Evaluation of Similarities, Differences and Associations of Arabian Horses Based on Phenotypic Morphometric Measurements, Gender and Hoof Diseases in Bauchi and Maiduguri

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Abstract

The value of the Arabian horse is largely associated with their external conformation and the hooves are one of the most indispensable features which decide on the horse's value. They play a fundamental role in Arabian horses, absorbing concussion, averting skids and shielding the sensitive parts of the digit. Therefore, the objective of this study is to use two way clustering of Arabian horses based on location, gender, diseases of the hoof using phenotypic morphometric measurements to determine the similarities, and differences between the variables. To evaluate prominent accounting principal components for the occurrence of hoof diseases associated with each variable using principal component analysis. Thirty Arabian horses were used for this study, fifteen Arabian horses each from Bauchi and Maiduguri were randomly selected comprising of nine [9] mares and twenty-one [21] stallions of various ages (mean 14.5 years ± 0.7 SE; range 5-20 years) and body weight (306 kg ± 11.04 SE; range 170–414 kg). Phenotypic morphometric measurements were obtained using a measuring stick, tailor’s tape and body weight measuring tape. Ages were determined from the information given by horse owners and dentition formula. Cluster analysis of Arabian horses from Bauchi and Maiduguri based on gender, locations and hoof diseases were classified into four clusters in relation to their phenotypic morphometric measurements to disclose the similarities and differences between the variables. The phenotypic morphometric measurements are all closely associated with the occurrences of the hoof diseases as divulged by the principal component analysis. In conclusion, regular trimming, shoeing and proper care of horses by horse raiders irrespective of the horse discipline or usage can protect the menace of hoof derangements.

Key words: Phenotypic morphometric measurements, Hoof Diseases, Location, gender, Similarities, Associations


1. Introduction

The value of the Arabian horses is mainly associated with their external conformation, because this particular breed is used primarily for competitions, presentations, traditional ceremonies, travelling and lots of other things. Therefore, the major criterion for their assessment is their aesthetic value, as well as, their correct body conformation. Arabian

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horses have been bred for many years and can boast a high reputation in the world. Attempts to epitomize the morphometrical pattern have been taken repeatedly for many horse breeds in recent years (1-3). Arabian horses are morphologically dissimilar (4), the mtDNA investigation has revealed that there is a strong genetic discrepancy of an Arabian mare, with only a few omissions (5). Furthermore, a reliably accomplished assortment and breeding by numerous breeders can clarify the variations observed (4). The hooves are one of the most important factors which decide on the horse’s value (6-7). They play a crucial role in the organism supporting it, absorbing concussion, preventing skids and protecting the sensitive portions of the digit. Different functions and biomechanics of the fore and hind limbs, bring on the differentiation of the hoof capsule form (6-7). The forelimbs are more burdened carrying the horse’s head and neck, in fact the total weight of the horse is loaded on the entire limbs (6-7). In an Arabian horse standing squarely, they are loaded with 57.0 % (in mares) to 58.7 % (in stallions) body mass (6-7). During movement, the concussion and strain on the horse locomotive system rapidly grow (8). The hind limbs are more active in pushing the horse forward, whereas the fronts mainly absorb the shock of landing (8). The more efficiently the hind limbs act, with the greater impetus the horse lands on its front limbs after each suspension phase (8). The strain on the hooves increases with speed when the impact shock is absorbed in shorter time (8). There were several defined hoof derangements that afflicts horses kept in a poorly managed environments (9-10). Thrush is defined as a chronic disease of the horn of the sole of a horse’s foot with sign of offensive smell (9-10). Thrush is characterized by an accumulation of black, malodorous, necrotic material, usually originating within the central or the collateral sulci of the frog of the hoof (9-11). Hoof crack is the separations or breaks in the hoof wall (12). There are different types of cracks depending on the location and originating line of the crack (13). Vertical cracks are divided into sand and grass crack (13). Soft sole is defined as soft, crumbly horn in the sole of the hoof (14-15). Bruised sole and corns are the common conditions that occur as a result of soft sole (12). Rupture of blood vessels in the dermis beneath the sole, frog or hoof wall due to thin sole that easily get injured lead to bruise formation. Bruising may later develop into an abscess which can lead to thrush and cause various degrees of lameness if left untreated (12). Hoof derangements are affected by many factors including breed, type of work, injury and management. Poor management is the most common contributory factor of hoof derangements. Phenotypic morphometric measurements could be associated with the development of hoof diseases and abnormalities. Therefore, there is the need for intensified sanitary improvement and shoeing of horses in the study areas.

