The Journal of Animal & Plant Sciences, 25(5): 2015, Page: 1251-1258
ISSN: 1018-7081

PRINCIPAL COMPONENT ANALYSIS OF MORPHOLOGICAL TRAITS OF ASSAM HILL GOAT IN EASTERN HIMALAYAN INDIA

G. Khargharia[1*], G. Kadirvel [2], S. Kumar[3], S. Doley[2], P. K. Bharti [4]and Mukut Das [5]

Livestock Production Division,
ICAR Research Complex for NEH Region, Umroi Road, Umiam, Meghalaya – 793 103
[*]Corresponding author E-mail – gautkhar74@gmail.com

ABSTRACT

The present study aimed to investigate the type and function of the Assam Hill goat of Northeast India. A total of 67 female animals of 2 to 4 years of age were randomly selected to record body weight and 13 linear body measurements and 21 body indices. The body weight (BW), body length (BL), height at withers (HAW), rump height (RH), rump length (RL), rump width (RW), chest depth (CD), heart girth (HG), paunch girth (PG), cannon bone length (CL), cannon bone circumference (CC), sacral pelvic width (SPW), shoulder width (SW) and sternum height (SH) were estimated to be 24.86 ± 0.80 kg, 61.48 ± 0.57, 54.57 ± 0.57, 58.05 ± 0.59, 14.57 ± 0.23, 13.11 ± 0.27, 27.68 ± 0.45, 71.93 ± 0.99, 86.05 ± 1.77, 12.14 ± 0.17, 7.71 ± 0.10, 76.93 ± 1.34, 15.66 ± 0.24 and 26.89 ± 0.49 cm, respectively. The height slope (HS), length index (LI), body index (BI), pelvic index (IP), dactyl thorax index (DTI), body ratio (BR), Baron and Crevat (BC), compact index (CI), balance, area index (AI) and relative cannon thickness index were found to be 3.43 ± 0.29, 1.14 ± 0.02, 86.87 ± 0.85, 92.49 ± 2.54, 9.82 ± 0.38, 0.93 ± 0.01, 93.18 ± 2.86, 5.48 ± 0.23, 5.63 ± 0.23, 3355.13 ± 48.84 and 12.95 ± 0.14 respectively. The correlation coefficients were found to be highest between BW and BL (0.86) and lowest between RW and PG (-0.32). Principal component (PC) analysis after varimax rotation produced four PCs which showed 85.84 per cent of the total variation. The coefficient of determination (R^2) value was found to be 0.74 when BL was included in the prediction model, but it increased to 0.87 when the other linear measurements viz. HG, RL, PG and SPW were included in the model. The inclusion of PCs to predict body weight of Assam Hill goat was found to be more precise. The study revealed that Assam Hill goat is elipometric, well adapted to the hilly terrain of Northeast India and suitable for meat production.

Keywords: Assam Hill goat, linear body measurements, body indices, regression, Principal component analysis.

INTRODUCTION

Assam Hill goat is a small breed of goat of eastern Himalayan region used mainly for meat production. Genetic improvement of indigenous livestock species is of importance because of their adaptation to harsh climatic condition and their disease tolerance capacity. They can also be valuable experimental animals in fundamental research and a potential store of unique genes, which may be useful when environmental concern necessitates changes in production system (Salako and Ngere, 2002).

Growth and development is important for production of meat animals. Body weight and body measurements are important parameters to describe growth. In addition to weight measurement, body measurements can describe completely an individual or a population (Salako, 2006a). Phenotypic characteristics are important in breed identification and classification. The first step of the characterization of local genetic resources is to assess variation of morphological traits (Delgado *et al.*, 2001). Linear body measurements could be used as selection criteria for improvement of meat production in goat (Khan *et al.*, 2006) and for prediction of body weight in goat (Mohammed and Amin 1997).

Different equations based on regression analysis have been recommended by various researchers (Adeyinka *et al.*, 2006; Khan *et al.*, 2006; Pesmen and Yardimci, 2008) to predict the body weight based on different body measurements in different goat breeds. But the same may not be applicable to Assam Hill goat. Alternative body measurements and indices estimated from various combinations of conventional and non-conventional body parameters not only provide superior guide to weight but are also used as indicators of type and function in domestic animals (Schwabe and Hall, 1989; Salako, 2006b).

