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Principal component analysis of body biometric traits in Marathwadi buffaloes

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ABSTRACT

The identification of livestock breed is a necessity for its long-term maintenance and utilisation. Principal component analysis of morphometric traits has proved successful for reduction in the number of features needed for morphological evaluation in livestock species, which keeps costs down and saves time and efforts. Eighteen body biometric traits, viz. Height at withers, Leg length, Neck length, Neck circumference, Body length, Chest girth, Abdominal girth, Face length, Face width, Ear length, Horn length, Horn base circumference, Distance between horns, Hip-bone distance, Pin-bone distance, Distance between hip and Pubis bone, Rump length and Tail length of 103 Marathwadi buffaloes were analysed by using Promax rotated PCA with Kaiser Normalization to explain body conformation. Highest correlation was observed between HW × LEG (0.77), KMO Measure of Sampling Adequacy was 0.794 while Bartlett's test of Sphericity was significant with chi-square value of 640.494. PCA revealed five components which explained about 61.91% of the total variation. First component explained 31.05% describing general body conformation with highest loadings for BH, CG, LEG and HB. The communality ranged from 0.43 (HC) to 0.78 (FW). Total variance explained by second, third, fourth and fifth component was 10.83%, 7.34%, 6.75% and 5.92% respectively. The rotated pattern matrix showed higher loadings of NC, PG, FL for Marathwadi buffaloes. Traits having high loadings in pattern matrix had high correlation with the components under structure matrix. Present study suggested that PCA can successfully reduce the dimensionality and first PC can be used in the evaluation and comparison of body conformation in Marathwadi buffaloes.

Keywords: Buffalo, Phenotypic Characterization, PCA, Marathwadi

Three distinct breeds of buffalo found in Maharashtra and recognized by NBAGR, Karnal are Nagpuri (Vidarbha area), Pandharpuri (Western Maharashtra), and Marathwadi (Marathwada region). The name of Marathwadi buffalo breed comes from its home territory, Marathwada region comprised of Parbhani, Nanded, Beed, Osmanabad, Jalna, Aurangabad, and Latur districts of Maharashtra. This breed reflects an ancient indigenous form with a lighter build and long flat horns, primarily maintained for milk production, dominates small herds in rural regions as a regular breeder (Gujar *et al*. 2003). Based on visible characteristics, phenotypic characterisation is used to detect and describe variety within and across various breeds (FAO 2012). Morphological characterisation is crucial for breed identification and help breeders to better select for growth, size, conformation, and body condition score. Although a large number of morphological qualities are required to describe a breed's or population's body conformation characteristic, these biometric traits are often closely linked among themselves, communicating more or less the same meaning.

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Principal Component Analysis (PCA) is a multivariate data reduction approach that includes extracting linear composites of observed variables with component scores to establish those measurements that can best describe body shape or breed traits and shared variance in a dataset. It reduces the number of features used for morphological evaluation of population, which saves money, time, and efforts. PCA has been used successfully to emphasise breed morphology, age, and sex differences, however yet not applied in the livestock breeds of Maharashtra, especially in case of Marathwadi the information available is scanty. Hence, the current study attempted to investigate relationships among different body measurements and the development of unobservable components to determine which of these measures best represent body conformation in Marathwadi buffaloes.

MATERIALS AND METHODS

Multivariate analysis technique, Principal component analysis was attempted on eighteen body biometric measures in 103 adults female Marathwadi buffaloes to develop a smaller number of PCs so as to avoid large number of traits recording for breed characterization and further to identify the traits for body conformation of this population. The body biometric traits considered for this study were Height at Withers (HW), Leg Length (LEG), Neck Length (NL), Neck Circumference (NC), Body Length (BL), Chest Girth (CG), Abdominal Girth (AG), Face Length (FL), Face Width (FW), Ear Length (EL), Horn Length (HL), Horn Circumference (HBC), Distance between two horns (DBH), Distance between two hip bone (HBD), Distance between two Pin Bone (PBD), Distance between Hip and Pubis Bone (DBHP), Rump Length (RL) and Tail Length up to Switch (TLS) collected from the Marathwadi buffaloes maintained at Livestock Instructional Farm, Udgir as well as from farmer's herds in the native breeding tract. To eliminate between-recorder effects, buffaloes were made to stand in an erect stance on a level floor and measurements were taken with a basic tape measure by the same technical person. In order to maintain accuracy of measurement, only the matured female buffaloes parturiated at least once were included to avoid the sex and age differences.

