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Research Article

Using factor analysis to characterise the body structure of male and female indigenous Tswana goat at the kid and grower ages

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Abstract

This study was conducted to estimate the relationships among body measurements and determine underlying factors describing the body structure of female and male Tswana goats at kid and grower age-groups. Body-weight (BW), body-length (BL), heart-girth (HG), height-at-withers (HW), shoulder-width (SW), neck-length (NL), tail-length (TL) and ear-length (EL) were recorded from 273 female and 278 male kids, 699 female and 281 male growers. Fifteen farmers keeping goats were randomly selected from each district excluding Tsabong and Ghanzi districts and records taken on a random sample of 4-12 animals *per* farm in 2001. Data were analysed to determine correlations among the variables and factors explaining the variability in the body structure of Tswana goats were extracted. Significant ($P<0.05$) strong and positive correlations ($r=0.81$ to 0.89) of BW to BL, HW and HG in male and female kids and male growers were found. There were significant weak to moderate correlations ($r=0.21$ to 0.51) between BW and SW while in female growers, the correlation between BW and HW was not significant ($P>0.05$). In female kids general body size factor explained 54% of the variation in body structure. For male kids and growers, general body size and shoulder width factors explained 72.3% and 61.3% of the variation respectively. Neck-length, body shape and shoulder-width factors explained 58.4% of the body variation in female growers. The identified one to three factors (height at withers, heart girth, shoulder width and body length) described the body structure of the Tswana goats and have potential use in selection for improved productivity.

Keywords: Body structure, eigenvalue, factor analysis, measurements, goats

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INTRODUCTION

Breed characterisation is recognised as the first approach to the sustainable utilisation of animal genetic resource for benefit of communities (Okpeku *et al*., 2011; Tolenkhomba *et al*., 2012). However, there is scanty research dealing with the characterisation of the genetic resources of goats (Lanari *et al.,* 2003) especially indigenous breeds. In particular, characterization of the Tswana goat breed is limited, hence these animals are not fully exploited for poverty alleviation and food self-security by the resource-limited farmers who keep this indigenous breed (Nsoso *et al*., 2004). Analysis of variance and correlations are widely used for phenotypic characterisation and to obtain relationships among linear body measurements of animals (Tolenkhomba *et al*., 2012). When the recorded traits are correlated, factors derived by principal components method can better explain the relationships (Pundir *et al*., 2011). Factor analysis, which is a multivariate data reduction technique, is used in an attempt to explain correlations among several variables in terms of one or more unobservable or latent factors (Johnson and Wichern, 2002). New linear combinations of variables are derived from the original variables and usually a few of these new variables are sufficient to describe the individual or group without too much loss of information (Pundir *et al*., 2011; Tolenkhomba *et al*., 2012). If these new and fewer variables are easy to measure and can be found then resource-limited farmers can use these to select their animals with less costs. Therefore, the objectives of this study were to estimate the relationships among body measurements and determine underlying factors that define the body structure or conformation in male and female Tswana goats at kid and grower ages.

MATERIALS AND METHODS

Data

The data set used in this study was part of the data described in detail by Nsoso *et al*. (2004) which was collected during the dry season between June and September 2001. Typically during this period natural pastures do not meet the nutrient requirements for animals, necessitating supplementary feeding. However supplementary feeding is not widely used in the traditional sector; for instance, only 5.9% of goat farmers reported using supplementary feeds (Statistics Botswana 2014). The study area covered representative areas of the six agricultural regions that spanned the whole of Botswana except for Tsabong and Ghanzi districts. In each district a total of 15 farmers keeping goats were randomly selected and records taken on a random sample of 4-12 animals *per* farm. Body weight (BW), body length (BL), heart girth (HG), height at withers (WH), shoulder width (SW), neck length (NL), tail length (TL) and ear length (EL) were recorded (Nsoso *et al*., 2004). In addition, age of each animal was estimated by dentition (Katongole *et al*., 1996). Two age sub-classes according to Katongole *et al*. (1996) were used namely; kids (0-12 months) and growers (13-24 months) of age. The data were recorded from 1531 indigenous Tswana goats comprising; 273 female and 278 male kids and, 699 female and 281 male growers.

