Exploratory Principal Component Analysis of Body Morphometric Traits as Affected by Age and Sex in Donkeys

Onoruoyiza Asuku Ibrahim (onoruoyiza@gmail.com)
Ahmadu Bello University: National Animal Production Research Institute
https://orcid.org/0000-0003-2557-4847

Kayode Anthony Olutunmogun
Ahmadu Bello University: National Animal Production Research Institute

Mallam Illya
Kaduna State University Faculty of Agriculture

Chima Martin Umego
Ahmadu Bello University

Opeyemi Rachel Alao
Ahmadu Bello University

Umar Aliyu Umar
Ahmadu Bello University

Research Article

Keywords: Morphometric traits, age, sex, donkey, PCA.

DOI: https://doi.org/10.21203/rs.3.rs-569335/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

An experiment was conducted to determine the principal component analysis of body morphometric traits as affected by age and sex in donkeys reared on a research station in the National Animal Production Research Institute, Shika-Zaria, Nigeria. This was based on the objective of classifying age and sex using the multivariate method of principal component analysis (PCA) on morphometric traits of donkeys. Data were collected from a total of 101 donkeys based on age and sex on body weight, heart girth, body length, height at withers, tail length, shoulder width, head width, ear length, head length, neck circumference and neck length. The data obtained were subjected to multivariate factor analysis with varimax rotation using IBM® SPSS® Version 21. The results obtained revealed that the age group ≤ 1 year had one PCA, 2–3 years age group had four PCA, 4–5 years group had three PCA while those ≥ 6 years had two PCA. Most of the variables in combination with age largely formed the block of PC1 while other PCA had one or two variables correlating with them. Most of the variables formed PC1 for the Jacks while head width (HW) and ear length (EL) formed PC2. The Jennies had its entire variable in one PCA. Therefore, PC1 had the highest loading for the variables both by age and by sex as the animals are relatively well adapted to their environment. It can be concluded that donkeys between 2-3 years have more PC correlation proportions.

Introduction

The domestic donkey (*Equus asinus*) in Nigeria just like other donkeys around the World are being used as sources of transportation in carrying building materials like building stones, bricks, tiles, lime, sand, embankments, garbage (Madani et al., 2018) and for carrying farm produce (Blench, 2004b). In Nigeria, about 16,000 donkeys are annually transported from the north to the southern part of the country for the sole purpose to consumption as meat (Blench, 2004b). However, in China, this species has become an economically important animal because the meat has been found not to only have high nutritional value but most importantly, the collacoriasini (donkey-hide glue) present is popularly used as a strong traditional Chinese medicine (Di et al., 2017). To the credit of this animal is also the production of milk for children who are allergic to bovine milk (Carrocio et al., 2000; Muraro et al., 2002) or who suffer from multiple food intolerances (Monti et al., 2012). Morphometric measurements have been found useful in contrasting size and shape of animals (Ibe and Ezekwe, 1994; Ajayi et al., 2008). These quantitative measurements for size and shape are essential for estimating genetic parameters in animal breeding activities (Chineke, 2000). Also, the morphological characteristics are inexpensive and assess the environmental influence on traits (Mondini et al., 2009). Some morphological characters such as morphometric traits are correlated with bodyweight (Ajayi et al., 2012). Thus, such morphometric traits could be used as markers in body weight improvement programmes and body weight predictors (Musa et al., 2018). However, correlations between body dimensions may be different if the dimensions are treated as bivariate rather than multivariate. This could be noticeable interrelatedness or lack of orthogonality of the explanatory variable. Therefore, employing the use of multivariate analysis like the principal component analysis (PCA) would be able to handle and cater for this limitation (Yakubu et al., 2009). Likewise, this technique of using PCA or multivariate method is capable of defining the underlying structure among variables through exploratory or confirmatory means (Hair et al., 2010) and yield more reliable predictions and classification.

Principal component analysis is a weighted linear combination of correlated variables, explaining a maximal amount of variance of the variable (Truxillo, 2000). Relationships from PCA analysis have been reported to exist among linear body traits in goats and other species which provide useful information on performance, productivity and carcass characteristics (Shoyombo et al., 2015). Animal breeders in particular are interested in the genetic zoo-diversity which represents a reason or resource to draw on to select, develop and improve exiting animals and new breeds. More broadly, genetically diverse livestock populations provide society with a wider range of options to meet the challenges of the future (Madani et al., 2018). It is on this basis therefore, that the study was conducted to have information on the effect of age and sex on the morphometric traits of donkeys reared on a research station in Shika, Zaria, Nigeria using principal component analysis.

