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Phenotypic characterization of Gesha horses in southwestern Ethiopia

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Abstract: Fifteen qualitative and 21 morphometric variables on a total of 394 adult horses (282 stallions and 112 mares) from three selected districts were recorded to characterize the horse populations in southwestern Ethiopia. General linear model, frequency, and multivariate analysis procedures of Statistical Analysis Software (SAS 9.0) were used to analyze the data. Sex and location significantly affected the studied traits. Stallions were larger than mares, and the Gesha horse population was the tallest, longest, and largest among the studied populations. The majority of the studied horses possess plain body colour patterns with red-coloured medium hair size. A higher frequency of white-coloured horses was observed with increasing age. Stepwise discriminant function analysis revealed that pelvic width, cannon bone length, and height at croup were the top three morphometric variables to discriminate the populations while head length, head neck circumference, chest width, cannon bone circumference, and croup length had the lowest discriminatory power. The results of discriminant function analysis showed advanced classification (76.7%) of the studied horses into their respective populations/locations. Finally, canonical discriminant function analysis categorized the horse populations into three distinct categories. The Gesha horse population was different from Masha and Telo horse populations while having a relatively higher relationship with the Masha horse population. However, the distances calculated in this study show only the relative size differences between each population. Such differences might not necessarily be due to breed (genetic) differences. Therefore, diversity studies through further genetic characterization are recommended to design conservation and breeding programmes.

Keywords: Ethiopia, Horse, Gesha, Phenotypic characterization

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Introduction

Horses are among the most important livestock species in the highlands of Ethiopia. In rural areas, horses are the main source of transportation, both for humans and agricultural goods. They are used in public events including social and cultural festivals, and are the most culturally respected and highly valued domestic animals in the country in general, and in southern and southwestern Ethiopia in particular (Kefena *et al*, 2012). The highlands of Keffa and Sheka zones in southwest Ethiopia are also among the most benefitted areas from the indigenous horses (Kefena *et al*, 2012). In these areas, horses were also used for traditional racing shows.

Ethiopia is reported to possess 2.1 million horses (Central Statistical Agency, 2020). However, in terms of standard characterization and documentation, the equine sector has received little attention. Until now, only one country-wide general study by Kefena *et al* (2012) was performed to phenotypically characterize the country's horse breeds, their geographical distribution and production environments. Accordingly, eight breeds (Abyssinian, Bale, Boran, Horro, Kafa, Kundido feral horse, Ogaden/Wilwal and Selale horse) were officially reported to exist in the country (Kefena *et al*, 2012; EBI, 2016).

However, due to different reasons, the study by Kefena *et al* (2012) did not cover or characterize three horse breeds (Boran, Kundido feral horse and Ogaden/Wilwal horses) out of the total eight breeds. Additionally, the lack of qualitative morphological data in the study, and the small sample size taken (95–106

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horses per breed) can be noted as limitations of the study. Similarly, the selected sampling sites were too narrow to represent the horse populations of the area. For example, the horse populations of southwestern Ethiopia were represented by a sample from a single site (Masha district). A preliminary study by a team of livestock experts from Keffa zone hinted at the presence of an unstudied unique horse population in Gesha district.

According to the results of this preliminary study, Gesha horses are said to be typical riding horses of the Keffa zone highlands. However, in the country-wide study by Kefena *et al* (2012), this population was represented by horses from the neighbouring Masha district. Therefore, further characterization studies were required to better understand the horse populations and quantify the level of relationships among them, thus providing a clear country-wide picture. Hence, the current study was designed to characterize the horse populations in southwestern Ethiopia using both quantitative morphometric measurements and qualitative morphological characteristics.

Materials and methods

Locations

This study was conducted in Keffa and Sheka zones of the Southern Nations Nationalities and Peoples Regional State (SNNPR), Ethiopia. Three locations were selected for the current study (Table 1, Figure 1). Gesha and Masha districts were sampled purposively: Gesha district (one of the ten districts in Keffa zone) is the location of the horses which were supposed to be unique and unaddressed before, while Masha district (one of the three districts in Sheka zone) is where the samples were taken for the previous country-wide study by Kefena *et al* (2012). Telo district was sampled randomly from Keffa zone to study the relationship of its horses with Gesha horses.

The sampling frame was defined after collecting available background information (origin, distribution, population size, and unique features) of the unstudied horse population through focus group discussions with livestock keepers and experts. Additionally, information regarding the sampling sites of the country-wide study was also taken from the reports of Kefena *et al* (2012).

Data collection

Quantitative and qualitative data were recorded from a total of 394 adult horses (282 stallions and 112 mares) based on the data collection procedures outlined in FAO (2012) and the previous country-wide study by Kefena *et al* (2012). Studied horses were carefully handled by their owners and trained personnel. Data were collected when the animals were calm and standing in an upright position on flat ground and early in the morning of the day before feeding and watering. To minimize measurement error, data were not taken from aggressive horses that did not stand properly. Similarly, to minimize subjectivity error, measurements and data recording were performed by the same researchers throughout the study. A centimetre-unit textile measuring tape was used for the morphometric measurements.

Twenty-one quantitative morphometric measurements (Table 2) and 15 qualitative characteristics (hair size, body colour pattern, colour of the body, head, muzzle, tail and hoof, presence/absence of stripe at dorsal body, shoulder and leg, profile of the face, back and croup, length of the tail and mane) were collected.

The following body measure indices were calculated from morphometric measurements (adapted from Bodó and Hecker (1992); Cabral *et al* (2004); Druml *et al* (2008); Bene *et al* (2013)).

- Body index = (Body length/Thorax girth) x 100
- Quadratic index = (Height at withers/Body length) x 100
- Caliber index = (Thorax girth/Height at withers) x (Cannon circumference/Height at withers) x 1000
- Overbuilt index = (Height at croup/Height at withers) x 100
- Chest index = (Chest width/Thorax girth) x 100
- Conformation index = (Thorax girth^2/Height at withers)/100

Data analysis

Data entry and management were performed using Microsoft Excel© worksheet. Analysis of the quantitative traits was performed separately for stallions, mares and sex-aggregated by fitting location and age as fixed variables. UNIVARIATE procedure of Statistical Analysis Software (SAS) 9.0 was used to detect outliers and test the normality of morphometric data (SAS Institute, 2002). Data on qualitative traits were subjected to chi-square (χ^2) tests of the frequency (FREQ) procedure of SAS 9.0 software. Quantitative morphometric and body measure indices data were analyzed using the general linear model (GLM) procedure of SAS 9.0 software, with adjusted Tukey-Kramer test to separate the least square means (LSM). Data analysis was performed using the following model: $Y_{ijk} = \mu + S_i + L_j + A_k + e_{ijk}$ where Y_{ijk} is an observation, μ is the overall mean, S_i is the fixed effect of ith sex (i = stallion, mare), L_j is the fixed effect of jth location (j = Telo, Gesha, Masha), A_k is the fixed effect of kth age (k = 4–11), and e_{ijk} is the random error attributed to the nth observation. The sex effect was removed from the class variables when the analysis was done separately for each sex.

Morphometric traits that better discriminate the horse populations from different locations were identified using the forward selection method of the stepwise discriminant function analysis (STEPDISC) procedure of SAS 9.0. The discriminant function analysis (DISCRIM) procedure of SAS 9.0. was also used to assign observations to locations and evaluate probabilities of misclassifications. Linear combination of morphometric variables that provide maximal separations between locations was performed using the canonical discriminant function analysis (CANDISC) procedure of SAS 9.0. The scored canonical variables were used to plot

Table 1. Climatic and agroecological features of the studied areas. Data from Bezabih (2012), Assefa *et al* (2013), Gebrmichael (2019).