2. Material and Methods

Thirty Arabian horses were selected randomly from Bauchi and Maiduguri of various ages (mean 14.5 years ± 0.7 SE; range 5-20 years) and body weight (306 kg ± 11.04 SE; range 170–414 kg) were used in this study. Fifteen Arabian horses each were randomly selected from Bauchi and Maiduguri comprising of nine [9] mares and twenty-one [21] stallions. The two Cities are located in North Eastern States of Nigeria (Bauchi and Borno States) respectively. Bauchi and Maiduguri, are the capital of these States. These Cities are represented by a circle [O] indicating Bauchi and a cross [+] indicating Maiduguri (Figure 1).
Twelve linear measurements such as body weight [BWT], height at withers [HAW], height at hip [HAP], length of left front hoof [LOLZH], length of right front hoof [LORZH], width of left front hoof [WOLZH], width of right front hoof (WORZH), length of left hind hoof [LOLZH], length of right hind hoof (LORZH), width of left hind hoof (WOLZH) and width of right hind hoof (WORZH) were measured in centimeters using a measuring stick, tailors tape and body weight measuring tape estimated in kilograms. Ages were determined from the information given by horse owners and dentition formula. The observed abnormalities or diseases associated with the hooves were as follows; Thrush = TH; Sand crack = SC; Soft sole = SS; Overgrown = OGH; No hoof diseases = NON.

The hooves of all the four legs of the horses were examined via observation and with the aid of hoof knife and hoof tester. All the hoof diseases were identified when the horses were in standing squared position.

2.1 Data analysis

The data were analysed using multivariate cluster and principal component analysis using JMP version 11 (SAS Institute Inc, Cary NC). The analysis was considered significant at (p< 0.05).

3. Results

Clustering is a multivariate technique of grouping rows together that share similar values (physiognomies). Table 1 showed the history of cluster Analysis Based on Gender, Location, Diseases of the Hoof and Phenotypic Morphometric Measurements of Arabian Horses from Bauchi and Maiduguri. Figure 2 through figure 4 showed two way clustering to determine similarities and differences between the occurrence of hoof diseases and or abnormalities, gender and locations based on phenotypic morphometric measurements obtained on Arabian horses. Clustering by hoof diseases, gender and locations were all partitioned into four clusters.

In cluster number one, represented by red colors showed hoof diseases affecting eight [8] Arabian horses made up of six [6] stallions and two [2] mares which share similar characteristics that are found in both Bauchi and Maiduguri. One Stallion from Maiduguri was afflicted by sand crack, two Mares from Maiduguri were afflicted by hoof diseases, and one was afflicted by thrush and the other one by sand crack. One Stallion from Maiduguri had none of these hoof diseases. Two Stallions from Bauchi had thrush and the other two Stallions had none of the hoof diseases.

In cluster number two which was the largest cluster, represented by green colors showed hoof diseases affecting seventeen [17] Arabian horses made up of twelve [12] stallions and five [5] mares which share similar characteristics that are found in both Bauchi and Maiduguri. Six Stallions from Maiduguri were afflicted by different hoof diseases, two by overgrown hoof, two by sand crack, one by soft sole, one had none of the hoof diseases while one Mare had thrush. Six Stallions from Bauchi were afflicted by different hoof diseases, two Stallions were afflicted by soft sole, two by thrush and two had none of the hoof diseases. Four mares were afflicted by different hoof diseases, one by overgrown hoof, one by soft sole, one by sand crack and one Mare had none of the hoof diseases and abnormalities.

In cluster number three which is the smallest cluster, represented by blue colors showed hoof disease affecting one Arabian horse from Maiduguri which did not share similar characteristics with any Arabian horse from Bauchi. The Stallion had an overgrown hoof. In cluster number four, represented by orange colors showed hoof diseases affecting four Arabian horses made up of two [2] stallions and two [2] mares which share similar characteristics that are found in both Bauchi and Maiduguri. Two Stallion was afflicted by thrush in Maiduguri, two Mares, one from Bauchi and the other one from Maiduguri were all afflicted by overgrown hoof.

