids.

Effect of birth type

Results of this study reflected that birth type was an important source of variation with respect to the wither height of kids at all stages of growth i.e. birth ($p<0.001$), pre-weaning ($p<0.01$), weaning ($p<0.001$), six months ($p<0.001$), nine months ($p<0.01$), twelve months ($p<0.001$) and fifteen months ($p<0.001$) age. Accordingly, wither height of Khari goat kids under this study was significantly higher for the kids born as singlet as compared the contemporary kids born as twins and triplets at all stages of growth. Average wither height of Khari goat kids in this study ranged from 28.02 cm for triplets and 29.29 cm for singlet at birth and reached to 60.87 cm and 62.45 cm for triplets and singlet at fifteen months age, respectively. In accordance to the findings of present study, Sapkota (2007) working on the goats of eastern, central and western region of Nepal reported highly significant effect of birth type on wither height at two months preweaning ($p<0.05$), weaning ($p<0.01$), and eight months post weaning ($p<0.001$) age of the kids, and confirmed the significantly higher wither height of single born kids as compared to those born as multiple at all stages of growth from birth to eight months post-weaning. However, wither height at birth and six months post weaning age of kids was not significantly influenced by the effect of birth type. Yilmaz et. al. (2013) working in Saanen and its crosses with Hair-goats reported in oppose to the findings of present study. Accordingly, wither height of kids was not significantly affected by the effect of birth type at all stages of growth under study.

Table 1. Effect of non-genetic factors on wither height (cm) at different stages of growth of Khari **kids in Nawalparasi, Nepal**

Fixed factors	No.	Birth	Weaning	Nine months	Fifteen months
Overall	1260	28.84±0.59	46.29±1.09	54.34±1.06	61.95±1.03
Altitude		NS	***	**	**
Lower	188	29.21±0.84	48.57±1.55	56.02±1.50	64.01±1.47
Upper	1072	28.49±0.51	44.02±0.92	52.67±0.89	59.89±0.87
Color		**	**	NS	NS
Black	460	29.34±0.59^{a}	46.44±1.09^{ab}	52.46±1.06	61.87±1.03
Black/white	45	28.17±0.68^{c}	45.42±1.25^{c}	53.44±1.21	61.37±1.18
Brown	537	29.09±0.58^{ab}	45.82±1.07^{bc}	54.24±1.04	61.85±1.01
Mixed	64	28.74±0.64^{b}	46.97±1.18^{a}	55.09±1.14	63.03±1.11
White	154	28.88±0.61^{b}	46.80±1.12^{a}	54.49±1.09	61.63±1.06
Season of kidding		*	***	NS	**
Spring	548	27.93±0.54^{c}	43.37±0.98^{c}	52.52±0.95	60.92±0.93^{c}
Rainy	26	27.24±1.59^{d}	49.59±2.92^{a}	58.32±2.84	65.36±2.77^{a}
Autumn	316	29.48±0.57^{a}	45.99±1.05^{b}	53.01±1.02	59.88±0.99^{d}
Winter	370	28.73±0.54^{b}	46.21±0.99^{b}	53.53±0.96	61.63±0.94^{b}
Parity		NS	***	NS	NS
Early (1st and 2nd)	424	28.75±0.37	42.08±0.68^{c}	51.74±0.66	59.96±0.65
Middle (3rd to 6th)	634	28.72±1.13	51.05±2.07^{a}	56.59±2.01	64.89±1.96
Late (> 7th)	202	29.06±0.92	45.75±1.69^{b}	54.71±1.64	60.99±1.60
Size of Dams		*	*	NS	NS
Small	152	28.15±1.10^{b}	44.40±2.02^{b}	52.44±1.96	60.79±1.91
Medium	902	28.40±0.41^{b}	44.98±0.75^{b}	54.71±0.73	62.02±0.71
Large	206	29.98±0.69^{a}	49.49±1.26^{a}	55.91±1.22	63.03±1.19
Sex		**	*	NS	**
Male	696	29.64±0.55	47.34±1.01	55.34±0.98	63.39±0.96
Female	564	28.04±0.75	45.24±1.38	53.34±1.34	60.49±1.31
Birth Type		***	***	**	***
Single	754	29.22±0.57^{a}	47.89±1.04^{a}	55.41±1.01^{a}	62.45±0.99^{a}
Twins	472	28.02±0.59^{b}	46.72±1.08^{b}	54.18±1.05^{b}	60.87±1.02^{b}
Triplets	34	29.29±0.73^{a}	44.25±1.34^{c}	53.44±1.30^{c}	62.52±1.27^{a}
Coefficient of Variation (CV)		6.70%	8.26%	6.68%	5.69%