Climate factors	Telo	Gesha	Masha
Altitude (m)	2,436–2,451	1,501–3,000	1,700–3,000
Temperature (°C)	17–25	15.1–20	16.7
Rainfall (mm)	1,278	2,001–2,200	2,192
Agroecology	Highland	Midland and highland	Midland and highland

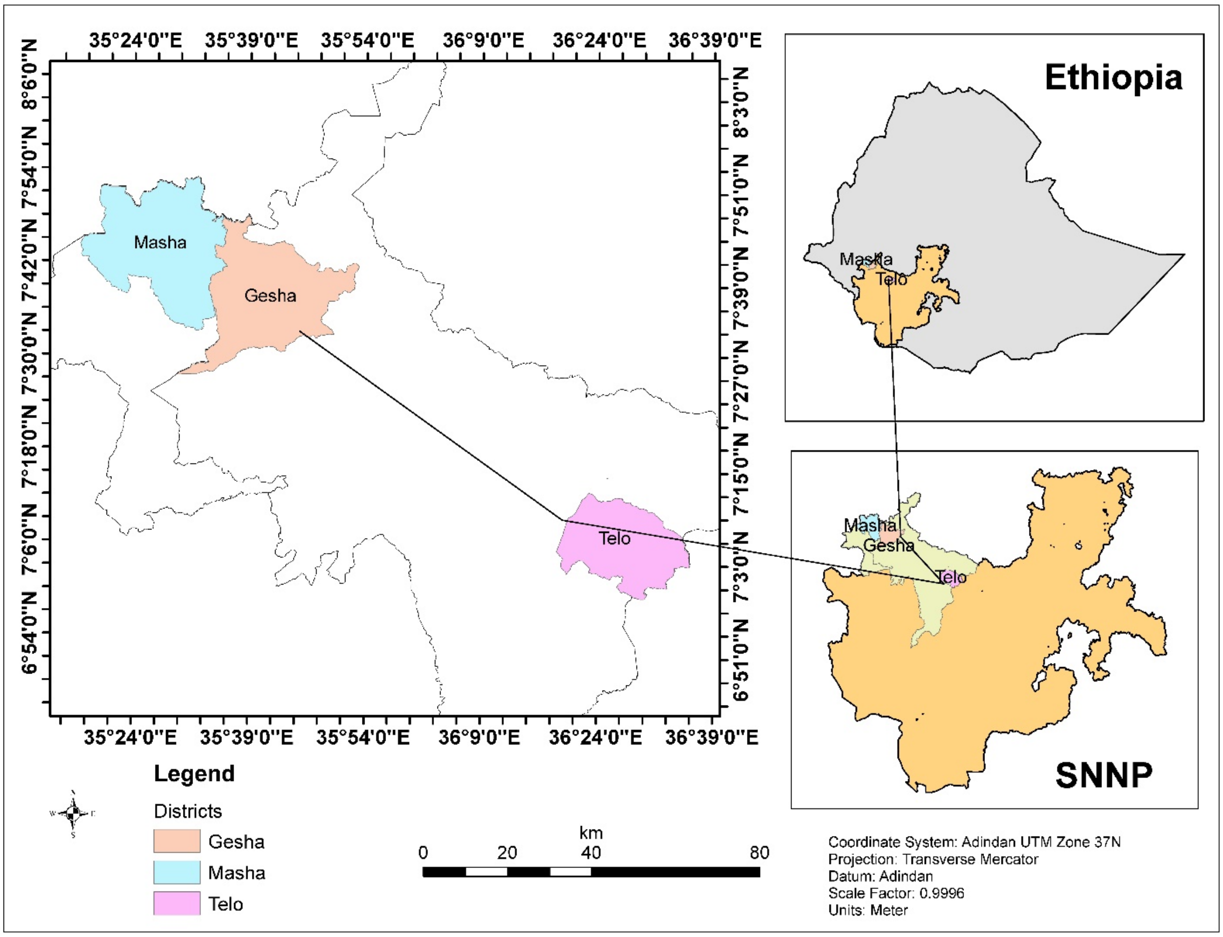

Figure 1. Map of the sampled locations and districts

pairs of canonical variables to get visual interpretation of location differences. Pairwise squared Mahalanobis distances between locations were computed as: $D^2\,(i|j) = (x_i - x_j)^{'}\,cov^{-1}\ \ (x_i - x_j)$. Where $D^2\,(i|j)$ is the distances between locations i and j, cov^{-1} is the inverse of the covariance matrix of measured variables, x_i and x_j are the means of variables in the i^{th} and j^{th} populations.

Results

Morphometric measurements and body measure indices

The effect of sex on the studied morphometric variables is presented in Table 3. Most measurements were higher for stallions than mares while ear length and barrel length measurements of the mares were higher than the stallions. On the other hand, body length and back length measurements were not significantly affected by sex.

To have a clear picture of the differences among locations, the analysis was performed separately for both sexes. The effect of location on the morphometric measurements of the stallions is presented in Table 4. All stallions' measurements were affected significantly by their location. Gesha stallions had significantly the highest values for most of the measurements except for cannon bone length where Telo stallions had higher values. Masha stallions had relatively higher measurement values than their counterparts from Telo district, and these populations shared more similarities. On the other hand, chest width, shoulder depth, body

Table 2. Description of the collected quantitative measurements. Adapted from FAO (2012); Kefena *et al* (2012).

No.	Morphometric measurements	Explanation of the measurements
1	Head length	Distance from the nape to the alveolar edge of the incisors I of the upper jaw
2	Head width	Distance between the upper side of the eyes measured perpendicularly to the head length
3	Ear length	Distance from the tip of the ear to the connection point with the head
4	Head neck circumference	Circumference of the neck at the connection point to the head
5	Neck length	Distance from the highest point of the withers to the nape with the neck in a relaxed position
6	Neck body circumference	Circumference of the neck at the connection point with the body
7	Chest width	Distance between two outer points of the humeral bones from the front
8	Shoulder depth	Distance from the withers to the shoulder joint
9	Thorax depth	Distance from the withers to the sternum
10	Thorax width	Distance between two hypothetical vertical parallel lines drawn at the thorax sides and along the withers' height line
11	Thorax girth	Measured in the place of the saddle girth
12	Cannon bone length	Distance from the lateral tuberculum of the os metacarpale IV to the fetlock joint
13	Cannon bone circumference	Smallest circumference of the forelimb's cannon bone
14	Height at wither	Distance from the highest point of the processus spinalis of the vertebra thoracic to the floor
15	Height at back	Distance from the deepest point of the back to the floor
16	Height at croup	Distance from the croup (rump) to the floor
17	Body length	Distance from the most cranial point of the shoulder joint to the most caudal point of the pin bone (scapulo-ischial length)
18	Back length	Distance from the caudal point of the shoulder joint perpendicular to the wither to the most cranial point of the hip joint measured in the saddle place
19	Pelvic width	Distance between the right and left coxal tubers of the ilium
20	Croup length	Distance between the sacral tuber (the highest point of croup) and ischiatic tuber (most posterior point of ischium or point of buttock or seat bone)
21	Barrel length	Distance from the most caudal point of the scapula to the most cranial and dorsal point of the point of the hip

length and back length measurements of Telo stallions were higher than Masha stallions.

The effect of location on the morphometric measurements of the mares is presented in Table 5. Most of the mares' measurements were affected significantly by their location except ear length, neck length, chest width and barrel length. Gesha mares were the biggest and heaviest among the studied populations: their circumferences of head–neck, neck–body and thorax, and heights at withers, back and croup, and pelvic width were significantly larger than Telo or Masha.

The effect of location on the morphometric measurements of the studied horse populations (sex-aggregated) is presented in Table 6. All the morphometric measurements of the studied horse populations were affected significantly by their location. Significantly, the Gesha horse population had the highest values for most of the measurements except for cannon bone length, which was higher in Telo horses.

Pearson correlation coefficients of the morphometric measurements of the horses (both sexes) from different locations are presented in Table 7. The majority of the traits were positively correlated. Higher positive correlation was observed between height at withers and height at back while lower positive correlation was observed between ear length and head neck circumference. Negative correlation was observed between thorax width and cannon bone length.

The effect of location on body measure indices of the studied horse populations (separately for each sex) is presented in Table 8. All the body measure indices of the studied horse populations were significantly affected by sex. Similarly, most of the body measure indices were significantly affected by their location.