Materials And Methods

Location of the study

The study was conducted at the Equine and Camel Research Farm of the National Animal Production Research Institute (NAPRI), Ahmadu Bello University, Shika-Zaria, Kaduna State. Shika is geographically situated in the Northern Guinea Savannah Zone between latitude 11° 12’ 42” N and longitude 7° 33’ 14” E at an altitude of 640m above sea level (Ovimaps, 2018). The climate is characterized by well defined dry and wet seasons which are divided into cold-dry season (November–February), the hot-dry season (late February-April) and the wet season (early May–October). Temperature during the harmattan season ranges from 14°C to 30°C and 21 to 36°C during the hot season. Relative humidity varies from approximately 21% during the harmattan to 37% during the hot season. The average temperature and humidity during the wet season are 24.8°C and 77%, respectively (IAR, 2017).

Experimental animals and management

A total of one hundred and one (101) donkeys were used for this study and were sampled from the herd of donkeys reared and managed in the Research Institute. The donkeys are phenotypically predominantly brown, grey, white and black with few spotted coat colors. Their hair type is short.
and smooth with few having rough and curly hair type. The donkeys were allowed to graze and forage on browse plants, consisting of different grass (*Cynodon dactylon*, *Imperata cylindrica*, *Pennisetum pedicellatum*) and leguminous species (*Centrosema pascuorum*, *Macrotyloma uniorum*). A bi-weekly supplementation of hay and concentrates was also provided. Water was provided ad libitum.

**Data collection**

Data collected were on age (≤ 1, 2–3, 4–5 and ≥ 6 years) and on sex bases. These were evaluated for morphometric traits.

**Morphometric measurements**

The morphometric measurements selected are the ones that are largely associated with body weight are then integrated into the principal component analysis. Reference marks used for morphometric measurements of the donkeys were according to the methods of Madani et al. (2018) and Sargentini et al. (2018). The morphometric measurement taken include chest girth (CG), body length (BL), hump height (HL), hump circumference (HC), height at withers (HAW), neck length (NL) and neck circumference (NC).

**Statistical analysis**

A simple descriptive statistics was used for Jacks and Jennies based on age and sex while for the PCA, the traits were subjected to multivariate factor analysis with Varimax rotation using IBM® SPSS® Version 21.

**Results**

The simple descriptive statistics of age and sex for the donkey population is presented in Table 1. The results show that the donkey herd used for this study had 20.8% Jacks in the population with a decreasing population as age increased however at the collection of data for this study, jacks between 2-3years were not selected which accounts for the relatively high number. This is expected as males not selected to remain in the herd are culled between 1-2years as a means to maintain a healthy male to female ratio in the population. Likewise, too many males (Jacks) in a population of donkeys leads to competition for herd dominance, resulting in regular fights; some of which can be extremely bloody and ultimately, deleterious to the herd.

Table 2 showed the Eigen-values and share of total variance of morphometric traits in donkeys based on age. The principal component reveals that multi-collinearity in age ≤ 1year is very high leading to the age group having only one PCA component from the analyzed variables as opposed to other age groups with two and above PCA components. All the variables at ≤ 1year all fell into the PC1. At age 2-3years, BWR, HG, BL, HAW, SW, HL, NC and NL best described the first principal component (PC1) while TL, EL and HW were correlated with PC2, PC3 and PC4 respectively. Age 4-5years had BWR, HG, BL, HAW and NC been the outstanding variables which correlated with PC1 while SW, HW and EL were correlated to PC2 whereas TL, HL and NL described PC3. The ≥ 6years variables had most of their correlations with PC1 with the exception of HL and NC which correlated with PC2. The first age group had all the variables been condensed into just one PCA and can be named whole body parts and that they all increase in equal proportions; the second age group with four PCs (PC1, PC2, PC3 and PC4) can be divided into central body part dimensions (PC1) and extreme body parts (PC2, 3 and 4). The third age group were also divided into central body part dimensions (PC1), body part width (PC2) and body part length (PC3) whereas the fourth age group was mostly condensed into whole body part (PC1) with the exclusion of HL and NC (PC2).

The total variance in the ≤ 1year age group accounted for total variance of 80.33% in PC1 while 2-3years age group had PC1 = 51.99%, PC2 = 14.58%, PC3 = 11.34% and PC4 = 9.34%. Also, in the 4-5years age group, PC1 = 38.89%, PC2 = 27.29% and PC3 = 10.27% whereas the ≥ 6years group had PC1 = 83.48% and PC2 = 12.31%. The result of Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy of the ages ranges between 0.51−0.872 and showed the suitability of the data for factor analysis. Also, the result from the Bartlett's test of sphericity with approximate Chi-square ranged between 288.94 − 752.37 and 55 degree of freedom confirmed the feasibility of factor analysis application on the data.