Statistical Analysis

All statistical analyses were performed using Statistical Analysis System software (SAS Version 9.2, 2002-2008). An initial analysis was carried out using the Procedure General Linear Model (GLM) fitting the model below to identify the factors significantly (P<0.05) affecting performance:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + e_{ijk}$$

Where Y_{ijk} is the observation of the eight traits of the goats studied, μ is the overall mean, α_i is the sex effect, β_j is the age effect, $\alpha\beta_{ij}$ is the sex and age interaction and e_{ijk} is the random error associated with each observation and ~NID (0,σ2). Effects of site or region was previously tested by Nsoso *et al*. (2004). Least squares means were separated using the least significant difference and their standard errors were reported. The Procedure CORR (SAS Version 9.2, 2002-2008) was used to determine correlations between BW, BL, SW, WH, HG, NL, TL and EL traits.

Based on the strength of the correlation matrices, underlying factors explaining the variability were extracted using the principal components method Procedure PRINCOMP (SAS Version 9.2, 2002-2008). The Kaiser criterion was used to determine the number of principal components extracted retaining only those with eigenvalues greater than 1 (Ford *et. al*., 1986; Johnson and Wichern 2002; Darlington 2010). An orthogonal set of factors were extracted by rotation using varimax method Procedure FACTOR ROTATE=VARIMAX (SAS Version 9.2 2002-2008). Thus the following orthogonal factor model (Johnson and Wichern 2002) was applied:

$$y_1 = l_{11}x_1 + l_{12}x_2 + \ldots\ldots + l_{17}x_p$$
$$y_2 = l_{21}x_1 + l_{22}x_2 + \ldots\ldots + l_{27}x_p$$

$$y_p = l_{p1}x_p + l_{p2}x_p + \ldots\ldots + l_{pp}x_p$$

Where $x_1, x_2, \ldots\ldots, x_p$ are the original measured traits; $y_1, y_2, \ldots.., y_p$ are new variables also called factors, which are uncorrelated with each other; $l_{11}, l_{21}, \ldots.., l_{pp}$ are coefficients called factor loadings chosen such that $y_1, y_2, \ldots.., y_p$ account for decreasing proportions of the total variance of the original variables $x_1, x_2, \ldots\ldots, x_p$. To simplify the interpretation of a factor, variables with loadings (l_{ip}) greater than 0.6 were considered important to the particular factor.

Communality estimates, (h^2), which is the proportion of a variable's variance explained by the factor structure, was used to describe the goodness of fit of the factors to the data (Johnson and Wichern 2002) where

$$h_i^2 = l_{i1}^2 + l_{i2}^2 + \ldots. + l_{im}^2$$

and l_{im} is the loading of the i^th^ variable on the m^th^ factor. These correlations are also called factor loadings (StatSoft Inc. 2012). The closer the communality value is to unity the more important the variable is in explaining the variation in the data. The computed factors were then named based on theoretical considerations.

RESULTS

Results from the analysis of variance showed a significant (P < 0.05) interaction between age group and sex. Hence all further analyses were applied within the sex and age-group. Significant differences (P < 0.05) between female and male goats were found in body weight, body length and height at withers within each age group. For heart girth significant differences were found between female and male kids only (Table 1). With other variables, no significant differences (P > 0.05) between females and males within age groups were observed. Generally, within each age group the male goats tended to be larger than their female counterparts (Table 1) in all studied variables. Correlations among variables were determined for each of the four sex and age groups separately and are presented in Tables 2 and 3.

Generally, the correlation coefficients between body weight and linear traits in female and male kids were positive and significant (Table 2). For both female and male kids, very strong and significant (P < 0.05) correlation coefficients (r >0.70) were found between body weight and heart girth, height at withers and body length (Table 2).

Moderate and significant (P < 0.05) correlations were found between body weight, neck length and tail length for male kids (Table 2).

All correlation coefficients between body weight and other linear measurements in female and male growers were positive (Table 3). For female growers, a strong and significant (P < 0.05) correlation (r=0.76) was found between body weight and heart girth while it correlated moderately with body length (r=0.57).

Body weight had weak but significant (P < 0.05) correlations to shoulder width, neck length, tail length and ear length. For male growers, body weight correlated strongly and significantly to heart girth (r=0.82), height at withers (r=0.79) and moderately to body length (r=0.68). Weak but significant correlations were found between body weight and other variables (Table 3).