Based on phenotypic morphometric measurements, the clusters were broadly divided into two major clusters. The first cluster was composed of the following phenotypic morphometric measurements; body weight, age, length of left front hoof, length of right front hoof, height at wither, height at hip and width of left front hoof; all of these phenotypic morphometric measurements largely pertain to the front hooves while, the second cluster was composed of the following phenotypic morphometric measurements; width of right front hoof, length of left hind hoof, length of right hind hoof, width of right hind hoof and width of left hind hoof; these measured parameters largely pertains to the hind hooves.

At each step the clustering process calculates the distance between each cluster, and combines the two clusters that are closest together. In figure 2, the number of clusters begins with 29, which is the number of rows in the data table.
minus one. The two closest points, OGH and SS, are joined to reduce the number of existing clusters to 29. They show as the first Leader and Joiner in the Clustering History table. The next two closest points are SS and TH, followed by OGH and SS. When SC is joined by OGH in the fifth line, OGH had already been joined by SS, making it the first cluster with one point. Furthermore, for the twelve phenotypic morphometric measurements obtained on Arabian horses found at Bauchi and Maiduguri the number of clusters begins with 11, which is the number of rows in the data table minus one. The two closest points, WOLFH and WORFH, are joined to reduce the number of existing clusters to 11. They show as the first Leader and Joiner in the Clustering History table. The next two closest points are LOLHH and LORHH, followed by LOLHH and WORHH. When WOLFH is joined by LOLHH in the fifth line, LOLHH had already been joined by WORHH, making it the third cluster with three points.

The distances between clusters as shown in the cluster history table divulged which hoof disease, gender and location first emanate as leader and which disease, gender and location joined the cluster afterward. Considering figure 2 through 4, the first hoof disease and or abnormality to appear was overgrown hoof affecting a Stallion from Maiduguri while, the second hoof disease to appear afterward was soft sole which affects a Stallion from Bauchi, these are largely accounted for by the phenotypic measurements affecting the width of left front hoof as a leader followed by the width of right front hoof afterwards as joiner. Subsequently, all these process occurred in their respective individual clusters as shown in figure 2 through 4.

Table 1. History of Cluster Analysis Based on Gender, Location, Diseases of the Hoof and Phenotypic Morphometric Measurements of Arabian Horses from Bauchi and Maiduguri

<table>
<thead>
<tr>
<th>Clusters</th>
<th>Gender</th>
<th>Location</th>
<th>Diseases of the hoof</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stallions (6)</td>
<td>Bauchi (4)</td>
<td>TH (2), NON (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maiduguri (2)</td>
<td>SC (1), NON (1)</td>
</tr>
<tr>
<td></td>
<td>Mares (2)</td>
<td>Bauchi (0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maiduguri (2)</td>
<td>SC (1), TH (1)</td>
</tr>
<tr>
<td>2</td>
<td>Stallions (12)</td>
<td>Bauchi (6)</td>
<td>SS (2), TH (2), NON (2),</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maiduguri (6)</td>
<td>OGH (2), SS (1), SC (2), NON (1)</td>
</tr>
<tr>
<td></td>
<td>Mares (5)</td>
<td>Bauchi (4)</td>
<td>OGH (1), NON (1), SS (1), SC (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maiduguri (1)</td>
<td>OGH (1),</td>
</tr>
<tr>
<td>3</td>
<td>Stallions (1)</td>
<td>Bauchi (0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maiduguri (1)</td>
<td>OGH (1)</td>
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<td>Mares (0)</td>
<td>Bauchi (0)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Maiduguri (0)</td>
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<tr>
<td>4</td>
<td>Stallion (2)</td>
<td>Bauchi (0)</td>
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<td></td>
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<td>TH (2)</td>
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<tr>
<td></td>
<td>Mares (2)</td>
<td>Bauchi (1)</td>
<td>OGH (1)</td>
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<tr>
<td></td>
<td></td>
<td>Maiduguri (1)</td>
<td>OGH (1)</td>
</tr>
</tbody>
</table>

Thrush =TH; SC = Sand crack; SS = Soft sole; OGH = Overgrown; NON = No hoof diseases

Principal component analysis is a multivariate technique used to derive a small number of independent linear combinations (principal components) of a set of measured variables (phenotypic measured variables) that capture as much of the variability in the original variables as possible. Principal component analysis is an exploratory data analysis tool and is also used for making predictive models. Principal component analysis accounts for the total variance of the observed variables (that is, the variance common to all variables and the variance unique to each variable). The phenotypic measured variables are correlated variables; you can use principal component analysis to show the most prominent directions of the high-dimensional variables. Using principal component analysis reduces the dimensionality of the phenotypic measured variables.