Desirable body conformation, from the meat production viewpoint, is such a complex character that little progress has been made in reducing it to a single corporal measurement which can be taken on the live animal. Conformation indices from different body measurements, an objective assessment of body conformation from the standpoint of type may be relatively easier (Mwacharo *et al.*, 2006). Beyond weight, type and function is becoming more important as a better indicator of the usefulness of the animal. Without some qualification and quantification of associated type and conformation, the value of weight only is limited. Combination of different linear measurements in the form of indices may be more useful to describe the type and function of animal. A more reliable assessment of morphometric relationship among livestock breed has been obtained using multivariate statistical tools such as principal component (PC) analysis (Yakubu *et al.*, 2009).

Principal component analysis (PCA) is an interdependence technique whose primary purpose is to define the underlying structure among the variables under study. Though the number of components generated in PCA equals the number of variables in the study, first few components accounts for the highest proportion of the total variance. PCA has been used as a tool in the assessment of the body shapes which could be of evolutionary significance as well as permit an understanding of the complex growth process going on in the body dimensions of an animal during growth period (Salako, 2006b). Results of principal component analysis not only impact the management of animals but also help in conservation and selection of multiple traits by breeders (Yunusa *et al.*, 2013).

The present investigation aimed to estimate the relationship among various linear body measurements and body weights of adult Assam Hill goats and to evaluate the various conformation indices constructed from linear body measurements.

MATERIALS AND METHODS

Study area: A total of 67 adult female Assam Hill goats (2-4 years of age) were used in the present investigation for collection of body weight and 13 different morphological measurements. The animals were reared in the Livestock Farm, Indian Council of Agricultural Research, Meghalaya of Northeast India under semi intensive system. The animals were allowed grazing for 3 to 4 hours in the morning (8.30 AM to 12 Noon) and then they were housed and provided with fodder viz. maize, hybrid napier, guinea grasses, cow pea, cabbage and cauli flower leaves and concentrate feed comprising maize, wheat bran, soya meal, ground nut cake, mineral mixture and salt (300-350 g/day/head).

Data collection: Measurements of 13 morphological characters viz. body weight (BW), body length (BL), height at withers (HAW), rump height (RH), rump width (RW), rump length (RL), heart girth (HG), sternum height (SH), chest depth (CD), paunch girth (PG), cannon bone length (CL), cannon bone circumference (CC), sacral pelvic width (SPW), and shoulder width (SW) were recorded. Measuring tape was used to record the length and girth measurements and weight of the individual animal was measured using electronic balance in the morning by the same person to avoid human error. Height measurements were taken using graduated stick. Before measuring various parameters, the animals were restrained and calmed properly. From the linear body measurements 21 body indices were calculated according to Alderson (1999), Chacón *et al.* (2011), Lopez *et al.* (1992), McManus *et al.* (2008) and Salako (2006b) methods in order to assess the type and function of the breed of goat under study. Morphological indices calculated are -

1. Height slope (HS) = Rump height – height at withers
2. Length index (LI) or Relative body index = Body length/ height at withers
3. Depth index (DI) = Chest depth/ height at withers
4. Girth index (GI) = Paunch girth/ Heart girth
5. Body index (BI) = (Body length/ Heart girth)* 100. When this measure is greater than 0.90, the animal is longiline; between 0.86 to 0.88 is medigline; and less than 0.85, it is brevigline.
6. Proportionality (Ipr) = (Height at withers/ Body length)*100
7. Pelvic index (PI) = (Rump width/ Rump length) * 100
8. Transverse pelvic (IPT) = (Rump width/ Rump height) *100
9. Longitudinal pelvic (IPL) = (Rump length/ Rump height) * 100
10. Relative depth of Thorax (IPRT) = (Chest depth/ Height at withers) * 100
11. Dactyl thorax index (DTI) = (Cannon bone circumference/ Heart girth) * 100. The DTI may not be more than 10.5 in light animals, upto 10.8 in intermediary; upto 11.0 in light meat animals and upto 11.5 in heavy meat type.
12. Pectoral index (PI) = [(Height at withers + Rump height)/2]/ Sternum height
13. Thoracic development (TD) = Heart girth/ Height at withers
14. Body ratio (BR) = Height at withers/ Rump height
15. Baron and Crevat (BC) or Conformation index = (Heart girth) ^{2}/ Height at withers
16. Weight (W) = (Heart girth) $^{3\ *}$ 80. Weight above 45 kg corresponds to large or hypermetric animals, between 35 and 45 kg medium or eumetric animals and below 35 kg, small or elipometric animals.
17. Compact index 1 (CI1) = (Weight/ Height at withers)/ 100. Compact index indicates how compact the animal is. Meat type animals have values above 3.15. Value close to 2.75 indicates dual purpose and close to 2.60 indicates that the animals are more suitable for milk purpose.
18. Balance = (Rump length x Rump width)/ (Chest depth x Shoulder width)
19. Width slope (WS) = Rump width/ Shoulder width
20. Area index (AI) = Height at withers x Body length