Table 1. Mean (±SE) live weight and linear body traits for different age-groups and sexes of indigenous Tswana goats sampled and measured from the whole of Botswana†

Variable	Kids		Growers	
	Female	Male	Female	Male
Body weight (kg)	18.0±0.52^{a}	18.8±0.51^{b}	33.2±0.32^{a}	33.8±0.51^{a}
Body length (cm)	46.9±0.47^{a}	47.9±0.47^{b}	58.5±0.29^{a}	59.2±0.46^{b}
Height at withers (cm)	51.7±0.67^{a}	53.2±0.67^{b}	63.5±0.42^{a}	64.7±0.66^{b}
Heart girth (cm)	58.8±0.48^{a}	59.7±0.48^{b}	75.5±0.30^{a}	75.8±0.47^{a}
Shoulder width (cm)	11.1±0.27^{a}	11.8±0.26^{a}	13.3±0.17^{a}	13.3±0.26^{a}
Neck Length (cm)	20.0±0.31^{a}	19.6±0.31^{a}	23.8±0.19^{a}	23.7±0.31^{a}
Tail length (cm)	12.2±0.13^{a}	12.9± 0.13^{a}	13.9±0.08^{a}	15.0±0.13^{b}
Ear length (cm)	15.3±0.20 ^{a}	15.4±0.20 ^{a}	17.0±0.13^{a}	17.3± 0.20^{a}
Sample size (N)	273	278	699	281
LSD (0.05)	0.74		0.61	

† - N is the sample size for each sub-class

^{abc} Means with different superscripts within a row and age-group differ significantly (*p*<0.05)

Table 2. Correlation coefficients among body weight and linear body measurements of female and male Tswana goat kids indigenous sampled and measured from the whole of Botswana

Trait	BW	BL	HW	HG	SW	NL	TL	EL
BW		0.78*	0.87*	0.88*	0.51*	0.21*	0.52*	0.55*
BL	0.82*		0.82*	0.81*	0.45*	0.18*	0.52*	0.39*
HW	0.86*	0.79*		0.89*	0.38*	0.24*	0.49*	0.52*
HG	0.88*	0.82*	0.90*		0.42*	0.23*	0.52*	0.48*
SW	0.21*	0.21*	0.14*	0.19*		0.11^{ns}	0.47*	0.38*
NL	0.65*	0.46*	0.68*	0.66*	0.10^{ns}		0.15*	0.11^{ns}
TL	0.67*	0.56*	0.65*	0.68*	0.19*	0.54*		0.39*
EL	0.47*	0.26*	0.49*	0.40*	0.07^{ns}	0.53*	0.41*	

† - Correlations on the upper triangle are for females while those on the lower triangle males

ns = not statistically significant at p<0.05 level of significance; * statistically significant at p<0.05 level of significance

Table 3. Correlation coefficients among body weight and linear body measurements of female and male Tswana goat growers sampled and measured from the whole of Botswana †

Trait	BW	BL	HW	HG	SW	NL	TL	EL
BW		0.57*	0.05ns	0.76*	0.17*	0.25*	0.21*	0.29*
BL	0.68*		0.08ns	0.45*	0.03ns	0.01ns	0.10*	0.10*
HW	0.79*	0.72*		0.07ns	0.00ns	0.07*	0.07ns	0.05ns
HG	0.82*	0.67*	0.76*		0.14*	0.28*	0.26*	0.27*
SW	0.28*	0.07ns	0.00ns	0.27*		0.02ns	0.16*	0.09*
NL	0.34*	0.21*	0.44*	0.30*	0.02ns		0.17*	0.31*
TL	0.48*	0.40*	0.46*	0.49*	0.22*	0.32*		0.17*
EL	0.36*	0.28*	0.34*	0.32*	0.12*	0.27*	0.27*	

† - Correlations on the upper triangle are for females while those on the lower triangle are for males

ns = not statistically significant at $p<0.05$ level of significance; * statistically significant at $p<0.05$ level of significance