Multivariate analysis

Stepwise discriminant function analysis revealed the order of importance of the studied morphometric variables in discriminating the horse populations (Table 9). The results were also confirmed by Wilk's lambda test (Table 9) where all the selected variables had a highly significant ($P < 0.0001$) contribution in discriminating the horse populations. Pelvic width, cannon bone length and height at croup were the first three important traits used in discriminating the studied horse populations. However, some morphometric variables like head length, head neck circumference, chest width, cannon bone circumference and croup length had the lowest dis-

Table 3. Least-square means ± standard errors of quantitative body measurements (cm) of the horse populations by sex.

Traits	Stallions	Mares	p-value
N	282	112	
Head length	53.2 ± 0.16	52.1 ± 0.23	< 0.0001
Head width	21.5 ± 0.06	21.2 ± 0.09	0.0015
Ear length	15.0 ± 0.09	15.5 ± 0.13	0.0033
Head neck circumference	58.9 ± 0.24	54.7 ± 0.36	< 0.0001
Neck length	59.4 ± 0.27	57.3 ± 0.40	< 0.0001
Neck body circumference	91.4 ± 0.37	84.3 ± 0.55	< 0.0001
Chest width	25.9 ± 0.13	24.3 ± 0.20	< 0.0001
Shoulder depth	53.4 ± 0.18	51.1 ± 0.27	< 0.0001
Thorax depth	61.8 ± 0.23	59.8 ± 0.33	< 0.0001
Thorax width	34.2 ± 0.16	32.9 ± 0.24	< 0.0001
Thorax girth	143.0 ± 0.44	138.6 ± 0.65	< 0.0001
Cannon bone length	24.0 ± 0.09	23.6 ± 0.14	0.0066
Cannon bone circumference	16.4 ± 0.06	15.6 ± 0.09	< 0.0001
Height at withers	131.8 ± 0.29	127.8 ± 0.43	< 0.0001
Height at back	129.0 ± 0.28	125.7 ± 0.41	< 0.0001
Height at croup	132.1 ± 0.28	129.1 ± 0.42	< 0.0001
Body length	125.0 ± 0.38	124.1 ± 0.56	0.1796
Back length	70.0 ± 0.26	70.2 ± 0.38	0.6114
Pelvic width	40.4 ± 0.16	39.5 ± 0.24	0.0016
Croup length	39.7 ± 0.18	38.6 ± 0.27	0.0020
Barrel length	67.0 ± 0.29	69.4 ± 0.43	< 0.0001

Table 4. Means and pairwise comparisons of morphometric measurements of the stallions from different locations. Means within a row bearing different superscripts are significantly different; ^{a} indicates the largest value.

Traits	Least Square Means (LSM ± SE)			Mean ± SE	CV	p-value
	Telo	Gesha	Masha			
N	94	136	52			
Head length	52.4 ± 0.27^b	54.2 ± 0.23^a	53.1 ± 0.36^b	53.2 ± 0.16	4.5	< 0.0001
Head width	21.0 ± 0.11^b	21.9 ± 0.09^a	21.6 ± 0.15^a	21.5 ± 0.07	4.6	< 0.0001
Ear length	14.5 ± 0.15^b	15.1 ± 0.13^a	15.4 ± 0.20^a	14.9 ± 0.08	8.9	0.0002
Head neck circumference	58.1 ± 0.43^b	60.8 ± 0.36^a	57.9 ± 0.57^b	59.3 ± 0.24	6.4	< 0.0001
Neck length	59.3 ± 0.48^b	60.6 ± 0.40^a	58.4 ± 0.63^b	59.4 ± 0.27	7.1	0.0049
Neck body circumference	88.8 ± 0.63^b	95.9 ± 0.53^a	89.9 ± 0.83^b	92.2 ± 0.41	6.1	< 0.0001
Chest width	26.0 ± 0.25^{ab}	26.7 ± 0.21^a	25.2 ± 0.33^b	26.0 ± 0.14	8.5	0.0008
Shoulder depth	53.5 ± 0.32^b	54.6 ± 0.27^a	52.1 ± 0.42^c	53.6 ± 0.18	5.3	< 0.0001
Thorax depth	59.6 ± 0.40^c	63.7 ± 0.33^a	61.9 ± 0.52^b	61.9 ± 0.25	5.7	< 0.0001
Thorax width	32.8 ± 0.30^c	35.5 ± 0.25^a	34.2 ± 0.39^b	34.1 ± 0.18	7.7	< 0.0001
Thorax girth	141.5 ± 0.78^b	149.0 ± 0.65^a	138.8 ± 1.02^b	143.6 ± 0.53	4.8	< 0.0001
Cannon bone length	24.8 ± 0.16^a	23.5 ± 0.14^b	23.6 ± 0.21^b	24.0 ± 0.09	6.0	< 0.0001
Cannon bone circumference	16.34 ± 0.11^b	16.9 ± 0.10^a	16.1 ± 0.15^b	16.5 ± 0.07	6.1	< 0.0001
Height at withers	130.7 ± 0.51^b	135.2 ± 0.43^a	129.6 ± 0.67^b	132.2 ± 0.31	3.4	< 0.0001
Height at back	127.8 ± 0.48^b	132.4 ± 0.41^a	127.0 ± 0.63^b	129.5 ± 0.30	3.3	< 0.0001
Height at croup	131.3 ± 0.50^b	135.8 ± 0.42^a	129.6 ± 0.7^b	132.8 ± 0.31	3.3	< 0.0001
Body length	125.3 ± 0.67^b	127.5 ± 0.56^a	122.4 ± 0.88^c	125.3 ± 0.38	4.7	< 0.0001
Back length	70.7 ± 0.44^a	71.1 ± 0.37^a	68.2 ± 0.58^b	70.1 ± 0.25	5.6	0.0003
Pelvic width	38.7 ± 0.29^c	42.3 ± 0.24^a	40.5 ± 0.38^b	40.5 ± 0.19	6.3	< 0.0001
Croup length	38.7 ± 0.33^b	41.1 ± 0.28^a	39.3 ± 0.43^b	39.7 ± 0.18	7.3	< 0.0001
Barrel length	66.1 ± 0.51^b	67.7 ± 0.43^a	67.1 ± 0.66^{ab}	66.8 ± 0.28	6.7	0.0287

Table 5. Means and pairwise comparisons of morphometric measurements of the mares from different locations. Means within a row bearing different superscripts are significantly different; ^{a} indicates the largest value.