*Note: *: Significant at 5% level (i.e. p<0.05); **: Significant at 1% level (i.e. p<0.01); ***: Significant at 0.1% level (i.e. p<0.001); NS: Non-significant (i.e. P≥0.05); Means, within an effect, with the different superscript are significantly different; LS mean: Least square means; SEM: Standard error of Means; No: Number of observations*

Heart girth

The overall mean heart girth of Khari goat kids at birth, pre-weaning, weaning, six months, nine months, twelve months and fifteen months in present study was determined 29.62 cm, 40.14 cm, 49.41 cm, 52.39 cm, 57.09 cm, 60.58 cm and 65.04 cm, respectively (Table 2). Bhattarai (2007) working on local Terai goats of Siraha, Nepal reported lower

values of heart girth as compared to the results of present study i.e. 28.91 cm, 39.40 cm, 45.06 cm, 50.47 cm and 56.89 cm at birth, pre-weaning, weaning, six months and eight months age. Similarly, Sapkota (2007) also reported the similar results while working on the goats of eastern, central and western region of Nepal. On the other hand, Ray et. al. (2015) and Tudu et. al. (2015) reported significantly lower values of heart girth of indigenous goats and Bengal goat kids at their respective ages in contrast to the findings of present study.

Effect of altitude

Results of present study reflected that altitude had non-significant influence on heart girth of Khari goat kids at almost all stages of growth except at weaning (Table 2). However, heart girth was significantly higher ($p<0.05$) for the kids of lower altitude as compared to the contemporary kids at upper altitude. Similarly, higher values of the trait were also observed for the kids at lower altitude at all stages of growth, though the variations were not significant as stated earlier. Sapkota (2007), in contrast to the findings this study, reported highly significant influence ($p<0.001$) of location (with varying altitude) on heart girth at the age of birth, two months, four months, six months, and eight months of goat kids sampled from eastern, central and western region of Nepal.

Effect of coat color

Coat color was reflected to be an important source of variation with respect to the hearth girth of Khari goat kids at birth ($p<0.001$) and weaning ($p<0.05$) in Nawalparasi, Nepal. Accordingly, results of present study revealed that heart girth significantly higher for the kids of black coat color (30.13 cm) at birth and for white coat color (50.12 cm) at weaning as compared to contemporary kids of other coat colors. The trait was not significantly affected by coat color at other stages of growth. Tudu et. al. (2015) reported significant influence ($p<0.05$) of coat color on heart girth of Bengal goats at all stages of growth indicating the higher value of heart girth of White Bengal goats followed by Brown Bengal and Black Bengal goats.

Effect of season of kidding

Results of this study reflected that season of kidding was an important source of variation with respect to the hearth girth of Khari goat kids at all stages of growth except at six months age (Table 2). Accordingly, heart girth was significantly higher for the kids born in autumn season at birth ($p<0.01$), rainy season at pre-weaning ($p<0.001$), weaning ($p<0.05$), and nine months ($p<0.05$), twelve months ($p<0.05$), and fifteen months ($p<0.05$), age of growth. Detail information on the effect of season of kidding on heart girth of Khari goat kids at different stages of growth is presented in Table 2. Sapkota (2007) compared the performance of goats representing eastern, central and western region of Nepal and reported the significant effect of season of kidding on heart girth of kids at two months pre-weaning ($p<0.001$) age. Whereas, the trait was not significantly affected by the season of kidding on weaning, six months and eight months post weaning ages.

Effect of parity

Results of this study indicated that parity of dams had significant influence on the heart girth at weaning ($p<0.01$), nine months and twelve months ($p<0.05$) age of Khari goat kids (Table 2). Accordingly, higher values of heart were observed for the kids born to the

dams of middle parity as compared to those born to the dams of early and late parity at all stages of growth. Detail information on the heart girth of Khari goat kids observed in present study is presented hereunder in Table 2. Yilmaz et. al. (2013) investigating the survival rate, growth performance and some body measurements of Saanen and its crosses with Hair-goats reported the significant effect ($p<0.01$) of dams' age on heart girth at the post weaning age of six months confirming the higher value of the trait for the kids born to the older dams as compared to those of younger ones. Whereas, heart girth at birth and weaning age of kids were not significantly influenced by the effect of dams' age. In contrast to the findings of present study, Sapkota (2007) reported non-significant influence of dams' parity on heart girth of goat kids at all stages of growth.