Figure 5 showed the phenotypic morphometric measured variables highlighted in yellow that accounted for the occurrence of hoof diseases and abnormalities in Mares in Bauchi and Maiduguri. These variables include the following: body weight, height at withers, height at hip, length of left front hoof, width of left front hoof, length of right front hoof, width of right front hoof and length of left hind hoof. However, body weight accounted significantly (Principal component 1 [BWT] = 81.252%; Chi-Squared = 80.065; P = 0.0259) for the occurrence of hoof diseases and abnormalities in Mares in the two cities, followed by height at withers which contributed (Principal component 2 [HAW] = 10.339%; Chi-Squared = 14.123; P = 1.0000) and is not significant statistically. The other principal components (3-8) each contributing a little with less variable cumulative percentages between each variable.
Figure 2. Dendrogram showing two way clustering of Arabian horses from Bauchi and Maiduguri based on hoof diseases using phenotypic morphometric measurements.

Figure 3. Dendrogram showing two way clustering of Arabian horses from Bauchi and Maiduguri based on gender using phenotypic morphometric measurements.

Figure 4. Dendrogram showing two way clustering of Arabian horses from Bauchi and Maiduguri based on locations using phenotypic morphometric measurements.
Figure 5. Phenotypic Morphometric Measured Variables Highlighted in Yellow Accounting for the Occurrence of Hoof Diseases in Mares in Bauchi and Maiduguri.

Figure 6 showed the phenotypic morphometric measured variables highlighted in green that accounted for the occurrence of hoof diseases and or abnormalities in Stallions in Bauchi and Maiduguri. These variables include the following; body weight, height at withers, height at hip, length of left front hoof, width of left front hoof, length of right front hoof, width of right front hoof, length of left hind hoof, width of left hind hoof, length of right hind hoof, width of right hind hoof and age. Principal components 1-10 accounted significantly for the occurrence of hoof diseases and or abnormalities in Stallions. However, principal components 11-12 each contributing a little with less variable cumulative percentages between each variable.
Figure 7 showed the phenotypic morphometric measured variables highlighted in blue that accounted for the absence of hoof diseases and or abnormalities in both Stallions and Mares in Bauchi and Maiduguri. These variables include the following: body weight, height at withers, height at hip, length of left front hoof, width of left front hoof and length of right front hoof. Principal components 1-5 accounted for the absence of hoof diseases and abnormalities in both Stallions and Mares. However, principal components 6 contributed significantly for the absence of hoof diseases and abnormalities in both Stallions and Mares in Bauchi and Maiduguri with a cumulative percentage of 100% (Principal component 6 [LORFH] = 0.144%; Chi-Square = 44.321; P = 0.0487).

Figure 7. Phenotypic Morphometric Measured Variables Highlighted in Blue Accounting for the Absence of Hoof Diseases (NON) in both Stallions and Mares in Bauchi and Maiduguri

Figure 8 showed the phenotypic morphometric measured variables highlighted in red that accounted for the occurrence of overgrown hoof in both Stallions and Mares in Bauchi and Maiduguri. These variables include the following: body weight, height at withers, height at hip, length of left front hoof and width of left front hoof. Principal components 1-4 accounted for the occurrence of overgrown hoof in both Stallions and Mares but, their contribution was not significant statistically and principal component 2 showed no association with overgrown hoof but accounted for 14.718%. However, principal components 5 contributed significantly for the occurrence of overgrown hoof in both Stallions and Mares in Bauchi and Maiduguri with a cumulative percentage of 100% (Principal component 5 [WOLFH] = 0.171%; Chi-Square = 65.775; P = 0.0017).