21. Relative cannon thickness index = (Cannon circumference/ Height at withers) x 100

Statistical analysis: Mean, standard error and correlation coefficients were computed using SPSS (2008). From correlation matrix, data were generated for the principal component (PC) factor analysis using the factor programme in SPSS. The PC analysis was verified for adequate determinant factor, sample adequacy using Kaiser-Meyer-Olkin test and sphericity using Bartlett's test.

Principal component analysis is a method for transforming the variables in a multivariate data set X_1, X_2, --------, X_p into new variable Y_1, Y_2,--------, Y_p, which are uncorrelated with each other and account for describing proportions of the total variance of the original variables (Everitt *et al.*, 2001; Mulyono *et al.*, 2009) defined as –

$Y_1 = a_{11}x_1 + a_{12}x_2 + ... + a_{1p}x_p$

$Y_2 = a_{21}x_1 + a_{22}x_2 + ... + a_{2p}x_p$

$Y_p = a_{p1}x_1 + a_{p2}x_2 + ... + a_{pp}x_p$

with coefficients being chosen so that, y_1, y_2,........, y_p account for decreasing proportions of the total variance of the original variables x_1, x_2, ..., x_p. To enhance the interpretability of the principal components, the varimax criterion of the orthogonal rotation method was employed in the rotation of the factor matrix.

Prediction of body weight from linear body measurements using the stepwise multiple regression procedure was carried out using the model –

$BW = a + b_i x_i + ... + b_k x_k$

Multiple regression procedure was also used to predict body weight from principal component factor scores according to the following equation –

$BW = a + b_iPC_i + ... + b_k PC_k$

Where BW is the body weight, 'a' is the regression intercept, b_i is the i^{th} partial regression coefficient of the i^{th} linear body measurement, x_i or the i^{th} principal component (PC).

RESULTS

Morphological traits: The means and standard error of linear body measurements of Assam Hill goats are presented in Table 1. The RH was found to be higher than the HAW indicating that the animal is sloppy. The body weight showed the maximum variation (14.99) followed by PG (9.63) and RW (9.55).

Phenotypic correlations: The phenotypic correlations among BW and various morphological measurements are presented in Table 2. A total of 81 correlations were estimated, out of which 23 correlations were positively significant (P<0.05, P<0.01) and 12 correlations were found to be negative. The correlation coefficients ranged between -0.32 (RW and PG) and 0.86 (BW and BL). Most of the correlations between RW and other linear measurements were negative. BW had higher correlations with BL (0.86), HG (0.79), RL (0.70), SPW (0.57) and PG (0.53), whilst lowest with SH (-0.32).

Body indices: The different body indices estimated for Assam Hill goats are presented in Table 3. The body ratio index showed that the Assam Hill goat is slightly lower at the withers than the rump. The BI (86.87), PI (92.49) and Ipr (88.52) are related to proportionality of the animal as a whole. The body length is marginally greater than height at withers (RBI-1.14) and body index value showed that the animals were medigline. The pectoral index revealed that the sternum height was almost half of the back height (2.11).

Pelvic indices, both IPT (22.76) and IPL (24.90) showed that the Assam Hill goats had narrow hips. The IPRT (50.88) is an indirect measure of leg length.

Principal component analysis: Out of 13 linear body measurements, 11 measurements were selected for principal component analysis (PCA). Anti image matrices and Kaiser-Meyer-Olkin measure of sample adequacy (0.60), Bartlett's test for sphericity (P<0.01, Chi square – 169.10) as well as the values of communalities gave credence to the appropriateness of the PCA (Table 4). Kaiser (1974) recommended the acceptable value of 0.5 for sample adequacy. The large communalities (0.71 to 0.95) observed in the present investigation indicate that a large number of variance has been shared by the variables, permitting the PCA to classify them. After varimax rotation of the component matrix, four PCs were extracted for the goat breed which accounted for 85.84 per cent of the total variance. There were variations in the pattern of loadings of the body measurements on each PC. First PC (PC1) was characterized by BL, RL, HG, PG and SPW and contributed the largest portion of the total variance (40.37%), which might be considered as body size factor. The second PC (PC2) comprised of four body dimensions (HAW, RH and CD) contributed 24.93 per cent to the total variance. The third PC (PC3) was influenced by RW and CL, which contributed 10.58 per cent of the total variance, whilst the fourth PC (PC4) had high factor loadings for SW contributing 9.96 per cent to the total variance.