Effect of size of dam

Findings of this study indicated that hearth girth Khari goat kids was significantly influenced by the size of dams only at the age of weaning (Table 2). There was a non-significant association between the size of dams and the heart girth of kids at other stages of growth i.e. at birth, pre-weaning, six months, nine months, twelve months and fifteen months. However, average heart girth of Khari goat kids was observed to be higher for the kids born to the dams of heavier/larger body size as compared to the contemporary kids born to the dams of medium or smaller size. Similarly, Yilmaz et. al. (2013) reported the significant effect of dams weight/size on heart girth of Saanen and its crosses with Hair-goats at the age of three months ($p<0.05$) and six months ($p<0.01$) except at birth ($p>0.05$), indicating higher value of heart girth with respect to the kids born to the dams with medium weight as compared to those born to the dams with lighter weight.

Effect of sex of kids

Sex of kids, in present study had significant influence on heart girth of kids at birth ($p<0.001$), pre-weaning ($p<0.05$), weaning ($p<0.05$), six months ($p<0.01$), nine months ($p<0.001$), twelve months ($p<0.001$), and fifteen months ($p<0.001$). Accordingly, male kids had 7.5%, 5.7%, 25.6%, 13.1%, 5%, 6.7%, and 6.3 % higher heart girth as compared to that of contemporary female kids at birth, pre-weaning, weaning, six months, nine months, twelve months and fifteen months age, respectively. Sapkota (2007) working in the goats of eastern, central and western region of Nepal reported the significant effect of sex on heart girth of kids at two months ($p<0.05$), weaning and six months ($p<0.01$) age. However, heart girth of kids at birth, weaning and eight months was not significantly affected by the sex of kids. Bhattarai (2007) also reported the variation in heart girth of local Terai goat kids with respect to the sex at different ages i.e. birth, pre-weaning, weaning, six months and eighth months indicating higher value of heart girth for male kids as compared to the females. Yilmaz et al. (2013) working in Saanen and its crosses with Hair-goats reported the significant effect ($p<0.05$) of sex on wither height of kids at six months age, however the trait was not significantly differed with respect to sex of kids at birth and weaning age. Similarly, heart girth was statistically significant ($p<0.05$) between the male and female in all age groups of Bengal goats where males showed higher measurements than their female counterparts (Tudu et. al., 2015). Results of present study was also in accordance with the findings of Kurnianto et. al. (2013) and Gyaneshwari et. al. (2007) working on local goats (Kejobong and Etawa Grade) in Central Java, Indonesia and Black Bengal goats in India, respectively. Furthermore, Elmaz et. al. (2012) reported significant influence ($p<0.05$) of sex

on heart girth at one month and 3 months age of kids of a newly defined indigenous goat breed in Turkey. Ray et. al. (2015) also confirmed the significantly (P<0.05) higher heart girth of males as compared to that of females at birth, three months, six months, nine months and twelve months age of kids. The detail information on the effect of sex on heart girth of Khari goat kids at different ages is presented in Table 2.

Effect of birth type

Heart girth of Khari goat kids was significantly influenced (p<0.001) by the effect birth type at all stages of growth i.e. at birth, pre-weaning, weaning, six months, nine months, twelve months and fifteen months (Table 2). Accordingly, the kids born as singlets had significantly larger heart girth at birth (30.56 cm), pre-weaning (41.47 cm), weaning (51.04 cm), six months (54.20 cm), nine months (58.58 cm), twelve months (61.91 cm) and fifteen months age (66.02 cm) as compared to the contemporary kids born as twins and triplets at their respective ages. Sapkota (2007) working on the goats of eastern, central and western region of Nepal reported significant effect of birth type on heart girth at birth (p<0.05), two months preweaning (p<0.01), weaning (p<0.05), and eight months post weaning (p<0.001), except six months age of the kids, and confirmed the significantly heart girth of single born kids as compared to those born as multiple at all stages of growth from birth to eight months post-weaning which was in accordance to the findings of present study. Yilmaz et. al. (2013) working in Saanen and its crosses with Hair-goats reported in disagreement to the findings of this study. Accordingly, heart girth of kids was not significantly affected by the effect of birth type at all stages of growth under study.