Traits	Least Square Means (LSM ± SE)			Mean ± SE	CV	p-value
	Telo	Gesha	Masha			
N	29	47	36			
Head length	51.9 ± 0.49^{ab}	53.0 ± 0.38^{a}	51.3 ± 0.45^{b}	52.1 ± 0.25	4.9	0.0128
Head width	20.6 ± 0.18^{b}	21.5 ± 0.14^{a}	21.5 ± 0.17^{a}	21.2 ± 0.10	4.4	0.0001
Ear length	15.2 ± 0.27	15.4 ± 0.21	15.9 ± 0.25	15.5 ± 0.13	9.1	0.1536
Head neck circumference	53.2 ± 0.70^{b}	56.7 ± 0.53^{a}	54.3 ± 0.64^{b}	54.9 ± 0.37	6.6	0.0002
Neck length	56.7 ± 0.75	58.4 ± 0.57	56.5 ± 0.69	57.2 ± 0.38	6.8	0.0597
Neck body circumference	81.3 ± 1.20^{b}	89.4 ± 0.91^{a}	81.7 ± 1.10^{b}	84.7 ± 0.71	7.3	< 0.0001
Chest width	23.9 ± 0.32	24.8 ± 0.24	24.0 ± 0.29	24.3 ± 0.16	6.8	0.0535
Shoulder depth	51.0 ± 0.54^{ab}	52.2 ± 0.41^{a}	49.9 ± 0.49^{b}	51.0 ± 0.30	5.4	0.0015
Thorax depth	58.7 ± 0.63^{b}	61.1 ± 0.48^{a}	59.7 ± 0.58^{ab}	59.9 ± 0.34	5.4	0.0069
Thorax width	31.4 ± 0.44^{b}	34.1 ± 0.34^{a}	33.2 ± 0.41^{a}	32.9 ± 0.27	7.0	< 0.0001
Thorax girth	135.9 ± 1.26^{b}	144.4 ± 0.96^{a}	134.6 ± 1.16^{b}	138.6 ± 0.81	4.7	< 0.0001
Cannon bone length	24.1 ± 0.27^{a}	22.9 ± 0.21^{b}	23.6 ± 0.25^{ab}	23.5 ± 0.14	6.0	0.0014
Cannon bone circumference	15.6 ± 0.15^{ab}	15.9 ± 0.11^{a}	15.4 ± 0.13^{b}	15.6 ± 0.08	4.9	0.0067
Height at withers	127.3 ± 0.81^{b}	130.3 ± 0.62^{a}	125.4 ± 0.75^{b}	127.9 ± 0.45	3.3	< 0.0001
Height at back	124.8 ± 0.84^{b}	128.4 ± 0.64^{a}	123.4 ± 0.77^{b}	125.8 ± 0.46	3.5	< 0.0001
Height at croup	128.3 ± 0.81^{b}	132.1 ± 0.61^{a}	126.3 ± 0.74^{b}	129.3 ± 0.47	3.2	< 0.0001
Body length	124.5 ± 1.13^{ab}	126.6 ± 0.86^{a}	121.0 ± 1.04^{b}	124.0 ± 0.65	4.7	0.0004
Back length	70.6 ± 0.80^{ab}	71.4 ± 0.61^{a}	68.1 ± 0.74^{b}	70.0 ± 0.44	6.0	0.0033
Pelvic width	38.6 ± 0.43^{b}	41.4 ± 0.33^{a}	38.4 ± 0.40^{b}	39.6 ± 0.27	5.7	< 0.0001
Croup length	38.8 ± 0.52^{ab}	39.6 ± 0.39^{a}	37.7 ± 0.47^{b}	38.7 ± 0.27	6.9	0.0120
Barrel length	68.8 ± 0.89	70.2 ± 0.68	69.4 ± 0.82	69.3 ± 0.47	6.7	0.4347

Table 6. Means and pairwise comparisons of morphometric measurements of the horses (both sexes) from different locations. Means within a row bearing different superscripts are significantly different; ^{a} indicates the largest value.

Traits	Least Square Means (LSM ± SE)			Mean ± SE	CV	p-value
	Telo	Gesha	Masha			
N	123	183	88			
Head length	52.0 ± 0.24^{b}	53.6 ± 0.20^{a}	52.2 ± 0.27^{b}	52.9 ± 0.14	4.6	< 0.0001
Head width	20.8 ± 0.10^{b}	21.7 ± 0.08^{a}	21.6 ± 0.11^{a}	21.4 ± 0.06	4.6	< 0.0001
Ear length	14.8 ± 0.14^{b}	15.3 ± 0.11^{a}	15.7 ± 0.15^{a}	15.1 ± 0.07	8.9	< 0.0001
Head neck circumference	55.8 ± 0.38^{b}	58.7 ± 0.31^{a}	56.0 ± 0.41^{b}	58.1 ± 0.23	6.5	< 0.0001
Neck length	58.1 ± 0.42^{b}	59.5 ± 0.34^{a}	57.4 ± 0.46^{b}	58.8 ± 0.23	7.0	0.0004
Neck body circumference	85.1 ± 0.58^{b}	92.5 ± 0.48^{a}	86.0 ± 0.64^{b}	90.1 ± 0.39	6.4	< 0.0001
Chest width	25.0 ± 0.21^{b}	25.7 ± 0.17^{a}	24.6 ± 0.23^{b}	25.5 ± 0.12	8.1	< 0.0001
Shoulder depth	52.3 ± 0.28^{b}	53.4 ± 0.23^{a}	51.0 ± 0.31^{c}	52.8 ± 0.17	5.3	< 0.0001
Thorax depth	58.9 ± 0.35^{c}	62.6 ± 0.29^{a}	61.0 ± 0.39^{b}	61.3 ± 0.21	5.7	< 0.0001
Thorax width	32.1 ± 0.25^{c}	34.8 ± 0.21^{a}	33.7 ± 0.28^{b}	33.8 ± 0.15	7.5	< 0.0001
Thorax girth	138.9 ± 0.68^{b}	146.6 ± 0.56^{a}	136.9 ± 0.75^{b}	142.2 ± 0.46	4.8	< 0.0001
Cannon bone length	24.5 ± 0.14^{a}	23.2 ± 0.12^{b}	23.6 ± 0.16^{b}	23.9 ± 0.08	6.0	< 0.0001
Cannon bone circumference	15.9 ± 0.09^{b}	16.4 ± 0.08^{a}	15.7 ± 0.10^{b}	16.2 ± 0.06	5.8	< 0.0001
Height at withers	128.8 ± 0.45^{b}	132.8 ± 0.37^{a}	127.7 ± 0.50^{b}	131.0 ± 0.28	3.4	< 0.0001
Height at back	126.1 ± 0.43^{b}	130.4 ± 0.36^{a}	125.5 ± 0.48^{b}	128.4 ± 0.26	3.4	< 0.0001
Height at croup	129.7 ± 0.44^{b}	134.0 ± 0.36^{a}	128.2 ± 0.48^{b}	131.8 ± 0.27	3.3	< 0.0001
Body length	124.8 ± 0.59^{b}	127.0 ± 0.49^{a}	121.7 ± 0.65^{c}	124.9 ± 0.33	4.7	< 0.0001
Back length	70.8 ± 0.40^{a}	71.2 ± 0.33^{a}	68.2 ± 0.44^{b}	70.1 ± 0.22	5.7	< 0.0001
Pelvic width	38.4 ± 0.25^{c}	41.8 ± 0.21^{a}	39.6 ± 0.28^{b}	40.3 ± 0.16	6.3	< 0.0001
Croup length	38.4 ± 0.29^{b}	40.4 ± 0.23^{a}	38.6 ± 0.32^{b}	39.4 ± 0.16	7.2	< 0.0001
Barrel length	67.4 ± 0.45^{b}	69.0 ± 0.37^{a}	68.3 ± 0.50^{b}	67.5 ± 0.25	6.6	0.0113

Table 7. Pearson correlation coefficients between each morphometric measurement (above diagonal) and level of significance (below diagonal) of the horses (both sexes) from the three locations. HL, Head length; HW, Head width; EL, Ear length; HNC, Head neck circumference; NL, Neck length; NBC, Neck body circumference; CW, Chest width; SD, Shoulder depth; TD, Thorax depth; TW, Thorax width; TG, Thorax girth; CBL, Cannon bone length; CBC, Cannon bone circumference; HAW, Height at withers; HAB, Height at back; HAC, Height at croup; BOL, Body length; BAL, Back length; PW, Pelvic width; CL, Croup length; BRL, Barrel length. *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.0001$; NS, Not Significant.