Table 3 shows the eigen-value and share of total variance of morphometric traits in donkeys based on sex. The male group had two components (PC1 and PC2) whereas the female group had one component (PC1). The male group had most of its variables correlated to PC1 regarded as whole-body parts with the exception of HW and EL while the female group had all the variables highly correlated into PC1. The total variance by sex showed that the male had PC1 = 66.5% and PC2 = 9.48% while the female group had PC1 = 64.566%. The result on KMO in male = 0.721, Bartlett’s test = 294.125 while degree of freedom = 55 whereas in the female component, KMO = 0.862, Bartlett’s test = 959.501 and degree of freedom = 55.

**Discussion**

**Simple descriptive statistics of donkey population by age and sex**

This report is in agreement with the report of Moehlman (1998) who stated that a donkey stallion controls a harem of bounded females which he defends from other invading or competing males. Also, that the male or the wild ass stallion in the arid condition literally control access to
resources like water for females and thus gain access to breed during estrus.

**Eigen values and share of total variance with factor loadings and communalities of morphometric traits in donkeys based on age**

In taking body part measurement in donkeys, it assists in knowing or estimating the age of the animal and the timing for the different management practices like weaning and breeding can be fixed accurately to bring animals to good and desired conditions. This follows the earlier reports of Shoyombo et al. (2015) and Mavule et al. (2013) in goats and sheep that measurement of some body parts aids to peg animals for desired traits and good management practices.

**Eigen values and share of total variance with factor loadings and communalities of morphometric traits in donkeys based on sex**

The results of Sargentini et al. (2018) revealed that PCA and canonical discriminant analysis (CDA) separate donkeys as Jacks or Jennies and further separate the Jennies using some body measurements based on heights and lengths as those suitable for saddle, trekking, and milk production. This result agrees with Sargentini et al. (2018) as most of the body measurements relates to activities of saddle or trekking.

In conclusion, the PCA loading indicates that donkeys between 2-3years have more PC correlation proportion. Therefore, donkey farmers and breeders can use it in the selection of breeding stocks for better productivity or as saddle, trekking or work animals. Variability as regards sex separates the animal to their different abilities as either males or females.

**Declarations**

**Short description of the authors contributions:**

O.A. and A.K. conceived and designed the research

C.M. and A.U. collected the data

O.A., A.K. and A.U. arranged and analysed the data

A.K., I. and R.O. wrote the manuscript.

All authors read and approved the manuscript.

**Acknowledgements**

The authors are grateful to the Executive Director National Animal Production Research Institute for releasing the facilities used for conducting the experiment. Our profound appreciation goes to the Equine and Camel Research Programme farm staff who assisted with the data collection and collation used for this paper.

**Statement of Animal Rights**

All human and animal studies have been approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

**Conflict of Interest Statement**

The authors have no conflicts of interest to declare.

**Data Availability Statement**

The data that support the findings of this study are available on request from the corresponding author (O.A.), upon reasonable request. Therefore, anyone interested should contact (O.A.) at onoruoyiza@gmail.com

**References**

1. Ajayi, F.O., Adeleke, M.A., Sanni, M.T., Yakubu, A. and Peter, S.O. (2012). Application of principal component and discriminant analysis to morpho-structural indices of indigenous and exotic chickens raised under intensive management system. *Tropical Animal Health and Production*, 44: 1247-1254.

2. Ajayi, F.O., Ejiofor, O. and Ironele, M.O. (2008). Estimation of body weight from linear body measurements in two commercial meat-type chickens. *Global Journal of Agricultural Science*, 7: 57–59.

3. Blench, R. (2004b). Natural resource conflicts in northwest Nigeria: A handbook and case studies. Mallam Dendo LTD Cambridge, United Kingdom, Page 106.
Tables

| Age (year) | Sex  | Total | % of males |
|------------|------|-------|------------|
|            | Jacks| Jennies|            |
| ≤ 1        | 7    | 38    | 45         | 15.5       |
| 2–3        | 11   | 13    | 24         | 45.8       |
| 4–5        | 2    | 23    | 25         | 8.0        |
| ≥ 6        | 1    | 6     | 7          | 14.3       |
| Total      | 21   | 80    | 101        | 20.8       |
Table 2