Table 2. Effect of non-genetic factors on heart girth (cm) at different stages of growth of Khari kids

Fixed factors	No.	Birth	Weaning	Nine months	Fifteen months
Overall	1260	29.62±0.58	49.41±1.05	57.09±1.02	65.04±1.17
Altitude		NS	*	NS	NS
Lower	188	29.78±0.83	50.89±1.50	57.72±1.45	66.29±1.67
Upper	1072	29.46±0.49	47.92±0.89	56.45±0.86	63.79±0.99
Color		***	*	NS	NS
Black	460	30.12±0.58^{a}	49.72±1.06^{a}	57.38±1.02	65.33±1.18
Black/white	45	28.90±0.66^{d}	48.10±1.21^{b}	55.85±1.17	63.61±1.35
Brown	537	29.78±0.57b^{c}	49.55±1.03^{a}	57.37±1.00	65.31±1.15
Mixed	64	29.47±0.63^{c}	49.54±1.14^{a}	57.39±1.10	65.84±1.27
White	154	29.83±0.60^{ab}	50.12±1.09^{a}	57.45±1.05	65.11±1.21
Season of kidding		**	*	*	*
Spring	548	28.54±0.52^{c}	46.84±0.95^{c}	55.63±0.92^{c}	63.36±1.06^{c}
Rainy	26	29.64±1.56^{b}	53.90±2.83^{a}	59.76±2.74^{a}	68,62±3.15^{a}
Autumn	316	30.60±0.56^{a}	48.43±1.02^{b}	56.00±0.99^{bc}	63.30±1.13^{c}
Winter	370	29.70±0.53^{b}	48.46±0.96^{b}	56.96±0.93^{b}	64.87±1.07^{b}
Parity		NS	**	*	NS
Early (1st and 2nd)	424	29.13±0.36	45.88±0.66^{c}	56.43±0.64^{b}	63.73±0.74
Middle (3rd to 6th)	634	30.30±1.10	54.00±2.00^{a}	59.77±1.94^{a}	67.99±2.23
Late (> 7th)	202	29.40±0.90	48.35±1.64^{b}	55.07±1.58^{b}	63.39±1.82
Size of dams		NS	*	NS	NS
Small	152	29.33±1.08	47.23±1.96^{b}	56.40±1.90	64.49±2.18

Medium	902	29.66±0.40	48.68±0.73[b]	57.24±0.70	64.74±0.81
Large	206	29.86±0.67	52.31±1.22[a]	57.66±1.18	65.88±1.36
Sex		***	*	***	***
Male	696	30.70±0.54	50.57±0.98	58.11±0.95	67.05±1.09
Female	564	28.54±0.74	40.25±1.34	55.30±1.30	63.02±1.49
Birth type		***	***	***	***
Single	754	30.56±0.56[a]	51.04±1.01[a]	58.58±0.98[a]	66.02±1.12[a]
Twins	472	29.37±0.58[c]	49.21±1.04[b]	56.66±1.01[b]	63.78±1.16[c]
Triplets	34	29.93±0.72[b]	48.00±1.30[c]	56.02±1.26[b]	65.31±1.45[b]
Coefficient of variation (CV)		6.33%	7.28%	5.95%	6.09%

*Note: *: Significant at 5% level (i.e. p<0.05); **: Significant at 1% level (i.e. p<0.01); ***: Significant at 0.1% level (i.e. p<0.001); NS: Non-significant (i.e. P≥0.05); Means, within an effect, with the different superscript are significantly different; LS mean: Least square means; SEM: Standard error of Means; No: Number of observations*

Body length

The overall mean body length of *Khari kids* at birth, pre-weaning, weaning, six months, nine months, twelve months and fifteen months, in present study was determined 28.09 cm, 37.46 cm, 43.94 cm, 47.04 cm, 51.67 cm, 55.53 cm, and 59.96 cm, respectively (Table 3). Bhattarai (2007) reported slightly higher values of body length local Terai goat kids at almost all stages of growth. Similarly, Sapkota (2007) also reported higher values of body length of goat kids from eastern, central and western region of Nepal at all stages of growth i.e. from birth to eight months stage. Yilmaz et. al. (2015) working on Saanen and its crosses with Hair-goats reported significantly higher values of body length of kids at birth, three months and six months age as compared to the findings of present study. However, Ray et. al. (2015) and Tudu et. al. (2015) reported significantly lower values of body length of indigenous goat kids from Odisha and Bengal goats from West Bengal, India in contrast to the results of this study.