Traits	HL	HW	EL	HNC	NL	NBC	CW	SD	TD	TW	TG	CBL	CBC	HAW	HAB	HAC	BOL	BAL	PW	CL	BRL
HL		0.48	0.16	0.35	0.22	0.48	0.41	0.49	0.51	0.38	0.55	0.08	0.41	0.59	0.56	0.56	0.39	0.36	0.42	0.28	0.29
HW	***		0.24	0.37	0.30	0.44	0.39	0.41	0.46	0.44	0.48	0.06	0.36	0.42	0.42	0.41	0.36	0.30	0.42	0.35	0.31
EL	**	***		0.001	0.14	0.07	0.14	0.08	0.17	0.20	0.11	0.03	0.10	0.11	0.11	0.11	0.11	0.16	0.19	0.20	0.23
HNC	***	***	NS		0.34	0.74	0.49	0.57	0.46	0.48	0.67	0.12	0.53	0.57	0.52	0.52	0.43	0.19	0.49	0.47	0.11
NL	***	***	**	***		0.49	0.35	0.42	0.39	0.39	0.53	0.13	0.44	0.53	0.53	0.54	0.47	0.32	0.38	0.40	0.23
NBC	***	***	NS	***	***		0.55	0.66	0.62	0.56	0.78	0.06	0.61	0.70	0.67	0.67	0.49	0.31	0.60	0.52	0.16
CW	***	***	**	***	***	***		0.56	0.45	0.41	0.59	0.23	0.47	0.47	0.41	0.43	0.41	0.40	0.45	0.40	0.25
SD	***	***	NS	***	***	***	***		0.57	0.47	0.73	0.20	0.55	0.69	0.65	0.66	0.56	0.39	0.49	0.51	0.29
TD	***	***	**	***	***	***	***	***		0.56	0.67	0.06	0.52	0.62	0.61	0.59	0.42	0.32	0.56	0.44	0.30
TW	***	***	***	***	***	***	***	***	***		0.66	-0.04	0.49	0.54	0.54	0.52	0.47	0.30	0.57	0.48	0.33
TG	***	***	*	***	***	***	***	***	***	***		0.09	0.66	0.78	0.76	0.76	0.67	0.47	0.72	0.60	0.36
CBL	NS	NS	NS	*	*	NS	***	***	NS	NS	NS		0.26	0.16	0.14	0.15	0.15	0.22	0.002	0.09	0.05
CBC	***	***	NS	***	***	***	***	***	***	***	***	***		0.63	0.60	0.61	0.51	0.39	0.51	0.44	0.20
HAW	***	***	*	***	***	***	***	***	***	***	***	**	***		0.96	0.94	0.60	0.45	0.60	0.55	0.28
HAB	***	***	*	***	***	***	***	***	***	***	***	**	***	***		0.93	0.57	0.43	0.57	0.54	0.28
HAC	***	***	*	***	***	***	***	***	***	***	***	**	***	***	***		0.63	0.47	0.59	0.56	0.31
BOL	***	***	*	***	***	***	***	***	***	***	***	**	***	***	***	***		0.51	0.54	0.50	0.58
BAL	***	***	**	**	***	***	***	***	***	***	***	**	***	***	***	***	***		0.41	0.29	0.37
PW	***	***	**	***	***	***	***	***	***	***	***	NS	***	***	***	***	***	***		0.59	0.35
CL	***	***	***	***	***	***	***	***	***	***	***	NS	***	***	***	***	***	***	***		0.26
BRL	***	***	***	*	***	**	***	***	***	***	***	NS	***	***	***	***	***	***	***	***	

Table 8. Body measure indices of the studied horse populations

Traits	Least Square Means (LSM ± SE)			Mean ± SE	p-value
	Telo	Gesha	Masha		
Stallions					
Body index	88.71 ± 0.40^{a}	85.60 ± 0.34^{b}	88.33 ± 0.53^{a}	87.36 ± 0.24	< 0.0001
Quadratic index	104.5 ± 0.47^{b}	106.2 ± 0.40^{a}	106.0 ± 0.62^{ab}	105.7 ± 0.25	0.0095
Caliber index	135.4 ± 1.16^{ab}	138.0 ± 0.98^{a}	132.8 ± 1.53^{b}	135.5 ± 0.65	0.0119
Overbuilt index	100.4 ± 0.16	100.5 ± 0.14	100.0 ± 0.21	100.4 ± 0.09	0.2523
Chest index	18.40 ± 0.15^{a}	17.89 ± 0.13^{b}	18.17 ± 0.20^{ab}	18.1 ± 0.08	0.0178
Conformation index	1.53 ± 0.014^{b}	1.65 ± 0.011^{a}	1.49 ± 0.018^{b}	1.56 ± 0.009	< 0.0001
Mares					
Body index	91.67 ± 0.75^{a}	87.75 ± 0.58^{b}	90.00 ± 0.69^{a}	89.57 ± 0.40	0.0002
Quadratic index	102.3 ± 0.79	103.2 ± 0.60	103.9 ± 0.72	103.4 ± 0.42	0.3730
Caliber index	130.7 ± 1.57	135.3 ± 1.20	131.4 ± 1.44	132.1 ± 0.89	0.0580
Overbuilt index	100.8 ± 0.25	101.4 ± 0.19	100.7 ± 0.23	101.0 ± 0.13	0.0617
Chest index	17.61 ± 0.21^{ab}	17.23 ± 0.16^{b}	17.88 ± 0.19^{a}	17.53 ± 0.10	0.0379
Conformation index	1.45 ± 0.02^{b}	1.60 ± 0.02^{a}	1.45 ± 0.02^{b}	1.50 ± 0.01	< 0.0001
Both sexes					
Body index	90.01 ± 0.37^{a}	86.71 ± 0.30^{b}	89.07 ± 0.41^{a}	87.99 ± 0.21	< 0.0001
Quadratic index	103.3 ± 0.42^{b}	104.8 ± 0.34^{a}	105.05 ± 0.46^{a}	105.1 ± 0.22	0.0036
Caliber index	133.5 ± 0.97^{b}	136.6 ± 0.80^{a}	131.9 ± 1.07^{b}	134.5 ± 0.53	0.0005
Overbuilt index	100.7 ± 0.14	100.9 ± 0.12	100.4 ± 0.16	100.6 ± 0.07	0.0579
Chest index	18.02 ± 0.13^{a}	17.55 ± 0.10^{b}	17.99 ± 0.14^{a}	17.95 ± 0.07	0.0019
Conformation index	1.50 ± 0.01^{b}	1.62 ± 0.01^{a}	1.47 ± 0.01^{b}	1.54 ± 0.01	< 0.0001

criminatory power and were not used in discriminating the horse populations.

The values and significant levels of different statistical tests used in the discriminant function analysis are shown in Table 10. All the statistical tests were significant showing the appropriateness of the model used in discriminating the horse populations.

Outputs of the canonical discrimination analysis including eigenvalues and class means under the first two canonical structures are presented in Table 11. Similarly, Table 11 also presents raw canonical coefficients used in constructing the two canonical variables (Can 1 and Can 2). Accordingly, the first canonical structure (Can 1) explained the majority (65.7%) of the total variability among the three horse populations. It also produced a greater eigenvalue and multiple correlation (0.70) between the classes (locations) and the morphometric measurements than the second canonical structure (Can 2). These results show the higher power of Can 1 compared with Can 2 in separating the horse populations from the studied locations. However, Can 2 also separated one-third of the population, which Can 1 is unable to separate. Accordingly, Can 1 separated Telo horses from the others while Can 2 separated Masha horses from the others.

Discriminant function analysis classified each individual observation into a known population/location (Table 12). Accordingly, an average of 76.7% of the sampled animals were classified into their respective population/location. The highest classification of individual horses into their respective locations was observed in the Telo horse population (79.7%) with a small error rate (20.3%). On the other hand, a high error rate (26.1%) was detected in the Masha horse population. The priors (33.3%) show the chance of every individual observation to be classified into the given three populations/locations.

Pairwise squared Mahalanobis distances between locations are shown in Table 13. All distances were significant. Gesha and Masha horse populations are closely related, while their distance from the Telo horse population is large.

A plot of the first two canonical structures discriminating the studied horse populations is presented in Figure 2. Accordingly, Can 1 separates the Telo horse population from the others, while Can 2 discriminates the Masha horse population from the others. Overall, the analysis categorized the horse populations into three distinct categories. Therefore, the Gesha horse population is different from the Masha and Telo horse populations. Furthermore, the Gesha horse population has more relationship with the Masha than the Telo horse population.

Qualitative characteristics

Chi-square and Cramér's V statistical values and level of significance for the effect of the class variables on the qualitative characteristics of the studied horse populations are presented in Table 14. All the traits were significantly affected by the location of the horse populations except body colour pattern and shoulder stripe. On the other hand, only five traits were significantly affected by the horses' sex and age. Face and back profile of the studied horse populations were found to be highly associated with location while the level of relationship of shoulder stripe with location was insignificant. A higher level of relationship between the horses' sex and age with their head colour was also observed.