Pearson's coefficient of correlation (r) and its significance was computed to determine the degree of association among the linear measurements. Data were inspected for adequacy in sampling using Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of Sphericity was performed to test the validity of the factor analysis of the data sets at 1% level of significance. Principal component analysis method was used to form uncorrelated linear combinations of the observed variables. PCA considers both the total variance and unique variance, and does not make any differentiation between these two. The objective of principal component analysis is to account for the maximum portion of the variance present in the original set of variables with a minimum number of composite variables. It assumes that the unique variance represents a small portion of the total variance (Sadek *et al*. 2006).

Eigenvalues, the sum of squared component loadings across all variables for each component represent the total amount of variance in each variable that can be explained by a given PC and a weight for each eigenvalue termed as eigen vector. The eigenvector times the square root of the eigenvalue gives the component loadings which can be interpreted as the correlation of each item with the principal component. Eigen values and proportion of the total variance were computed. Eigen vectors were estimated and loadings of variables were determined. The eigen values were obtained by spectral decomposition of the data matrix and arranged in decreasing order of the corresponding eigenvalues, which equals to the variance of components. Thus, the first component had the largest variance. For selecting the optimal number of components that were of course smaller than the total number of items, Kaiser criterion of choosing the components having Eigenvalues greater than one (Kaiser, 1960) and scree plot technique was applied. To improve the interpretability of the factor solution by reaching simple structure, Promax rotation, an oblique rotation, which allows factors to be correlated was used. The pattern matrix, structure matrix and factor rotation matrices and based on rotated solutions three-dimensional factor loading plot was developed. All the analysis were carried out using statistical software SPSS (version 24).

RESULTS AND DISCUSSION

Out of the many uses of principal component analysis, the major use is reduction of number of traits, if the large number of observed variables have some redundancy. The correlated traits, indicate measuring of the same underlying construct. The correlation coefficient estimated for different eighteen body traits ranged from -0.001 between DBHP × HBC to 0.77 between HW × LEG in Marathwadi buffaloes (Supplementary Table 1). The highest correlations observed was between HW x LEG followed by CG × HW (0.589), AG × CG (0.584), DBHP × RL (0.555), AG × NC (0.542) and CG × HBD (0.521) in Marathwadi buffaloes. Most of the higher correlations were observed among the traits responsible for body built of the animals like, height, leg length, chest girth and abdominal girth, might be due to the fact that these traits grow uniformly with the growth of animals, higher in heavy buffaloes and lower in the small size buffaloes. In agreement to this finding, the range of correlation coefficient in different body biometric traits were reported as -0.04 to 0.74 in Murrah crossbred (Melo *et al.* 2018), -0.06 to 0.57 in Murrah buffaloes (Dhillod *et al.* 2017) and -0.005 to 0.776 in Gojri buffaloes (Vohra *et al*. 2015).

Out of the total 153 correlation combinations, 57 combinations were observed having moderate to high correlation ranging between 0.3 to 0.77 and most of these were highly significant at 1% level significance. Total 121 correlations were significant at 5% or 1% level, only 9 correlations were reported having negative values. Distance between two pin bones (PBD) was found having small and negative correlation with many of the body traits and most of the correlation coefficients between PBD and other traits were non-significant. The significant and positive correlations amongst the various body measurements suggest high predictability among different traits (Vohra *et al.* 2017). Johari *et al*. (2009) reported higher correlation values in different body biometric traits in swamp buffaloes.