Based on the generally significant and moderate to high correlations, factors were extracted separately for each of the four sex and age groups (Tables 4 and 5). In female kids, only one factor with an eigenvalue of 3.8 was retained based on Kaiser criterion (Table 4). This factor was called general body size and had high loadings on height at withers (l2=0.90), heart girth (l2=0.90), body length (l2=0.87), tail length (l2=0.70), moderate loadings for ear length (l2=0.64) and shoulder width (l2=0.61) and, a very low loading on neck length (l2=0.29) (Table 4). This factor explained 53.5% of the total variability observed in body structure. Based on the strength of communalities, important variables to measure in characterising the body structure of female kids were height at withers (h2=0.81), heart girth (h2=0.81) and body length (h2=0.77), see Table 4. For male kids, two factors with eigen values of 4.1 and 1.0 were retained, respectively (Table 4). Factor 1 explained 58.0% of the variability and loaded highly on height at withers (l2=0.92), heart girth (l2=0.91), neck length (l2=0.81), body length (l2=0.77) and tail length (l2=0.77). This factor also loaded moderately on ear length (l2=0.65) and very low on shoulder width (l2=0.08). This factor was called general body size. Factor 2 explained 14.3% of the total variation in body structure and loaded highly on only one variable, shoulder width (l2=0.90) and therefore it was termed shoulder width. These two factors explained 72.3% of the total variation in body structure (Table 4). Based on the strengths of communalities, the most important variables to measure in describing the body structure of male goat kids are height at withers (h2=0.87), heart girth (h2=0.87), shoulder width (h2=0.81) and body length (h2=0.72) followed by neck length (h2=0.67) and tail length (h2=0.62), (Table 4). Hence the body structure of male Tswana goat kids can be characterised using their general body size and shoulder width. Based on the Kaiser criterion, in female growers, three factors with eigenvalues of 1.9, 1.1 and 1.0 respectively were retained (Table 5). The first factor explaining 27.7% of the variability in body structure and loaded highly on neck length (l2 =0.82) and ear length (l2=0.72). This factor was called neck length. Factor 2 loaded highly on body length (l2=0.90) and heart girth (l2=0.75) and explained 15.8% of the total variability in body structure. The factor was called body shape. The third factor, which loaded highly on shoulder width (l2=0.85) explained 14.8% and, was termed shoulder width. The three factors together explained 58.3% of the total observed variation in body structure (Table 5). Based on the strength of communality values, important variables to measure in characterising the body structure of female grower were body length (h2=0.82), shoulder width (h2=0.72) and heart girth (h2=0.70), Table 5. For male growers, two factors with eigenvalues of 3.1 and 1.2 respectively, were retained and together explained 61.4% of the total variation (Table 5). Factor 1 explaining 46.1% of the total variation in body structure had high loadings on height at withers (l2 =0.92), heart girth (l2 =0.83) and body length (l2=0.81). It also had moderate loadings on tail length (l2 =0.62) and neck length (l2=0.57). This factor was called general body size. The second factor explaining 15.3% of the total variation in body structure had low factor loadings in all variables except shoulder width which had a loading of l2=0.96. The factor was therefore termed shoulder width. Based on communalities, important variables to measure were shoulder width (h2=0.92), height at withers (h2=0.84) and heart girth (h2=0.76), Table 5. Hence the body structure of male growers can be characterised using general body size and shoulder width.

Table 5. Eigen values, proportion of total variance explained along with factor loadings and communalities of the body measurements of male and female Tswana goat growers sampled and measured from the whole of Botswana

	Female				Male		
Trait	Factor1 l^2	Factor2 l^2	Factor 3 l^2	Communality h^2	Factor 1 l^2	Factor 2 l^2	Communality h^2
Body Length	-0.11	0.90	-0.05	0.82	0.82	0.04	0.65
Height at withers	0.20	0.24	-0.37	0.23	0.92	-0.06	0.84
Heart Girth	0.35	0.75	0.14	0.70	0.83	0.28	0.76
Shoulder Width	0.04	0.07	0.85	0.72	0.02	0.96	0.92
Neck Length	0.82	0.01	-0.08	0.67	0.57	-0.12	0.34
Tail Length	0.38	0.24	0.45	0.41	0.62	0.34	0.51
Ear Length	0.72	0.11	0.06	0.53	0.49	0.18	0.28
Eigen value	1.9	1.1	1.0		3.1	1.2	
Variance explained (%)	27.7	15.8	14.8		46.1	15.3	

DISCUSSION

Higher numbers of females at grower than males of the same age is common (Katongole *et al*. 1996; Fajemilehin and Salako 2008). This is because farmers prefer to keep female goats while male goats are sold to provide income (Nsoso *et al*., 2004; Khan *et al*., 2006; Moaeen-ud-Din *et al*., 2006; Ojedapo *et a*l., 2007; Kunene *et al*., 2009; Fajemilehin and Salako 2008). Such flock structures are important because farmers are cognisant of the fact that to maintain a constant flock size, more reproductive active females are required than males (Katongole *et al*., 1996).