The majority of the studied horse populations possess a plain body colour pattern with red, medium hair size, and long tail and mane with a mainly black muzzle, tail and hoof (Tables 15 and 16, Figure 3). All horses had sloppy croup with the absence of leg stripe. Short hair size, convex face and straight back profiles were observed more frequently on stallions than mares. The majority of the Gesha horses had red body and head (Figure 3, C and D) while white-striped red head was also frequently observed. White body and head colour were observed more frequently on Telo horses. Around half of the horse population from Masha district had black and white hoof, which was rarely observed in the other horse populations.

The effect of age on the colour-related qualitative characteristics of the studied horse populations is presented in Figure 4. Little effect of age on the colour-related qualitative characteristics was observed. As the age of the studied horses increased, the proportion of horses with white body colour showed a significant increase ($p < 0.0001$), while the proportion of the other colours decreased.

Similarly, the proportion of horses with white head colour showed a significant increase ($p < 0.05$) with age, while the proportion of horses with grey head colour decreased. The proportion of the others (red and red with white stripe) remained constant.

Finally, older horses also showed a higher proportion of white tail colour ($p < 0.01$) while the proportion of horses with black tail decreased. The proportion of the others (red and grey) remained the same.

The majority of the Gesha horses had a dorsal stripe and slightly convex face profile, which can be considered their unique characteristics (Table 9). A curved back profile was predominantly observed in Telo horses, which distinguished them from the others. A slight effect of sex on the qualitative characteristics was observed: shorter hair, a slightly convex face and a straight back profile were observed mainly in stallions.

Discussion

Morphometric measurements

The studied morphometric measurements produced reliable information to characterize and differentiate the three horse populations phenotypically. Besides studying the main effect (location), the effects of age and sex were also analyzed to see if they could cause a significant difference. The effect of age was not significant,

Table 9. Summary of the stepwise discriminant function analysis. Traits are listed in ascending order used in discriminating the horse populations from different locations.

Step	Variables entered	Partial R-square	F value	Pr > F	Wilks' Lambda	Pr < Lambda
1	Pelvic width	0.2214	55.60	< 0.0001	0.7785	< 0.0001
2	Cannon bone length	0.1561	36.06	< 0.0001	0.6570	< 0.0001
3	Height at croup	0.1362	30.68	< 0.0001	0.5675	< 0.0001
4	Head width	0.0888	18.91	< 0.0001	0.5171	< 0.0001
5	Body length	0.0574	11.79	< 0.0001	0.4874	< 0.0001
6	Ear length	0.0500	10.16	< 0.0001	0.4630	< 0.0001
7	Thorax depth	0.0381	7.62	0.0006	0.4454	< 0.0001
8	Shoulder depth	0.0531	10.76	< 0.0001	0.4218	< 0.0001
9	Neck body circumference	0.0393	7.84	0.0005	0.4052	< 0.0001
10	Back length	0.0308	6.07	0.0025	0.3927	< 0.0001
11	Barrel length	0.0336	6.63	0.0015	0.3795	< 0.0001
12	Thorax width	0.0272	5.32	0.0053	0.3692	< 0.0001
13	Thorax girth	0.0306	5.99	0.0028	0.3578	< 0.0001
14	Height at withers	0.0191	3.67	0.0264	0.3510	< 0.0001
15	Height at back	0.0227	4.39	0.0131	0.3430	< 0.0001
16	Neck length	0.0200	3.83	0.0225	0.3362	< 0.0001
-	Head length	0.0029	0.55	0.5754	-	-
-	Head neck circumference	0.0002	0.05	0.9555	-	-
-	Chest width	0.0028	0.52	0.5947	-	-
-	Cannon bone circumference	0.0019	0.36	0.6946	-	-
-	Croup length	0.0011	0.20	0.8210	-	-

Table 10. Values and significant levels of different statistical tests. DF, degrees of freedom.

Statistic	Value	F value	Num DF	Den DF	Pr > F
Wilk's lambda	0.3362	17.03	32	752	< 0.0001
Pillai's trace	0.8298	16.71	32	752	< 0.0001
Hotelling-Lawley trace	1.4280	17.35	32	668.29	< 0.0001
Roy's Largest Root	0.9718	22.90	16	377	< 0.0001

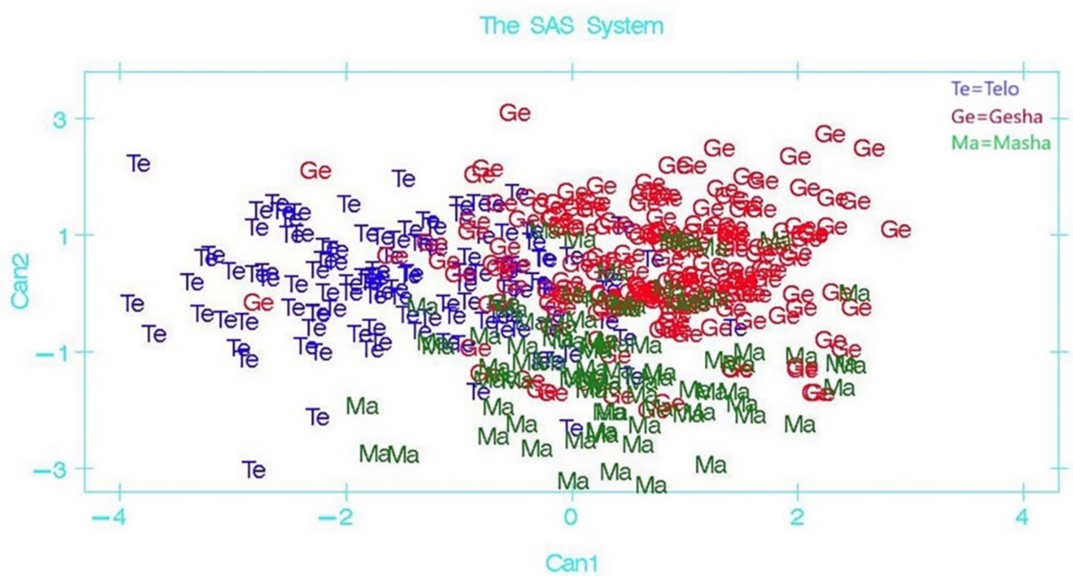

Figure 2. Plot of the first two canonical structures discriminating the three horse populations.

Table 11. Canonical correlations, eigenvalues, and class means.

	Can 1	Can 2
Multivariate Statistics		
Canonical Correlation	0.7020	0.5805
Eigenvalue	0.9718	0.5083
Proportion	0.6566	0.3434
Class (location) means		
Telo	-1.4394	0.1662
Gesha	0.7827	0.5109
Masha	0.3841	-1.2949
Raw canonical coefficients		
Head width	0.3332	-0.2810
Ear length	0.1426	-0.1680
Neck length	-0.0526	-0.0230
Neck body circumference	0.0552	0.0332
Shoulder depth	-0.1501	0.0289
Thorax depth	0.0693	-0.1063
Thorax width	0.0581	-0.1371
Thorax girth	-0.0134	0.0875
Cannon bone length	-0.3522	-0.1375
Height at withers	-0.1633	-0.0871
Height at back	0.1627	-0.0541
Height at croup	0.0777	0.2509
Body length	-0.0567	0.0267
Back length	-0.0606	0.0513
Pelvic width	0.1924	-0.0206
Barrel length	0.0350	-0.0723

which might be due to the nature of the sampling, which included adult horses only. On the other hand, sex significantly affected the studied traits. Stallions had higher values than mares on most morphometric measurements, in line with Rensch's rule (Rensch, 1950). According to Rensch (1950), males of a given species are usually larger than females. Such differences between stallions and mares may be ascribed to levels of testosterone secreted by stallions, which leads to larger muscle mass and skeletal development (Baneh and Hafezian, 2009). Similar results were also reported by Kefena *et al* (2012), Ghezelsoflou *et al* (2018) and Sadek *et al* (2006) on Ethiopian, Iranian Turkoman and Arabian horses, respectively.