Sampling adequacy and suitability of data for reduction are the two another important assumption to be assessed for confirming the eligibility of data for principal component analysis. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO-MSA) is a statistic that indicates the part of variance in certain biometric traits that might be caused by underlying factors (Kaiser 1958). Bartlett's test of Sphericity is another statistic to assess the strength of the relationship among biometric variables. Kaiser-Meyer-Olkin Measure of Sampling Adequacy was 0.794 for Marathwadi buffaloes determining that the responses given with the samples are adequate (Table 1). Kaiser (1974) recommended KMO 0.5 as a minimum (hardly acceptable), values between 0.7-0.8 acceptable, and values above 0.9 are excellent. As the sampling size is concerned, a common rule is at least 10-15 observation per variable should be there (Field 2000). Tabachnick and Fiedel (2001) observed 300 responses for sampling analysis is probably adequate for any factor analysis. In the present study, the number of samples per variable was 103 in all eighteen traits subjected for principal component analysis. KMO value lesser than 0.50 probably could not generate the fair results of the factor analysis. In agreement with the present findings, the KMO values reported are 0.74 in Chhattisgarhi buffalo (Vohra *et al*. 2017) and Gojri buffalo (Vohra *et al*. 2015), 0.75 in Hill cattle (Verma *et al*. 2015) and 0.70 in Murrah buffaloes (Dahiya *et al*. 2020). However, higher estimate of sampling adequacy was reported as 0.891 in Kankrej cows (Pundir *et al*. 2011), Tolenkhomba *et al*. (2012 and 2013) for local cows of Manipur (0.60) and Manipuri bulls (0.609) respectively; Shah *et al*. (2018) for Cholistani cattle (0.692); Sinha *et al*. (2021) for udder and teat conformation traits in Sahiwal cows (0.669) observed lower estimates for KMO measures of sample adequacy.

Table 1. KMO and Bartlett's test in Marathwadi

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.794
Bartlett's Test of Sphericity	Approx. Chi-Square	640.494
	df	153
	Sig.	.000

The overall significance of the correlation matrix was tested using Bartlett's test of sphericity for biometric traits and chi-square was 640.494 significant at 1% level, indicating that null hypothesis of the correlation matrix as an identity matrix is rejected (Table 1). Correlations tested with Bartlett's test of Sphericity for the biometric traits was reported significant in buffaloes (Vohra *et al*. 2015, 2017) and cattle (Pundir *et al*. 2011, Tolenkhomba *et al*. 2013, Verma *et al*. 2015, Shah *et al*. 2018). Taken together, KMO measure of sample adequacy and Bartlett's test of sphericity validated the suitability of data for factor analysis (PCA) using eighteen body biometric traits in Marathwadi breed of buffalo.

Initial communalities are the estimates of the variance in each variable accounted for by all components hence it is always equal to 1 for correlation analysis. Communalities presented in Table 2 varied from 0.78 (face width) to 0.43 (horn base circumference). The higher estimate (> 0.5) for 15 body biometric traits in Marathwadi buffaloes showed that the extracted components represent the variables well except horn base circumference and distance between two horns. Vohra *et al*. (2017) also reported lower estimates of communalities of rump length (0.51) and horn circumference (0.53) indicating less importance of these traits for explaining the body conformation in Chhattisgarhi buffaloes. Higher estimates of communalities were reported in Egyptian buffaloes ranging from 0.78 (rump width) to 0.96 (height at hips, height at withers) by Shahin *et al*. (1993).

Initial eigen values or amount of variance in the original variables accounted for by each component ranged highest (5.590) by first component to the lowest (0.143) by 18th component. The % of variance as ratio of the variance accounted for by each component to the total variance in all of the variables presented in Table 3 showed highest variance accounted by first component as 31.057. Although a number of components extracted were equal to the number of variables under study, however to retain the few components those account for meaningful amounts of variance and important for interpretation, two criteria were applied. The eigenvalue-one criterion, also known as the Kaiser criterion stated any component with an eigenvalue greater than 1.00 has to be retained and interpreted. Component with eigen value lesser than 1 were considered as trivial. Five components were extracted using Kaiser Rule criterion. Another criterion to decide how many components to be used for analysis was scree plot. The components on the steep slope of the plot till "bent of elbow" were extracted while the components on the shallow slope contribute little to the variability. The bent of elbow shows a "break" between the components with relatively large eigenvalues and small eigenvalues (Fig 1).

Table 2. Communalities in Marathwadi buffaloes

Trait	Communalities in Marathwadi Buffalo	
	Initial	Extraction
HW	1.000	.740
LEG	1.000	.692
NL	1.000	.548
NC	1.000	.677
BL	1.000	.671
CG	1.000	.585
AG	1.000	.728
FL	1.000	.493
FW	1.000	.782
EL	1.000	.622
HL	1.000	.529
HBC	1.000	.430
DBH	1.000	.445
HBD	1.000	.593
PBD	1.000	.566
DBHP	1.000	.724
TLS	1.000	.550
RL	1.000	.768