Effect of altitude

Results of this study reflected that altitude was confirmed as an important source of variation with respect to the body length of Khari goat kids at birth ($p<0.05$), pre-weaning ($p<0.01$), weaning ($p<0.01$), six months ($p<0.05$) and fifteen months age ($p<0.05$), except nine and twelve months (Table 3). Accordingly, kids from lower altitude were observed always to be longer as compared to the contemporary kids from upper altitude. Sapkota (2007) working in the goats of eastern, central and western region of Nepal also reported the highly significant effect ($p<0.001$) of location (resembling to altitude) on the body length of kids at birth, pre-weaning, weaning, six months and eight months age indicating longer body of the goats from Chitwan district as compared to those from Siraha, Udaypur and Tanahun districts.

Effect of coat color

Findings of this study reflected that coat color of the kids had significant influence on body length of Khari goat kids at weaning ($p< 0.01$), six months($p< 0.05$), nine months ($p< 0.05$), twelve months ($p< 0.01$) and fifteen months age ($p< 0.01$), except at birth and pre-weaning (Table 3). Accordingly, kids of mixed coat color had longer body at pre-weaning, nine months, and fifteen months; and that of white coat color at birth, weaning, six months

and twelve months age. Tudu et. al. (2015) reported significant influence ($p<0.05$) of coat color on body length of Bengal goats at all stages of growth indicating the higher value of the trait in White Bengal goat kids followed by Brown Bengal and Black Bengal goats.

Effect of season of kidding

Results of this study confirmed that body length of Khari goat kids was only significantly influenced ($p<0.01$) by the season of kidding at pre-weaning (Table 3). The trait at the age of birth, weaning, six months, nine months, twelve months and fifteen months age were not significantly differ according to the variation in the season of kidding. However, body length of Khari goat kids in this study was higher for the kids born in autumn season at birth and weaning age; rainy season at pre-weaning and six months age; and winter season at nine, twelve, and fifteen months age of growth. Sapkota (2007) in contrast to the findings of this study, reported the significant effect of season of kidding on body length at pre-weaning ($p<0.001$) and eight months ($p<0.05$) age of goat kids from eastern, central, and western region of Nepal, indicating higher value of body length for the kids born in wet season at birth, dry season at pre-weaning, weaning, six months and eight months age.

Effect of parity

Parity of dams had significant influence body length of kids at pre-weaning ($p<0.05$), weaning ($p<0.001$) and six months ($p<0.01$) age (Table 3). However, body length of kids at birth, nine months, twelve months and fifteen months did not have significant influence with respect to the parity of dams. Kids from dams in middle parity had the longest body length followed by the kids born from the dams of late and early parity at all stages of growth. Yilmaz et. al. (2013) investigating the survival rate, growth performance and some body measurements of Saanen and its crosses with Hair-goats reported non-significant effect of dams' age on body length at birth, three months and six months age. Similarly, Sapkota (2007) reported non-significant influence of dams' parity on heart girth of goat kids indicating higher value of body length for the kids born to the does of late parity at birth and eight months age, and that of middle parity at pre-weaning, weaning, and six months age.

Effect of size of dam

Body length of Khari goat kids in this study was significantly ($p<0.05$) affected by the size of dams at weaning age (Table 3). Whereas, the trait was not significantly influenced by the effect of dams' size at other stages of growth of Khari goat kids ($p>0.05$). However, results reflected that, body length of the kids at all stages of growth were determined to be higher for the kids born to larger dams as compared to those born to medium and smaller dams. Similarly, Yilmaz et al. (2013) reported the non-significant effect of dam's weight/ size on body length of Saanen and its crosses with Hair-goats at birth, three months and six months age.