Figure 8. Phenotypic Morphometric Measured Variables Highlighted in Red Accounting for the Occurrence of Overgrown Hoof (OVER) in both Stallions and Mares in Bauchi and Maiduguri

Figure 9 showed the phenotypic morphometric measured variables highlighted in light green that accounted for the occurrence of sand crack in both Stallions and Mares in Bauchi and Maiduguri. These variables include the following: body weight, height at withers, height at hip and length of left front hoof. Principal components 1-4 accounted for the occurrence of sand crack in both Stallions and Mares. However, principal components 1-4 contributions were not significant statistically for the occurrence of sand crack in both Stallions and Mares in Bauchi and Maiduguri (Principal component 1 [BWT] = 59.807%; Chi-Square = 5.151; P = 1.0000); Principal component 2 [HAW] = 19.497%; Chi-Square = 12.634%; Chi-Square = 16.698; P = 1.000; and Principal component 4 [LOLFH] = 8.062%; Chi-Square = 36.740; P = 0.8230). The body weight accounted for 59.807% for the occurrence of sand crack but indicated no significant association with the occurrence of sand crack in Mares and Stallion in Bauchi and Maiduguri.
Figure 8. Phenotypic Morphometric Measured Variables Highlighted in Red Accounting for the Occurrence of Overgrown Hoof (OGH) in both Stallions and Mares in Bauchi and Maiduguri.

Figure 9. Phenotypic Morphometric Measured Variables Highlighted in Light Green Accounting for the Occurrence of Sand Crack (SC) in both Stallions and Mares in Bauchi and Maiduguri.

Figure 10 showed the phenotypic morphometric measured variables highlighted in light blue that accounted for the occurrence of soft sole in both Stallions and Mares in Bauchi and Maiduguri. These variables include the following; body weight, height at withers and height at hip. Principal components 1-3 accounted for the occurrence of soft sole in both Stallions and Mares, However, principal components 1-3 contributions were not significant statistically for the occurrence of soft sole in both Stallions and Mares in Bauchi and Maiduguri (Principal component 1 [BWT = 66.684%; Chi-Square = 2.682; P = 1.0000]; Principal component 2 [HAW = 24.448%; Chi-Square = 18.408; P = 1.0000]; Principal component 3 [HAP = 8.868%; Chi-Square = 48.676; P = 0.8386]. Principal components 1-3 also showed some degree of associations but statistically are not significant.
Figure 10. Phenotypic Morphometric Measured Variables Highlighted in Light Blue Accounting for the Occurrence of Soft Sole (SS) in both Stallions and Mares in Bauchi and Maiduguri

Figure 11 showed the phenotypic morphometric measured variables highlighted in indigo that accounted for the occurrence of thrush in both Stallions and Mares in Bauchi and Maiduguri. These variables include the following; body weight, height at withers, height at hip, length of left front hoof, width of left front hoof, length of right front hoof and width of right front hoof. Principal components 1-7 accounted for the occurrence of thrush in both Stallions and Mares, However, principal components 1-7 contributions were not significant statistically for the occurrence of thrush in both Stallions and Mares in Bauchi and Maiduguri (Principal component 1 [BWT = 68.535%; Chi-Square = 19.382; P = 1.0000]; Principal component 2 [HAW = 22.285%]; Principal component 3 [HAP = 3.670%]; Principal component 4 [LOLFH = 2.532%; Principal component 5 [WOLFH = 1.833%; Principal component 6 [LORFH = 0.878%; Chi-Square = 3.637; P = 1.000; Principal component 7 [WORFH = 0.269%; Chi-Square = 23.271]). Height at withers accounted for 22.285%, height at hip accounted for 3.670%, length of left front hoof accounted for 2.532% and width of right front hoof accounted for 1.833% for the occurrence of thrush but they all indicated no significant association with the occurrence of thrush in Mares and Stallion in Bauchi and Maiduguri.