Prediction of body weight from interdependent linear body measurements and their unrelated independent principal components: The summary of stepwise multiple regression analysis and models for predicting body weight from interdependent morphological measurements and independent principal component factor scores are presented in Table 5. Body length and heart girth accounted for 73.6 and 62.0 per cent of variation in body weight respectively. When these two traits were combined, 80 per cent of the variation of body weight was explained. This result is also evident from the high correlation of body weight with body length and heart girth (r =0.86, r = 0.79) respectively. Height at withers alone showed only 10.0 per cent variation in body weight. The accuracy of the model was increased to 86.3 per cent when rump length and paunch girth were included and to 86.5 per cent when rump length, paunch girth and sacral pelvic width were included along with heart girth and body length. The prediction model including body length, heart girth, rump length and paunch girth may be considered best for prediction of body weight of Assam Hill goat.

The use of PC1 explained 64.4 per cent of the total variation in body weight. When all the PCs were included, considerable improvement in the amount of variance (R^2= 0.75) was observed and found to be the best prediction model.

Table 1. Mean and standard error (Mean ± SE) for different linear body measurements of adult Assam Hill goat.

Traits	Mean ± SE	Coefficient of variation (%)
Body weight (kg)	24.86 ± 0.80	14.99
Body length (cm)	61.48 ± 0.57	4.37
Height at withers (cm)	54.57 ± 0.57	4.89
Rump height (cm)	58.05 ± 0.59	4.81
Rump length (cm)	14.57 ± 0.23	7.28
Rump width (cm)	13.11 ± 0.27	9.55
Chest depth (cm)	27.68 ± 0.45	7.61
Heart girth (cm)	71.93 ± 0.99	6.46
Paunch girth (cm)	86.05 ± 1.77	9.63
Cannon bone length (cm)	12.14 ± 0.17	6.50
Cannon bone circumference (cm)	7.71 ± 0.10	6.34
Sacral pelvic width (cm)	76.93 ± 1.34	8.18
Shoulder width (cm)	15.66 ± 0.24	7.13
Sternum height (cm)	26.89 ± 0.49	8.49

Table 2: Correlation coefficients among the linear body measurements of Assam Hill goat

	BW	BL	HAW	RH	RL	RW	CD	HG	PG	CL	SPW	SW	CC	SH
BW	1.00													
BL	0.86**	1.00												
HAW	0.14	0.06	1.00											
RH	0.14	0.08	0.87**	1.00										
RL	0.70**	0.69**	0.07	0.16	1.00									
RW	-0.12	-0.06	0.22	0.33	0.01	1.00								
CD	0.33	0.14	0.57	0.57**	0.22	0.15	1.00							
HG	0.79**	0.71**	0.25	0.30	0.78**	-0.21	0.36	1.00						
PG	0.53*	0.56*	0.31	0.26	0.61**	-0.32	0.28	0.87**	1.00					
CL	0.31	0.24	0.55**	0.57**	0.29	0.59**	0.69**	0.18	0.06	1.00				
SPW	0.57*	0.56*	0.12	0.16	0.09	-0.18	0.30	0.84**	0.83**	0 .20	1.00			
SW	0.27	0.06	0.14	0.02	0.76**	-0.05	0.24	-0.05	-0.27	0.18	-0.06	1.00		
CC	0.19	0.12	0.45*	0.42	0.03	0.13	0.15	0.24	0.24	0.13	0.23	0.30	1.00	
SH	-0.14	-0.06	0.65**	0.48	-0.12	0.13	-0.26	-0.04	0.10	0.00	-0.14	-0.05	0.39	1.00
	BW	BL	HAW	RH	RL	RW	CD	HG	PG	CL	CC	SPW	SW	SH

* =p < 0.05, ** = p < 0.01, BW=body weight, BL=body length, HAW=height at withers, RH=rump height, RL=rump length, RW=rump width, CD=chest depth, HG=heart girth, PG=paunch girth, CL=fore cannaon length, SPW=sacral pelvic width, SW=shoulder width, CC=cannon bone circumference, SH=sternum height

Table 3. Morphological indices of Assam Hill goat.