According to Kefena *et al* (2012), Selale horses (the tallest and typical riding horses in Ethiopia) had values of 131.2 ± 0.4, 125.6 ± 0.4, and 131.7 ± 0.5cm for heights at withers, back and croup, respectively. The current study revealed that Gesha horses are the tallest horses in Ethiopia with a value of 132.8 ± 0.37, 130.4 ± 0.36, and 134.0 ± 0.36cm for heights at withers, back and croup, respectively (Table 6). However, these values were much lower than the reports of Zechner *et al* (2001) for Lipizzan horses studied in different locations in Europe, and Ghezelsoflou *et al* (2018) for Iranian Turkoman horses in Iran. The tall and big body of the Gesha horse population in Ethiopia indicates that they

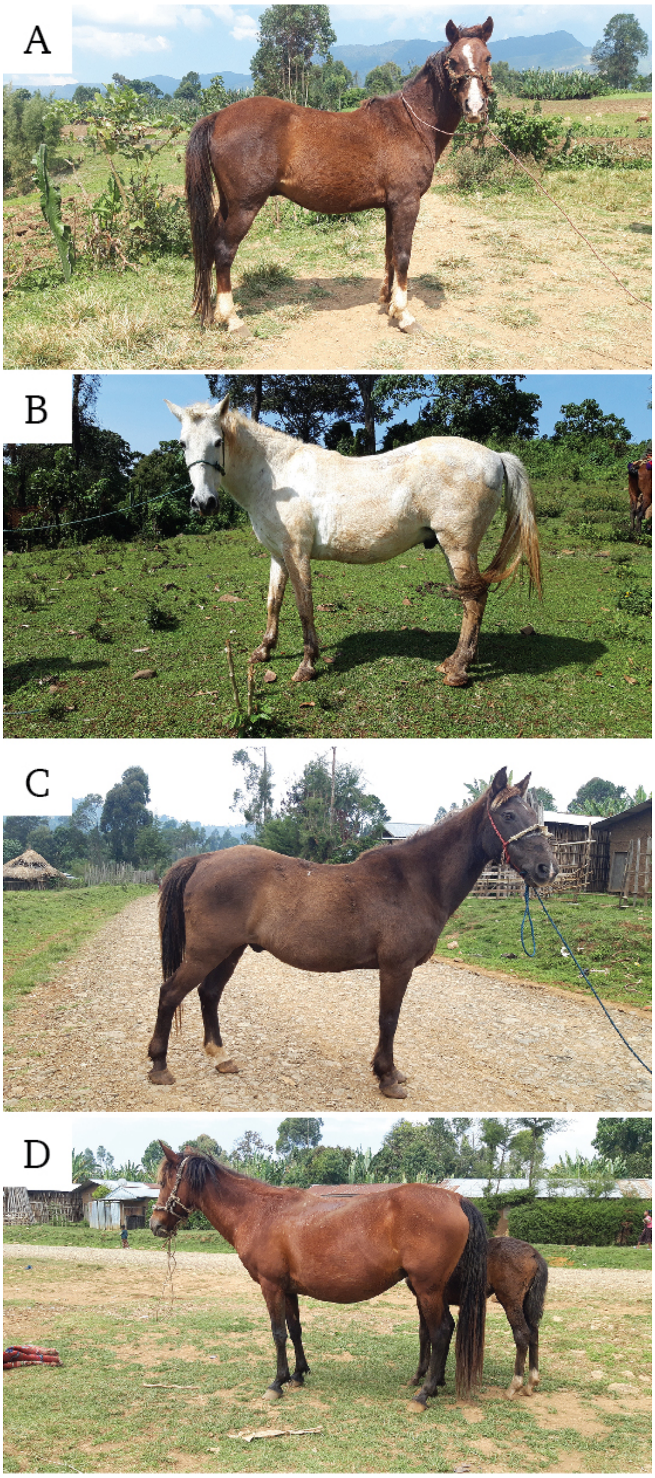

Figure 3. A, Telo stallion; B, Masha stallion; C, Gesha stallion; D, Gesha mare. Photo: Amine Mustefa, EBI

can be categorized as typical saddle horses. This is in line with the study by Kristjansson *et al* (2016) in Iceland, which showed a higher riding ability as the horses' height increased. Traditionally, Gesha horses, which are known for their aggressiveness, are also known and recognized as typical riding horses.

The barrel and neck lengths, and cannon bone length and circumference for all the populations from the current study are comparable with the reports of Kefena *et al* (2012) on all Ethiopian horse populations. The

Table 12. Number and percentage of observations classified into locations.

From location	Telo	Gesha	Masha	Total
Telo	98 (79.7%)	14 (11.4%)	11 (8.9%)	123 (100%)
Gesha	19 (10.4%)	140 (76.5%)	24 (13.1%)	183 (100%)
Masha	7 (7.9%)	16 (18.2%)	65 (73.9%)	88 (100%)
Total	124 (31.5%)	170 (43.1%)	100 (25.4%)	394 (100%)
Error rate	0.203	0.235	0.261	0.233
Priors	0.333	0.333	0.333	

Table 13. Squared Mahalanobis distance between locations; output of the multivariate analysis calculated using the quantitative measurements. *** shows the significance of the distance calculations at $p < 0.0001$.

From location	Telo	Gesha	Masha
Telo	**0**		
Gesha	5.06***	**0**	
Masha	5.46***	3.42***	**0**

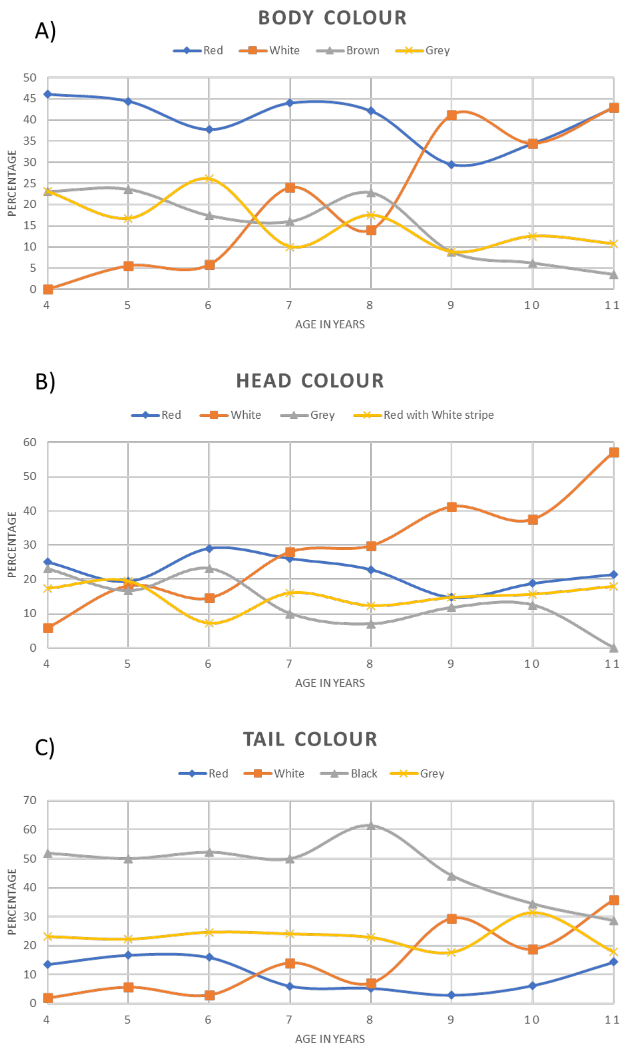

Figure 4. Effect of age on colour characteristics of horse populations. A) Body colour; B) Head colour; C) Tail colour.

body length of Gesha horses (127.0 ± 0.49cm) is lower than the reports of Kefena *et al* (2012) for all Ethiopian horse populations. On the other hand, the head and back lengths of Gesha horses (53.6 ± 0.20 and 71.2 ± 0.33cm, respectively) is higher than all Ethiopian horse populations (Kefena *et al*, 2012). Such wide disagreement might be due to differences in points of measurement. The thorax girth of Gesha horses (146.6 ± 0.56cm) is comparable with Selale (146.6 ± 0.8cm), Bale (145.3 ± 0.7cm), and Horro horses (145.5 ± 0.6cm) while it was higher than Abyssinian horses (140.4 ± 0.5cm) and lower than Keffa horses (152.6 ± 0.7cm) (Kefena *et al*, 2012).