Effect of sex of kids

Results of present study revealed that sex of kids had significant influence on the body length of kids at birth ($p<0.001$), weaning ($p<0.05$), six months ($p<0.05$), nine months ($p<0.05$), twelve months ($p<0.001$), and fifteen months age ($p<0.001$) except at pre-weaning ($p>0.05$) age of growth (Table 3). Sapkota (2007) working in the goats of eastern, central and western region of Nepal reported significant effect of sex on body length at pre-weaning

($p<0.01$), weaning ($p<0.05$), and six months ($p<0.0$) age of kids. Bhattarai (2007) on the other hand also reported higher body length of male kids as compared that of contemporary female kids. Yilmaz et. al. (2013) working in Saanen and its crosses with Hair-goats reported the significant effect ($p<0.05$) of sex on body length of kids at six months age, however the trait was not significantly differed with respect to sex of kids at birth and three months age. Similarly, the body length was statistically significant ($p<0.05$) between the male and female in all age groups of Bengal goats where males showed higher measurements than their female counterparts (Tudu et. al., 2015). Results of present study was also supported by Kurnianto et. al. (2013) and Gyaneshwari et. al. (2007) working on local goats (Kejobong and Etawa Grade) in Central Java, Indonesia and Black Bengal goats in India, respectively. Furthermore, Elmaz et. al. (2012) working in Honamli goat kids in Turkey reported significant influence ($p<0.05$) of sex on body length at 3 months age of kids. On the other hand, Ray et. al. (2015) had confirmed the significantly ($P<0.05$) higher body length of males as compared to that of females at birth, three months, six months, nine months and twelve months age of kids.

Effect of birth type

Results of this study reflected that birth type was an important source of variation ($p<0.001$) with respect to the body length of kids at all stages of growth i.e. birth, pre-weaning, weaning, six months, nine months, twelve months and fifteen months age (Table 3). Accordingly, body length of Khari goat kids under this study was significantly higher for the kids born as singlet as compared the contemporary kids born as twins and triplets at all stages of growth. Average body length of Khari goat kids in this study ranged from 27.59 cm for triplets and 28.47 cm for singlet at birth and reached to 50.09 cm and 60.56 cm for triplets and singlet at fifteen months age, respectively. Sapkota (2007) working on the goats of eastern, central and western region of Nepal reported significant effect of birth type on body length at two months preweaning ($p<0.05$), weaning ($p<0.01$), and eight months post weaning ($p<0.001$) age of the kids, and confirmed the significantly higher body length of single born kids as compared to those born as multiple at all stages of growth from birth to eight months post-weaning. However, wither height at birth and six months post weaning age of kids was not significantly influenced by the effect of birth type. Yilmaz et. al. (2013) working in Saanen and its crosses with Hair-goats reported the significant influence ($p<0.05$) of birth type on body length of kids at six months age except at birth and three months.

Table 3. Effect of non-genetic factors on body length (cm) at different stages of growth of Khari kids