Figure 11. Phenotypic Morphometric Measured Variables Highlighted in Indigo Accounting for the Occurrence of Thrush (TH) in both Stallions and Mares in Bauchi and Maiduguri
Figure 12 showed the phenotypic morphometric measured variables highlighted in red that accounted for the occurrence of hoof diseases in Arabian horses in Bauchi. These variables include the following: body weight, height at withers, height at hip, length of left front hoof, width of left front hoof, length of right front hoof, width of right front hoof, length of left hind hoof, width of left hind hoof and length of right hind hoof. Principal components 1-10 accounted for the occurrence of hoof diseases and abnormalities in Arabian horses in Bauchi. However, principal components 5-10 contributions were not significant and associated with the occurrence of hoof diseases and abnormalities in Arabian horses in Bauchi (Principal component 1 [BWT = 58.299%; Chi-Square = 145.470; P = 0.0001]; Principal component 2 [HAW = 19.362%; Chi-Square = 72.103; P = 0.1662]; Principal component 3 [HAP = 9.110%; Chi-Square = 34.730; P = 0.9783]; Principal component 4 [LOLFH = 5.259%; Chi-Square = 12.824; P = 1.000]; Principal component 5 [WOLFH = 3.666%; Principal component 6 [LORFH = 2.848%]; Principal component 7 [WORFH = 0.981%];Principal component 8 [LOLHH = 0.293%]; Principal component 9 [WOLHH = 0.138%];Principal component 10 [LORHH = 0.044%]). Principal component 5-10; width of left front hoof accounted for 3.666%, length of right front hoof accounted for 2.848%, width of right front hoof accounted for 0.981% and width of right front hoof accounted for 1.833% for the occurrence of thrush but they all indicated no significant association with the occurrence of thrush in Arabian horses in Bauchi.

Figure 12. Phenotypic Morphometric Measured Variables Highlighted in Red Accounting for the Occurrence of hoof diseases in Arabian horses in Bauchi

Figure 13 showed the phenotypic morphometric measured variables highlighted in yellow that accounted for the occurrence of hoof diseases and abnormalities in Arabian horses in Maiduguri. These variables include the following: body weight, height at withers, height at hip, length of left front hoof, width of left front hoof, length of right front hoof, width of right front hoof, length of left hind hoof, width of left hind hoof, length of right hind hoof, width of right hind hoof and age. Principal components 1-10 accounted significantly for the occurrence of hoof diseases and abnormalities in Arabian horses in Maiduguri. However, principal component 11 contribution was not significant and associated with the occurrence of hoof diseases and abnormalities in Arabian horses in Maiduguri while, principal component 12 (age) is not significant in it contribution to the occurrence of hoof diseases in Arabian horses in Maiduguri.
4. Discussion

The significance of the Arabian horses is mostly associated with their exterior conformation and the hooves are one of the supreme features which decide on the horse’s value. They play a vital role in horses, protecting the sensitive portions of the digit, preventing skids and absorbing concussion. In the present study, each cluster represents Arabian horses of similar characteristics and each cluster is entirely unique and different to the other cluster. The wide-ranging hoof diseases and or abnormalities affecting the Arabian horses in each cluster could be attributed to the different usage of the Arabian horses. This finding is similar to the study conducted by Nurul Syuhada et al. (12) that indicated the relationship between usage of horses and hoof derangements showed significant differences for thrush and chipped hoof. However, there were no significant differences in hoof ring and hoof crack in their study regarding horse usage.

In the current study, the phenotypic morphometric measurements were partitioned into two clusters, the first cluster divulged a close association between hoof disease, gender and locations with the measured parameters pertaining to the front hooves, body weight, height at withers and hip. This finding could explain the reason why in the present study there was a higher incidence of hoof diseases and or abnormalities affecting the front hooves compared to the hind hooves. This finding is in accord to the study conducted by (6-7) who postulated that the forelimbs are more loaded carrying the horse’s head and neck, in fact the total weight of the horse is laden on the entire limbs. In a warm-blooded horse standing evenly, they are loaded with 57.0 % (in mares) to 58.7 % (in stallions) body mass. Furthermore, the second cluster disclosed a close association between hoof disease, gender and locations with the measured parameters pertaining to the hind hooves. This finding could elucidate why in the present study there was a low incidence of hoof diseases and or abnormalities affecting the hind hooves. This finding is in consensus to the study conducted by (6-7) who hypothesized that the hind-limbs are more energetic in propelling the horse forward, while the front hooves largely absorb the shock of landing.

In the present study, the distances between clusters showed which hoof disease, gender and location first emanate as leader and which disease, gender and location joined the cluster afterward. The first hoof disease and or abnormality
to appear was overgrown hoof is affected a Stallion from Maiduguri whereas, the second hoof disease to appear afterward was soft sole which affects a Stallion from Bauchi, these are largely accounted for by the phenotypic measurements affecting the width of the left front hoof as a letter followed by the width of the right front hoof afterwards as a joiner. This finding agrees with the work of (7) who postulated that the front hoof capsules have shorter heel length and different hoof angles than hinds whereas (16) observed the solar surface, the fore hooves are wider and more rounded than the hind hooves which are narrower and more triangular or peer-shaped. Another study hypothesized that that the horn in front hooves grew at the rate of 0.12 cm slower than in hind hooves in suckling’s, 0.07 cm lesser in weanlings and in older animals the tendency was opposite: it grew at the rate of 0.06 cm faster than in hinds (7). These findings agree with the present study where the first hoof disease or abnormality to appear was the overgrown hoof followed by soft sole.