The significant increase in body weight and linear traits from the kid to the grower stages of growth and development in both sexes is consistent with findings of Nsoso *et al*. (2004) and Khan *et al*. (2006). Butterfield (1988) explained that this represents growth and development of normal farm animals where body weight and linear body traits increase with age. The moderate to high positive and significant correlation coefficients between body weight and linear body traits are consistent with the findings of Adeyinka and Mohammed (2006) and Cam *et al*. (2010) who reported similar results and concluded that linear body measurements can be used to estimate body weight in goats. Furthermore, such moderate to high correlations are essential because they characterise relationships between body weight and linear body traits. Consistent with Sebolai *et al*. (2012), predictive equations based on such relationships can be derived, which could ultimately be used to make measuring tapes that can be applied in selection, marketing and general management of this indigenous goat breed kept by the resource-limited farmers who predominantly farm under traditional systems.

Except for female growers, the first factor that was retained in describing the body structure was called general body size and it explained between 46-58% of the total variability. This was consistent with the findings of Shahin and Hassan (2000) who characterised body shape characters at marketing age of three rabbit breeds using factor analysis and reported a first factor called general size which accounted for 75% of the variability in New Zealand White, 80% in Black Baladi and for 81% in the Red Baladi rabbits.

Except for female kids which only had one factor retained, the two to three factors retained together explained 58% to 72% of the variation in body structure of male kids and growers. This is consistent with the findings of Moses (2010) who reported three factors for West African Dwarf goats accounting for 86.6% and 75.2% of the total variation in the body structure of males and females respectively. Similar findings were also reported by Okpeku *et al*. (2011) who applied factor analysis in characterising indigenous goats in Southern Nigeria and extracted two factors for each sex of the two breeds studied. Pundir *et al*., (2011) applied factor analysis in their study to explain the body conformation of Kankrej cows and found three important factors explaining 66.02% of the total variation.

Based on factor loadings and communalities, the common most important traits to measure in characterising the body structure of kids and growers of Tswana goats were identified as height at withers, heart girth, shoulder width and body length. This is consistent with Tolenkhomba *et al*. (2012) who applied factor analysis in studying the local cows of Manipur in India and found that some of the traits such as ear length and tail length had very low communalities indicating that the traits are less effective in accounting for variation of body conformation as compared to other traits. Pundir *et al*. (2011) reported that factor analysis with varimax rotation reduced the number of biometric traits to be used to explain body conformation in their study. The reduction in the number of variables to describe the body structure is beneficial to the resource poor farmers who experience challenges in keeping records and also simplifies and makes implementation of breeding programmes easy. Hence Okpeku *et al*. (2011) concluded that factor analysis could be used alongside other traits in evaluating animals for management purposes.

CONCLUSIONS

Sex and age influenced parameters indicating that estimates should be determined separately to be beneficial. Strong and positive correlations between body weight and body length, height at withers and heart girth in male and female kids were found. Weak to moderate and significant correlations were found between body weight and shoulder width. The observed correlations describe relationships between body weight and linear body traits. Two factors characterising Tswana male kids and male growers were identified as general body size and shoulder width and explained 72.3% and 61.4% of the common variation in their body structure respectively. In female kids, 53.5% of the variability in body structure was explained by the general body size factor only while the neck-length, body shape and shoulder width factors accounted for 58.3% in female growers. Four variables were identified as important in characterising the body structure of the studied goats which were body length, height at withers, heart girth and shoulder width. Ear length and tail length were not necessary in characterising these goats and could be left out from measurement without much loss of information. Therefore, the body structure of the studied Tswana goats can be described using one to three factors. These identified factors have potential use as selection criteria in improving the productivity of Tswana goat through breeding. Further studies applying confirmatory factor analysis are recommended to validate these findings before extensively using them in breeding programmes.

Conflict of Interest BS is the Deputy Dean; BOJAAS is funded by the Office of the Dean of Faculty of Agriculture

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