Fixed factors	No.	Birth	Weaning	Nine months	Fifteen months
Overall	1260	28.09±0.67	43.94±1.07	51.67±0.95	59.96±0.98
Altitude		*	**	NS	*
Lower	188	29.29±0.96	45.79±1.52	52.47±1.36	61.41±1.39
Upper	1072	26.87±0.57	42.08±0.90	50.86±0.81	58.50±0.82
Color		NS	**	*	**
Black	460	28.28±0.68	43.97±1.07^{bc}	51.61±0.96^{ab}	59.94±0.98^{b}
Black/white	45	27.71±0.77	42.82±1.22^{c}	50.49±1.09^{b}	58.42±1.12^{c}
Brown	537	28.16±0.66	43.65±1.05^{bc}	51.71±0.94^{ab}	60.15±0.96^{b}
Mixed	64	27.97±0.73	44.38±1.16^{ab}	52.43±1.03^{a}	61.13±1.06^{a}
White	154	28.39±0.69	44.87±1.10^{a}	52.10±0.99^{a}	60.15±1.01^{b}
Season of kidding		NS	NS	NS	NS
Spring	548	27.56±0.61	42.88±0.96	51.44±0.86	60.12±0.88
Rainy	26	28.42±1.81	44.26±2.87	51.75±2.57	60.14±2.63
Autumn	316	28.49±0.65	44.51±1.03	51.68±0.93	59.18±0.95
Winter	370	27.88±0.61	44.12±0.97	51.81±0.87	60.38±0.89
Parity		NS	***	NS	NS
Early (1st and 2nd)	424	26.94±0.42	41.26±0.67^{b}	51.22±0.60	59.46±0.61
Middle (3rd to 6th)	634	29.26±1.28	49.05±2.03^{a}	52.71±1.82	61.40±1.86
Late (> 7th)	202	28.05±1.05	41.50±1.66^{b}	51.07±1.49	59.00±1.52
Size of dams		NS	*	NS	NS
Small	152	27.36±0.47	42.08±1.24^{b}	50.59±0.66	59.50±0.68
Medium	902	27.96±0.78	43.22±0.74^{b}	51.78±1.78	59.92±1.13
Large	206	28.93±1.25	46.52±1.99^{a}	52.63±1.11	60.46±1.82
Sex		***	*	*	***
Male	696	29.31±0.63	44.99±0.99	52.85±0.89	61.56±0.91
Female	564	26.87±0.86	42.88±1.36	50.49±1.22	58.35±1.24
Birth type		***	***	***	***
Single	754	28.47±0.65^{a}	45.30±1.03^{a}	53.03±0.92^{a}	60.56±0.94^{a}
Twins	472	28.20±0.83^{b}	43.64±1.06^{b}	51.31±0.95^{b}	60.22±1.21^{b}
Triplets	34	27.59±0.67^{c}	42.87±1.32^{c}	50.66±1.18^{c}	59.09±0.97^{c}
Coefficient of variation (CV)		8.00%	8.27%	6.68%	5.69%

CONCLUSION

Based on the findings of current study, it can be concluded that the importance of morphological characterization of and the relationship between the non-genetic determinants with the major body linear traits of Nepalese indigenous Khari goats shouldn't be undermined. Results revealed the existence of wide range of morphological variations within the Khari goat populations with respect to altitude, coat color, kidding season, dam's parity, dam's size, birth type, and sex of kids. For instance, significant effect of sex on three linear body measurements at different stages of growth indicates the existence of sexual dimorphism in the goat populations in the research area. Significant effect of location on linear body measurements is an indication of influence of management and environments on

the performance of the goat populations in the areas. These widely varying morphological traits and the significant effect of the non-genetic determinants on them could be exploited for future goat genetic improvement programs by selecting breeding stock with superior phenotypic merit with respect to major morphological traits such as body length, wither height and heart girth.

ACKNOWLEDGEMENT

The author expresses sincere thanks and heartfelt gratitude to University Grants Commission (UGC), Sanothimi, Bhaktapur for partial financial assistance for this piece of work. Directorate of Research and Extension (DOREX) and Faculty of Animal Science, Veterinary Science and Fisheries under Agriculture and Forestry University are highly acknowledged for the constant technical and administrative facilitation for this scientific work. Most importantly, Prof. Dr. Manaraj Kolakshyapati, Prof. Dr. Naba R. Devkota, Dr. Shreeram P. Neopane, Uday C. Thakur, Neena A. Gorkhali, and Saroj Sapkota are specially acknowledged for their everlasting support and cooperation during the course of this study. Participant farmers of Hupsekot Rural Municipality, Deurali, Nawalparasi are highly appreciated and sincerely acknowledged for their constant and selfless support during the entire period of field experiment.

REFERENCES

Bhattarai, N. (2007). Morphological characterization and productive performance of Terai goat in Siraha, Nepal. (Unpublished master thesis). *Institute of Agriculture and Animal Sciences*, Tribhuvan University, Nepal. 92p.

Bhattarai, N., Gorkhali, N. A., Kolakshyapati, M., & Sapkota, S. (2019). Breeds and Breeding System of Indigenous and Crossbred Goats in Nepal. *In Goats (Capra)*. IntechOpen. DOI: http://dx.doi.org/10.5772/intechopen.82821

Bolacali, M. (2010). The investigation of various production traits of Saanen goat raised in Mus region. (Unpublished doctoral dissertation), Yüzüncü Yil Universityesi Saglık Bilimleri Enstitusu, Van.

Duncan, D.B. (1955). Multiple Range and Multiple F Tests. *Biometrics*, 11:1-42.