Index	Mean ± SE
Height slope	3.43 ± 0.29
Length index / Relative body index	1.14 ± 0.02
Depth index	0.51 ± 0.01
Girth index	1.20 ± 0.03
Body index (IB)	86.87 ± 0.85

Proportionality (Ipr)	88.52 ± 1.21
Pelvic index (IP)	92.49 ± 2.54
Transverse pelvic (IPT)	22.76 ± 0.44
Longitudinal pelvic (IPL)	24.90 ± 0.48
Relative depth of thorax (IPRT)	50.88 ± 0.71
Dactyl thorax index (DTI)	9.82 ± 0.38
Pectoral index (PI)	2.11 ± 0.03
Thoracic development (TD)	1.32 ± 0.02
Body ratio (BR)	0.93 ± 0.01
Baron & Crevat (BC)/ Conformation index	93.18 ± 2.86
Compact index (CI)	5.48 ± 0.23
Balance	5.63 ± 0.23
Width slope (WS)	0.84 ± 0.02
Area index (AI)	3355.13 ± 48.84
Weight (W)	30.13 ± 1.27
Relative cannon thickness index	12.95 ± 0.14

Table 4. Eigenvalues, total variance, factor and factor loadings after varimax rotation with Kaiser Normalization in Assam Hill goat.

Traits	PC1	PC2	PC3	PC4	Communalities
Body length	0.83	-	-	-	0.72
Height at withers	-	0.93	-	-	0.88
Rump height	-	0.90	-	-	0.86
Rump length	0.90	-	-	-	0.84
Rump width	-	-	0.92	-	0.91
Chest Depth	-	0.75	-	-	0.71
Heart girth	0.91	-	-	-	0.93
Paunch girth	0.80	0.30	-0.34	-0.30	0.95
Shoulder width	-	-	-	0.96	0.94
Sacral pelvic width	0.89	-	-		0.83
Cannon bone length	-	0.58	0.69		0.87
Eigenvalues	4.44	2.74	1.16	1.10	
Percentage of total variance	40.37	24.93	10.58	9.96	
Cumulative %	40.37	65.30	75.88	85.84	

Table 5. Relationships between body weight and linear body measurements of adult Assam Hill goat.

Component	Prediction equation	SE	R^2
Original body measurements as independent variables			
BL	BW= - 48.34 + 1.19 BL	9.80	0.74
HAW	BW = 14.21 + 0.20 HAW	16.90	0.10
HG	BW = - 20.62 + 0.63 HG	7.97	0.62
HG and BL	BW= - 47.44 + 0.29 HG + 0.84 BL	8.72	0.80
BL, HG, RL and PG	BW= -51.32 + 0.78BL + 0.71HG – 0.20RL – 0.23PG	7.84	0.86
BL, HG, RL, PG and SPW	BW= -50.82 + 0.77BL + 0.73HG – 0.07RL – 0.21PG – 0.06SPW	8.08	0.87
Orthogonal traits as independent variables			
PC1	BW = 24.86 + 2.99 PC1	0.50	0.64
PC1 and PC2	BW = 24.86 + 2.99 PC1 + 0.32 PC2	0.51	0.65
PC1, PC2 and PC3	BW = 24.86 + 2.99 PC1 + 0.32 PC2 + 0.17 PC3	0.52	0.65
PC1, PC2, PC3 and PC4	BW = 24.86 + 2.99 PC1 + 0.32 PC2 + 0.17 PC3 + 1.22 PC4	0.44	0.76

DISCUSSION

The present findings were lower for BW, HG, HAW, BL and CD than Sannen goats (Pesmen and Yardimci, 2008) and goats of Pakistan (Khan *et al.*, 2006). Coefficient of variation was found to be highest for body weight (14.99), which could be important for selection and improvement. The coefficient of variation found in the present investigation is in accordance with the results of other studies in goats (Herrera *et al.*, 1996); and sheep (Janssens and Vandepitte, 2004).