The magnificence of a horse is influenced by its body conformation, body measurements and the associations among the dimensions; consequently, metric measured parameters of the exterior can become a selection tool for the horse (17-18). Among the typical measurements used in horse breeding, the most noteworthy external variable is the height at withers (2). This is similar to the findings of the present study where height at withers was among the variables that influence the occurrence of hoof diseases particularly those affecting the front hooves. Body dimensions have been used to identify breeds, origin, and relationship through the medium of head measurements or to identified size and body shapes measured could improve selection for growth by enabling the breeder to recognize early maturing and late maturing animals based on the different body size measurements (19-21). In the present study these phenotypic morphometric measurements were undertaken to divulge if there is any relationship between these measurements and occurrence of hoof diseases. The present study has indicated the percentage contributed by each of the measurements based on types of hoof diseases and or abnormalities, gender and locations, including which of the diseases, gender and locations comes as a leader and which join next in the process.

In the present study, the occurrences of the hoof diseases are all closely associated with the phenotypic morphometric measurements. The finding from the current study was similar to the study conducted by (14-15) where the occurrences of compression of the hoof wall were assumed to be due to the episodes of severe trauma during the work and compression of the hoof wall tubules during heavy workloads. In the present study, the occurrence of thrush was also similar to grass crack which was largely attributed to unhealthy environment, sandy and hard surface of the terrain as seen in Maiduguri and Bauchi respectively. The neglect of daily foot care and improper trimming is the most probable cause of the incident (22). Most of the horses that have thrush had wet sole leading to chipping and crack. It is also caused by improper trimming of the hooves leading to hoof imbalance (mediolateral or dorso palmar imbalance) allowing chipped and grass crack to develop (22-23). According to (14-15) Hoof wall cracks are usually illustrated by their location, length, depth and presence or absence of hemorrhage or infection.

In a study carried by (14-15), the prevalence of superficial quarter cracks and toe cracks were higher, and (24-25) deduced that the hoof wall becomes increasingly thinner to the quarter and it is more sensitive to cracks; consequently, thinner quarter walls could have a higher incidence of cracks than that at the toe. Besides, heel and quarter cracks are recurrently linked with under-run heels and long toes and this hypothesis support our observation of cracks in the current study. Stashak (24), reported that incessant hoof wall growth makes it susceptible to splitting and cracks. In the present study, sand crack was the second with a least incidence rate. This type of crack could occur by an injury to the coronary band or blow in the hoof wall. The crack may go unnoticed until the farrier spot it and seldom increase in size and usually require no treatment. However, if the hoof is left undermined by excess moisture and mediolateral imbalance horizontal crack can set the stage for a vertical crack to occur. The findings from the current study is in accord with the studies conducted by (11, 16).

In the present study, Sand crack may result from injury to the coronet or from an infection that breaks out the coronet vertically. It may also cause by uncoordinated movement of the horse where it might strike the coronet and also it can develop with mediolateral and diagonal imbalance. These findings are in agreement with the study conducted by Stashak, (13). In the current study, from the observation and by personal interview with the keepers, these horses frequently urinate in large amount, and left in the stable for a prolonged period, creating a wet saw dust leading to the development of thrush in an environment that was suitable and enriched for bacterial growth. Frequent removal of the
sawdust will reduce the problems and improve the hygiene of the environment. The correlation between phenotypic morphometric measurements and hoof derangements showed significant associations with the occurrence of hoof conditions (12). Different usage of horses had different frequencies of concussion to the ground leading to hoof diseases (26). Prolonged contact of the hooves to the ground such as soil could also lead to thrush and *Fusobacterium necrophorum* infection in the soil. This finding is in agreement to study carried out by (27).

4.1 Conclusion

In conclusion, regular trimming, shoeing and proper care of horses by horse raiders irrespective of the horse discipline or usage can protect the menace of hoof derangements. It is also recommended that proper sanitary measures to be instituted in the stables by horse owners.

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Conflict of interest

The authors declare no conflict of interest.

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