Elmaz O., Saatci, M., Mamak, N., Dag, B., Aktas, A.H., & Gok, B. (2012). The determination of some morphological characteristics of Honamli goat and kids, defined as a new indigenous goat breed of Turkey. *Kafkas Univ Vet FakDerg* 18(3): 481-485.

FAO (2020). Domestic animal diversity information system. Rome. (available at http://www.fao.org/dad-is/). Retrieved on 14th August, 2020.

Gyaneshwari, T., Anjali, H., Roy, S., Bera, S., Pradhan, P.C., & Samanta, A.K. (2007). Studies on association of body weight with body measurement in Black Bengal goat under village condition of West Bengal. *J. Interacademicia* 11: 455-460.

Hagan, J.K., Apori, S.O., Bosompem, M., Ankobea, G., Mawuli, A., Al-Hagan, E.T. (2012). Morphological Characteristics of Indigenous Goats in the Coastal Savannah and Forest Eco-Zones of Ghana. *J. Anim Sci Adv.* 2(10): 813-821.

Harvey, W.R. (1990). Users' Guide for LSMLMW and MIXMDL. PC-2 Version. *Mixed Model Least Squares and Maximum Likelihood Computer Program*.

Henderson, C.R. (1953). Estimation of variance and covariance components. *Biometrics*, 9:226-252.

Kolachhapati, M.R. (2006). Phenological study of hill goats under different management systems and nutritional regimes. (Unpublished doctoral dissertation). Institute of Agriculture and Animal Sciences, Tribhuvan University, Nepal. 148p.

Kurnianto, E., Sutopo, S., Purbowati, E., Setiatin, E.T., Samsudewa, D. & Permatasari, T. (2013). Multivariate analysis of morphological traits of local goats in Central Java, Indonesia. *Iranian Journal off Applied Animal Science,* 3, 361–367.

MoALD. (2019). *Statistical Information on Nepalese Agriculture.* Agri-business Promotion and Statistics Division (ABPSD), Ministry of Agriculture and Livestock Development (MoALD), Singh Durbar, Kathmandu, Nepal.

Neopane, S.P. (1997). Genetics of productive traits in a Nepalese Hill goat flock. (Unpublished doctoral dissertation). University of London, UK. 278p.

Neopane, S.P. (2000). Selection for improvement of the productivity of Hill goats in Nepal. *Proceedings of the 7th International Conference on Goats.* Organized by International Goat Association, France. pp. 206-208.

Patro P.C. and Mishra, M. (1987). Performance of Ganjam breed of goats under field condition in Orissa : A note. *Ind J. Anim Prod Management*, 3: 40-43.

Poudel, J.R. (2020). *Evaluation of Boer Cross with Different Breeds of Goat in Surkhet, Nepal.* (Unpublished master thesis). Agriculture and Forestry University, Rampur, Chitwan, Nepal.

Ray S., Nayak, G.D., Dhal, S.K., Mishra, S.K., Sahoo, G., Mishra, S., & Dash, S.K. (2015). Non-genetic effect on body weight and body measurement of indigenous goats at different stages of growth in north central plateau climatic zone of Odisha, India. *Explor Anim Med Res* 5(2): 196-201.

Salako, A.E. & Ngere, L.O. (2002). Application of multifactorial discriminant analysis in the morphometric structural differentiation of West African Dwarf (WAD) and Yankasa sheep in South West Nigeria. *Nigerian Journal of Animal Production*. 29:163-167.

Sapkota, S. (2007). Comparative performances of goats representing eastern, central and western development regions of Nepal. (Unpublished master thesis). Institute of Agriculture and Animal Sciences, Tribhuvan University, Nepal. 138p.

Simsek, U.G. & Bayraktar, M. (2006). Investigation of growth rate and survivability characteristics of pure Hair goats and Saanen x pure Hair goats Crossbreeds (F1). *Firat Universitesi Saglik Bilimleri Dergisi,* 20 (3): 229-238.

Tudu, N.K., Pyne, S.K. & Ghosh, N. (2015). Comparative biometrics and performances of three colour varieties of Bengal goats in their home tract. *Explor Anim Med Res* 5(2): 183-189.

Yilmaz, O., Kucuk, M., Bolacali, M., & Cak, B. (2013). Investigation of survival rate, growth performance and some body measurements of Saanen x Hair goat F1 crossbred and pure Hair goat kids raised in semi-intensive conditions, 19(4), 835–840.