The phenotypic correlations of body weight with body length and heart girth found in the present investigation are in concordance with the results of Khan *et al.* (2006) and Pesmen and Yardimci (2008) except with HAW. Tsegaye *et al.* (2013) reported higher correlation between body weight and heart girth, height at withers and rump height, but lower values between body weight and body length and rump length in Hararghe Highland goat of Ethiopia compared to the results of the present investigation. Positive and highly significant correlations in the present investigation would be useful for predicting boy weight in Assam Hill goat as reported by Salako (2006b). The high phenotypic correlations between body weight and other linear body measurements indicate that selection for body measurements will favour the selection for body weight.

Morphological indices are used to describe the size and proportion of an animal, which are the relationship among various linear body measurements. Conformation indices are relationships among body measurements that are used to describe the proportions and general size of parts of animals. The pelvic index is used to determine the proportionality of the hind quarters and could be related to reproductive capability (Cerqueira *et al.*, 2011). The PI indicated the low meat production ability of Assam Hill goat. But, the animals are predominantly used for meat production. This could be one of the reasons for introduction of other breeds for crossbreeding to improve the production potential. The balance is essential for the animals to climb hills and descend valleys effectively. The weight index showed that the animal was small or elipometric, which was also evident from the Baron and Crevat index. The value of length index in the present investigation is in agreement with the findings of Salako (2006b) in WAD sheep. Chacon *et al.* (2011) reported that Cuban Creole goats and their crossbreds were lower at withers compared to the rump, which contradicts the result of the present investigation. They also reported almost similar body index (85.29), pelvic transverse (21.81), relative depth of thorax (47.66), width slope (84.50), thoracic development (1.26), higher proportionality (93.19), pelvic longitudinal and Baron and cravat (BC) and lower pelvic index (76.00) and compact index (5.20) in Cuban Creole goat compared to the present results. The DTI in the present study is greater than the results reported by other authors in sheep (Chacon *et al.*, 2011; Casanova *et al.*, 2013). The various conformation indices studied revealed that the Assam Hill goat is well adapted to the hilly terrain of eastern Himalaya region and suitable for meat production.

The present results showed that the breed under study was short, with a body close to the ground, which might correspond to its adaptation to hilly terrain. The compact index showed that the animals were suitable for meat production and they had good thoracic development. This is an important criterion for animals in terms of fitness and good respiratory system, especially in high altitude. The width slope indicated that the animals were narrow at the fore quarter compared to the hind quarter.

The DTI gives the indication of skeletal fineness; it is greater in meat animals compared to milk animals. The relative cannon thickness index in the present study showed medium legs, which is important to grazing animals for grazing in large areas with less difficulty.

The result of the present investigation is similar to other studies that used principal component factor analysis as reported by Kurnianto *et al.* (2013) in goat; Yunusa *et al.* (2013) and Yakubu (2013) in sheep. The candidate traits loaded in the same component were classified together and it may be concluded that the elements present in the same cluster probably have common genomic sites for their genetic control; therefore pleiotropy may be implicated. The relevance of principal component analysis as a multivariate statistical tool was evident in the reduction of large number of explanatory variables into components that gave a better description of size and shape. The principal components obtained could be useful in evaluating the Assam Hill goats for selection programme. Since correlations between principal components are zero, the selection of animals for any principal component will produce independent response in terms of other principal components (Pinto *et al.*, 2006). In morphometric application of PCA, PC1 was acceptable as a size vector and PC2 as a shape vector as reported in goat (Okpeku *et al.*, 2011) and sheep (Yakubu *et al.*, 2011).

A combination of linear body measurements would provide a good estimator for body weight. This is in agreement with other authors (Atta and El Khidir, 2004; Afolayan *et al.*, 2006; Fajemilehin and Salako, 2008). In the present study, HAW was found to be less reliable in predicting body weight, which is in agreement with the results reported by earlier workers (Sulabo *et al.*, 2006; Machebe and Ezekwe, 2010; Tadesse *et al.*, 2012). The present results indicated that morphological measurements could be used fairly for prediction of body weight. However, the use of body measurements to predict body weight should be considered with care due to multicollinearity, which has been shown to be associated with unstable regression estimates (Ibe, 1989; Ogah, 2011). The use of principal component scores (orthogonal traits) gave a better and reliable assessment of body weight since it was able to break multicollinearity, a problem associated with the use of interdependent original body dimensions (Yakubu *et al.*, 2009).