In the present study, the identified five components in Marathwadi buffalo explained cumulative percentage of variance of 61.90% (Table 3). First component accounted for 31.05% of the variation. The extracted component matrix presented in Table 4 revealed that the first principal component was represented by significant positive high loadings of HW (0.79) followed by CG (0.74), LEG (0.73), HBD (0.70), NC (0.66) and AG (0.64). First component can be used in the evaluation and comparison of body biometry of Marathwadi buffaloes using height at wither, chest girth, leg length, hip bone distance, neck circumference

Table 3. Total variance explained by different components in Marathwadi buffalo

Total Variance Explained							
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	5.590	31.057	31.057	5.590	31.057	31.057	4.471
2	1.950	10.833	41.890	1.950	10.833	41.890	3.954
3	1.322	7.342	49.232	1.322	7.342	49.232	2.988
4	1.216	6.756	55.988	1.216	6.756	55.988	2.917
5	1.066	5.920	61.908	1.066	5.920	61.908	1.149
6	.914	5.075	66.983				
7	.880	4.889	71.872				
8	.806	4.479	76.351				
9	.690	3.834	80.185				
10	.599	3.327	83.513				
11	.583	3.241	86.753				
12	.481	2.670	89.424				
13	.463	2.572	91.995				
14	.401	2.229	94.225				
15	.353	1.961	96.186				
16	.302	1.677	97.862				
17	.242	1.343	99.206				
18	.143	.794	100.000				

and abdominal girth. First component seemed to be explaining the maximum of body built or body condition in Marathwadi buffaloes and the buffaloes could successfully be selected for better body condition and body built using first PC. Similar to the present finding of Marathwadi buffalo, Vohra *et al*. (2015) extracted four components with total variability of 70% and first component explaining maximum of general body condition in Gojri buffaloes. Comparatively similar percentage of variability (31.05%) explained by first component in Marathwadi buffalo was reported in Gojri buffalo (31.45%), Hill cattle (34.7%) and Kankrej Cows (38.89%) by Vohra *et al*. (2015), Verma *et al*. (2015) and Pundir *et al*. (2011), respectively. Wither height or body height as a major contributing trait for component in the general body conformation was also reported by Tolenkhomba *et al*. (2012 and 2013), Vohra *et al*. (2015), Shah *et al*. (2018), Melo *et al*. (2020), and Sinha *et al*. (2021) in different animals.

Table 4. Extracted principal component matrix for biometric traits in Marathwadi buffalo

Trait	Component Matrix				
	1	2	3	4	5
HW	.797	-.250	.147	.073	-.126
CG	.747	-.027	-.126	-.071	.075
LEG	.737	-.191	.064	.212	-.250
HBD	.707	.218	-.098	-.146	.120
NC	.668	.161	-.418	.086	-.148
AG	.647	.175	-.320	-.369	-.203
RL	.554	-.453	.050	-.496	.089
TL	.543	-.122	.357	.326	-.083
DBH	.542	-.323	-.103	.138	-.127
FL	.523	-.014	-.454	.034	-.110
NL	.508	.453	.025	.282	-.062
EL	.466	-.300	.321	.425	.176
PBD	.116	.581	-.042	-.019	.462
HL	.399	.513	.277	-.169	-.037
HBC	.411	.482	.047	.099	.129
BL	.453	.338	.565	-.173	-.048
DBHP	.442	-.370	.241	-.455	.355
FW	.320	-.204	-.291	.295	.683

The second component explained 10.83% of total variance with high loading of pin bone distance (0.58), horn length (0.51) and horn circumference (0.48). The second component extracted in Marathwadi buffalo can identify the breed based on horn characteristics. Third component explained 7.34% of variance and showed high component loadings for body length (0.56) while the fourth and fifth component accounted for around 6.75% and 5.92% of total variability with comparatively higher loading for ear length and face width, respectively. In agreement to the present findings of Marathwadi buffalo, first factor represented the general shape and size of the cow and second component was reported to have higher importance for horn characteristics in Cholistani cattle (Shah *et al.* 2018). Likewise, in Kankrej cows also, second factor accounted for 12.36% with higher loading for horn characteristics (Pundir *et al*. 2011). Dahiya *et al*. (2020) explained 69.52% of total variation from four components in Murrah buffaloes and the first component reported to explain 28.678% variation in general body conformation