Eigen values and share of total variance with factor loadings and communalities of morphometric traits in donkeys based on age

| Variables | ≤ 1year | 2-3years | 4-5years | ≥ 6year |
|-----------|---------|----------|----------|---------|
|           | PC1     | PC2      | PC3      | CM      | PC1     | PC2      | PC3      | CM      | PC1     | PC2     | CM      |
| BWR       | 0.959   | 0.919    | 0.855*   | 0.273   | -0.049  | 0.873    | 0.650*   | 0.281   | 0.490   | 0.742   | 0.950*  | 0.269   | 0.976   |
| HG        | 0.859   | 0.737    | 0.926*   | 0.184   | 0.097   | 0.109    | 0.914    | 0.351   | -0.158  | 0.908   | 0.982*  | 0.171   | 0.994   |
| BL        | 0.942   | 0.888    | 0.860*   | -0.085  | 0.079   | 0.221    | 0.801    | 0.835*  | -0.358  | 0.839   | 0.976*  | 0.172   | 0.982   |
| HAW       | 0.980   | 0.961    | 0.852*   | -0.220  | 0.294   | 0.208    | 0.904    | 0.825*  | -0.395  | 0.895   | 0.979*  | 0.187   | 0.994   |
| TL        | 0.817   | 0.668    | 0.013    | 0.902*  | 0.218   | 0.017    | 0.862    | 0.369   | -0.02   | 0.683*  | 0.603   | 0.884*  | 0.369   | 0.918   |
| SW        | 0.803   | 0.645    | 0.734*   | 0.459   | -0.203  | 0.012    | 0.790    | 0.024   | 0.858*  | 0.293   | 0.823   | 0.988*  | 0.052   | 0.978   |
| HW        | 0.894   | 0.799    | 0.133    | 0.002   | -0.076  | 0.948*   | 0.922    | 0.318   | 0.799*  | -0.079  | 0.746   | 0.896*  | 0.404   | 0.966   |
| HL        | 0.846   | 0.715    | 0.810*   | -0.509  | 0.244   | 0.071    | 0.981    | 0.043   | 0.60    | 0.837*  | 0.706   | 0.502   | 0.793*  | 0.882   |
| EL        | 0.835   | 0.697    | 0.074    | 0.162   | 0.935*  | -0.071   | 0.911    | 0.211   | 0.830*  | 0.071   | 0.738   | 0.902*  | 0.303   | 0.906   |
| NC        | 0.969   | 0.940    | 0.854*   | 0.058   | -0.300  | 0.194    | 0.859    | 0.769*  | -0.021  | 0.102   | 0.603   | 0.028   | 0.975*  | 0.952   |
| NL        | 0.931   | 0.867    | 0.789*   | -0.214  | -0.117  | -0.313   | 0.780    | -0.157  | 0.543   | 0.698*  | 0.806   | 0.975*  | 0.195   | 0.988   |
| Eigen value | 8.837   | 5.719    | 1.601    | 1.250   | 1.027   | 4.278    | 3.001    | 1.129   | 9.18    | 1.35    |         |         |         |         |
| % variance | 80.33   | 51.99    | 14.58    | 11.37   | 9.34    | 38.89    | 27.29    | 10.27   | 83.48   | 12.31   |         |         |         |         |

CM = Communiity, BWR: Body wright, HG: Heart girth, BL: Body length, HAW: Height at withers, TL: Tail length, SW: Shoulder width, HW: Head width, HL: Head length, EL: Ear length, NC: Neck circumference, NL: Neck length

Table 3: Eigen values and share of total variance with factor loadings and communalities of morphometric traits in donkeys based on sex

| Variables | Male | Female |
|-----------|------|--------|
|           | PC1  | PC2    | Communalitiy | PC1  | Communalitiy |
| RWT       | 0.947*| 0.139  | 0.917        | 0.949| 0.901        |
| HG        | 0.980*| -0.007 | 0.961        | 0.933| 0.871        |
| BL        | 0.978*| -0.066 | 0.962        | 0.946| 0.895        |
| BH        | 0.876*| -0.075 | 0.773        | 0.833| 0.693        |
| TL        | 0.747*| 0.132  | 0.576        | 0.780| 0.608        |
| SW        | 0.870*| -0.085 | 0.765        | 0.865| 0.747        |
| HW        | 0.294 | -0.561*| 0.401        | 0.314| 0.099        |
| EL        | 0.297 | 0.813* | 0.750        | 0.393| 0.154        |
| HL        | 0.761*| -0.012 | 0.579        | 0.757| 0.573        |
| NC        | 0.928*| -0.107 | 0.873        | 0.895| 0.800        |
| NL        | 0.895*| -0.043 | 0.803        | 0.872| 0.760        |
| Eigen value | 7.315 | 1.043  | 7.102        | 66.5 | 9.484        |
| % variance | 66.5 | 9.484  | 64.566       | 99.9 | 99.9         |

BWR: Body wright, HG: Heart girth, BL: Body length, HAW: Height at withers, TL: Tail length, SW: Shoulder width, HW: Head width, HL: Head length, EL: Ear length, NC: Neck circumference, NL: Neck length