Conclusion: The extracted principal components from different linear body measurements represent the general body size and shape of the goat population. The study indicated that principal components can be used effectively for selection of animals based on a group of variables that are related to one another. The prediction of body weight based on principal component factor scores is more reliable than the use of interrelated individual linear body measurements. The information obtained in the present study would be useful for phenotypic characterization of Assam Hill goat.

Acknowledgements: The authors are thankful to the Director, ICAR Research Complex for NEH Region, Meghalaya for providing necessary facilities to carry out the study. The authors are also grateful to the staff of Livestock Farm for rendering help during data collection.

REFERENCES

Adeyinka, I. A. and I. D. Mohammed (2006). Accuracy of body weight prediction in Nigeria Red Sokoto Goats raised in North Eastern Nigeria using linear body measurement. Pakistan J. Biol. Sci. 9 (15): 2828-2830.

Afolayan, R. A., I. A. Adeyinka and C. A. M. Lakpini (2006). Prediction of live weight from objective Body Weight From live-dimensional traits in Yankassa sheep. Proceeding of the 31 Annual Conference of Nigerian Society for Animal Production, March 12th -15th 2006, Bayero University, Kano, Nigeria.

Alderson, G. L. H. (1999). The development of a system of linear measurements to provide an assessment of type and function of beef cattle. Anim. Genet. Resour. Info. 25: 45-55.

Atta, M. and O. A. El Khidir (2004). Use of Heart Girth Wither Height and Scapulaischial Length for Prediction of Live Weight of Nilotic Sheep. Small Rumin. Res. 55 (1-3): 233-237.

Casanova P., M. Pere, E. S. Mwaanga, M. Caballero, J. Sabate and S. Valenzuela (2013). Biometrical multivariate study of the Zambian indigenous Fat-tailed sheep. Int. J. Livest. Prod. 4 (9): 148-154.

Cerqueira, J. O. L., X. Feas, A. Iglesias, L. F. Pacheco and J. P. P. Araujo (2011). Morphological traits in Portuguese Bordaleira deEntre Douro e Minho sheep: divergence of the breed. Anim. Reprod. Sci. 51: 635-641.

Chacon, E., F. Macedo, F. Velazquez, S. R. Paiva, E. Pineda and C. McManus (2011). Morphological measurements and body indices for Cuban Creole goats and their crossbreds. Rev. Brasileria de Zootecnia, 40 (8): 1671-1679.

Delgado, J. V., C. Barba, M. E. Camacho, F. T. P. S. Sereno, A. Martinez and J. L. Vega-Pla (2001). Livestock characterization in Spain. Anim. Genet. Resour. Info. 29: 7-18.

Everitt, B. S., S. Landau and M. Leese (2001). Cluster analysis. 4th edn., Arnold Publisher, London.

Fajemilehin, O. K. S. and A. E. Salako (2008). Body measurement characteristics of the West African Dwarf (WAD) goat in deciduous forest zone of Southwestern Nigeria. African J. Biotech. 7 (14): 2521-2526.

Herrera, M., E. Rodero, M. J. Gutierrez, F. Pena and J. M. Rodero (1996). Application of multifactorial discriminant analysis in the morphostructural differentiation of Andalusian caprine breeds. Small Rumin. Res. 22: 39-47.

Ibe, S. N. (1989). Measures of size and conformation in commercial broilers. J. Anim. Breed. Genet. 106: 461-469.

Janssens, S. and W. Vandepitte (2004). Genetic parameters for body measurements and linear type traits in Belgian Blue du Maine, Suffolk and Texel sheep. Small Rumin. Res. 54: 13-24.

Kaiser, H. F. (1974). An index to factorial simplicity. Psychometrika, 39 (1): 31-36.

Khan, H., F. Muhammed, R. Ahmed, G. Rahimullah and M. Zubair (2006). Relationship of body weight with linear body measurements in goats. J. Agric. Biol. Sci. 1 (3): 51-54.

Kurnianto, E., S. Sutopo, E. Purbowati, E. T. Setiatin, D. Samsudewa and T. Permatasari (2013). Multivariate analysis of morphological traits of local goats in Central Java, Indonesia. Iranian J. Appl. Anim. Sci. 3 (2): 361-367.

López, J. L., A. Arguello, J. Henríquez, C. Alvarez and N. Darmanin (1992). Contribution to the study of black canary pig. Archivos de Zootec. 41: 531-536.