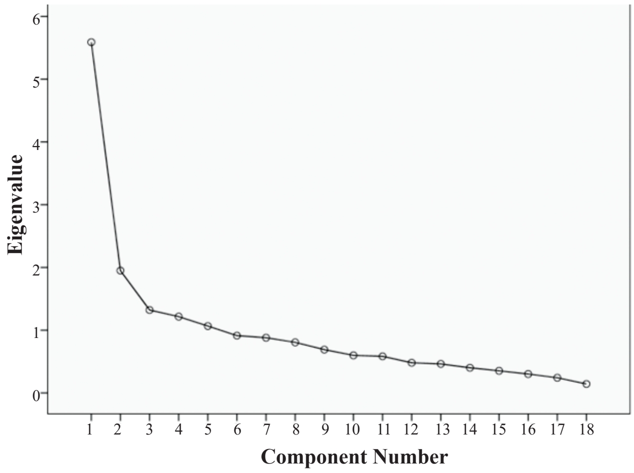

Fig. 1. Scree plot for principal component of Marathwadi buffaloes.

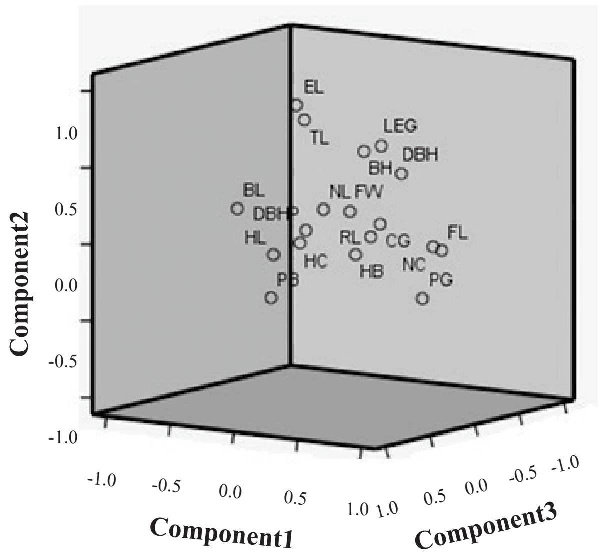

Fig. 2. Component plot in rotated space for body biometric traits of Marathwadi buffaloes.

while in Egyptian buffalo bull most of the common variability (88%) in body dimensions could be accounted for by components representing general size, body depth and height, and head width (Shahin *et al.* 1993).

The Oblique (Promax) rotation method with Kaiser normalization was applied, considering that components are correlated with one another. The Promax rotation can be calculated quickly hence considered best for the large size of data. Further, oblique rotation preferred over orthogonal rotation as it oversimplifies the data and the "hidden factors" were rarely be uncorrelated if they are reflecting something in reality. The component plot of the three components in rotated space for different body biometric traits of Marathwadi buffalo is depicted in Fig. 2. The pictorial representation may not be much helpful; however, it can be appreciated how the variables are organized in the common factor space. Body length, horn length and pin bone distance were observed in 2nd plane of rotated space.

The variance explained by the extracted factors after rotation made the adjustment as the total variance explained found 4.471, 3.954, 2.988, 2.917 and 1.149 by 1st to 5th retained components, respectively, in Marathwadi buffaloes. The pattern matrix (Supplementary Table 2) showed higher loadings of NC, PG, FL for 1st component, EL, TLS, LEG and HW for 2nd component, and HL, BL, PBD for 3rd component, DBHP and RL for 4th component and FW had high loadings with 5th component in Marathwadi buffaloes. Vohra *et al*. (2015) indicated that the first PC could be used in the evaluation and comparison of body biometry in female buffaloes using HC, FW, and FL while second PC has shown high component loadings of HG, PG, BL and HW in Gojri buffalo through pattern matrix. The results revealed that the traits having high loadings for the components under pattern matrix, the same had shown high correlation with the components under structure matrix.

High correlation amongst most of the body biometric traits, high KMO values for measure of sample adequacy and significant chi-square values for Bartletts test of sphericity confirms the suitability of 18 body biometric traits for multivariate data analysis, i.e. principal component analysis in Marathwadi buffaloes. The results of principal component analysis suggested that extracted PCs could be used with sufficient reduction in number of body biometric traits recorded for explanation of maximum variability in body conformation of Marathwadi buffaloes. Significant positive high loadings of first component with the biometric traits explaining body built or body condition suggested Marathwadi buffaloes could successfully be selected for better body condition and body built using first principal component, while the second component extracted in Marathwadi buffalo can identify the breed, based on horn characteristics.

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