Machebe, N. S. and A. G. Ezekwe (2010). Predicting body weight of growing finishing gilts raised in the tropics using linear body measurements. Asian J. Experimental Biol. Sci. 1 (1): 162-165.

Mohammed, I. D. and J. D. Amin (1997). Estimating body weight from morphometric measurements of Sahel (Borno White) goats. Small Rumin. Res. 24: 1-5.

McManus, C., G. S. Filho, H. Louvandini, L. T. Dias, R. A. Teixeira and L. S. Murata (2008). Growth of Saanen, Alpine and Toggenburg goats in the federal district, Brazil: genetic and environmental factors. Ciencia Anim. Brasileira, 9 (1): 68-75.

Mulyono, R. H., A. Gunawan and C. Sumantri (2009). Characteristics of size and shape of body dimension of Madura and Rote (Indonesia) Fat-Tailed sheep using Principal component analysis. The 1st International Seminar on Animal Industry. Pp 253-258.

Mwacharo, J. M., A. M. Okeyo, G. K. Kamande and J. E. O. Rege (2006). The small East African shorthorn zebu cowsin Kenya. In: Linear body measurements. Trop. Anim. Health Prod. 38: 65-74.

Ogah, D. M. (2011). Assessing size and conformationof the body of Nigerian indigenous Turkey. Slovak J. Anim. Sci. 44: 21-27.

Okpeku, M., A. Yakubu, S. O. Peters, M. O. Ozoje, C. O. N. Ikeobi, O. A. Adebambo, I. G. Imumorin (2011). Application of multivariate principal component analysis to morphological characterization of indigenous goats in Southern Nigeria. Acta Argiculturae Slovenica. 98 (2): 101-109.

Pesmen, G. and M. Yardimci (2008). Estimating the live weight using somebody measurements in Saanen goats. Archiva Zootech. 11(4): 30-40.

Pinto, L. F. B., I. U. Packer, C. M. R. De Melo, M. C. Ledur and L. L. Coutinho (2006). Principal components analysis applied to performance and carcass traits in the chicken. Anim. Res. 55: 419-425.

Salako, A. E. (2006a). Application of morphological indices in the assessment of type and Function in sheep. Int. J. Morph. 24:8- 13.

Salako, A. E. (2006b). Principal component factor analysis of the morphostructure of the immature Uda sheep. Inter. J. Morph. 24: 571-574.

Salako, A. E. and L. O. Ngere (2002). Application of multifactorial discriminant analysis in the Morphometric structural differentiation of the WAD and Yankasa sheep in the humid southwest Nigeria. Nigerian J. Anim. Prod. 29 (2): 163-167.

Schwabe, A. E. and S. J. G. Hall (1989). Dystocia in nine British breeds of cattle and its relationships to the dimensions of the dam and calf. The Vet. Record, 125**:** 636-639.

SPSS (2008). Computer Software 17.0 SPSS inc., Chicago, Illinois-60606, USA.

Sulabo, R. C., J. Quackenbush, R. D. Goodband, M. D. Tokach, S. S. Dritz, J. M. DeRouchey and J. L. Nelssen (2006). Validation of flank to flank measurements for predicting boar weight. Swine Day Report Kansas State University Swine Day. Report of Progress pp. 19-23

Tadesse, A., T. Gebremariam and S. K. Gangwar (2012). Application of linear body measurements for predicting body weight of Abergelle goat breed in Tigray Region, Northern – Ethiopia. Global J. Biosci. Biotech. 1(2): 314-319.

Tsegaye, D., B. Belay and A. Haile (2013). Linear body measurements as predictor of body weight in Hararghe Highland Goats under Farmers Environment: Ethiopia. Global Vet. 11 (5): 649-656.

Yakubu, A. (2013). Principal component analysis of the conformation traits of Yankasa sheep. Biotech. Anim. Husban. 29 (1): 65-74.

Yakubu, A., D. Kuje and M. Okpeku (2009). Principal components as measure of size and shape in Nigerian indigenous chickens. Thai J. Agric. Sci. 42 (3): 167-176.

Yakubu, A., A. E. Salako and A. R. Abdullah (2011). Varimax rotated principal component analysis of the zoometrical traits of Uda sheep. Archieva Zootech. 60: 813-816.

Yunusa, A. J., A. E. Salako and O. A. Oladejo (2013). Morphometric characterization of Nigerian indigenous sheep using multifactorial discriminant analysis. International J. Biodiv. Conserv. 5 (10): 661-665.