Body measure indices

The body index shows the length of the animal. A long animal is best suited for speed, a short animal for strength (Torres and Jardim, 1981). Long animals have a body index value greater than 90, while a value less than 85 indicates that the animal is short (Torres and Jardim, 1981). According to Table 8, the Telo and Masha mares were categorized as long horses. However, in reality, Gesha stallions are known for their speed.

The caliber index, which shows the overall size of the horse, increases with age and size (Kaps *et al*, 2005). Kaps *et al* (2005) observed its increase from 119.1 to 135 in Lipizzan horses from 6 to 36 months of age. The current findings show the comparably big size of Gesha stallions.

The overbuilt index of a horse indicates the proportion of its height at withers and at croup. A horse with downhill conformation (height at croup higher than height at withers) is indicated as the best riding horse by Padilha *et al* (2017), since stronger muscles in the hind limbs and taller hind limbs indicate greater power for jumping and the ability to give a solo performance. In line with the current findings, Mcmanus *et al* (2005) in Campeiro horses, Rezende *et al* (2014) in Brazilian sport horses and Mariz *et al* (2015) in Quarter horses reported a slightly downhill conformation. However, uphill conformation was reported as an important characteristic by Lucena *et al* (2015) in Marchador horses and Kristjansson *et al* (2016) in Icelandic horses.

According to Torres and Jardim (1981), a riding horse must have a conformation index value of 2.1125. A value above this threshold shows the suitability of a horse for work. The conformation index values found in the current study were between 1.47 and 1.65 (Table 8),

Table 14. Statistical values for chi-square and Cramér's V, and level of significance (probabilities) for the effects of location, sex and age on the qualitative characteristics of the studied horse populations: aggregate sex. χ^2, chi-square; prob., probabilities; *, < 0.05; **, < 0.01; ***, < 0.0001; NS, Not significant.

Qualitative traits	Location			Sex			Age		
	χ^2 value	Cramér's V	Prob.	χ^2value	Cramér's V	Prob.	χ^2value	Cramér's V	Prob.
Body colour	43.1	0.234	***	6.4	0.127	NS	95.2	0.201	***
Head colour	34.8	0.210	*	19.4	0.222	*	90.5	0.432	*
Muzzle colour	37.1	0.217	***	5.9	0.122	NS	42.2	0.164	*
Tail colour	23.7	0.173	**	9.6	0.156	*	58.1	0.192	**
Hoof colour	55.8	0.266	***	1.9	0.069	NS	38.2	0.220	**
Hair size	21.3	0.233	***	12.4	0.178	**	9.7	0.157	NS
Body colour pattern	8.7	0.105	NS	0.07	0.014	NS	8.3	0.103	NS
Dorsal stripe	16.5	0.205	**	0.2	0.021	NS	10.5	0.163	NS
Shoulder stripe	1.8	0.068	NS	1.6	0.064	NS	4.8	0.111	NS
Face profile	52.9	0.367	***	4.1	0.102	*	4.3	0.105	NS
Back profile	52.8	0.366	***	4.0	0.101	*	2.6	0.081	NS
Tail length	28.4	0.190	***	4.2	0.103	NS	17.4	0.149	NS
Mane length	52.8	0.259	***	2.5	0.080	NS	10.0	0.112	NS

Table 15. Percentages of colour-related qualitative traits of the horses (both sexes) from different locations.

Colour-related qualitative traits		Location			Sex	
		Telo	Gesha	Masha	Stallions	Mares
Body colour	Red	30.1	50.8	35.2	42.2	37.5
	Brown	20.3	13.1	21.6	14.5	24.1
	Gray	16.3	15.8	20.5	18.1	14.3
	White	20.3	13.1	18.2	17.4	14.3
	Tan	0.8	5.5	4.6	3.5	4.5
	Black	9.8	1.1	0.0	3.2	4.4
	Red and white	2.4	0.6	0.0	1.1	0.9
Head colour	White	30.9	19.7	28.4	26.9	20.5
	Gray	18.7	12.0	13.6	15.3	12.5
	Red	21.1	26.2	18.2	24.5	18.8
	Red with white stripe	5.7	21.9	12.5	14.9	14.3
	Black	14.6	9.8	9.1	10.3	13.4
	Black with white stripe	0.8	1.6	4.5	1.8	2.7
	Brown	5.7	4.9	9.1	3.5	12.5
	Brown with white stripe	1.6	0.6	1.1	0.7	1.8
	Tan	0.8	1.1	0.0	1.1	0.0
	Tan with white stripe	0.0	2.2	3.4	1.1	3.6
Muzzle colour	Black	51.2	36.6	37.5	39.4	46.4
	White	26.8	19.7	12.5	22.7	14.3
	Red	10.6	25.7	18.2	19.1	10.6
	Gray	11.4	9.3	21.6	13.5	10.7
	White and Black	0.0	8.7	10.2	5.3	8.9
Tail colour	Black	52.0	53.0	36.4	48.6	50.0
	Gray	26.0	19.7	26.1	25.2	17.9
	White	13.8	8.7	12.5	11.7	9.8
	Red	4.9	14.8	12.5	11.0	11.6
	Brown	3.3	3.8	12.5	3.5	10.7
Hoof colour	Black	91.9	74.9	52.3	74.1	77.7
	Black and White	4.9	21.8	47.7	22.7	21.4
	White	3.2	3.3	0.0	3.2	0.9

Table 16. Percentages of qualitative traits of the horses (both sexes) from different locations.

Qualitative traits		Location			Sex	
		Telo	Gesha	Masha	Stallions	Mares
Hair size	Short	42.3	43.2	15.9	42.2	23.2
	Medium	57.7	56.8	84.1	57.8	76.8
Body colour pattern	Plain	95.9	99.4	100	98.6	98.2
	Pied	1.6	0.6	0.0	0.7	0.9
	Shaded	2.4	0.0	0.0	0.7	0.9
Dorsal stripe	Absent	67.5	44.3	57.9	53.9	56.3
	Present	32.5	55.7	42.1	46.1	43.7
Shoulder stripe	Absent	99.2	99.4	97.7	98.6	100
	Present	0.2	0.6	2.3	1.4	0.0
Face profile	Straight	86.2	45.4	65.9	59.6	70.5
	Slightly convex	13.8	54.6	34.1	40.4	29.5
Back profile	Straight	44.7	76.5	87.5	72.0	61.6
	Curved	55.3	23.5	12.5	28.0	38.4
Tail length	Short	2.4	0.0	0.0	1.1	0.0
	Medium	40.7	22.4	14.8	28.7	20.5
	Long	56.9	77.6	85.2	70.2	79.5
Mane length	Short	4.9	0.0	0.0	2.1	0.0
	Medium	48.0	16.9	39.8	31.9	31.3
	Long	47.1	83.1	60.2	66.0	68.7

with Gesha stallions having the highest conformation index values among the studied populations.

Multivariate analysis

Stepwise discriminant function analysis selected and ranked the morphometric variables according to their importance in discriminating the studied horse populations. The inclusion of height at croup and body length within the top five discriminatory variables is comparable with the reports of Kefena *et al* (2012), who classified them among the top four variables to discriminate Ethiopian horse populations. The results of discriminant function analysis showed an advanced classification (76.7%) of the studied horses into their respective populations/locations. This high value shows the dissimilarity among the studied populations. Canonical discriminant function analysis revealed the higher power of Can 1 than Can 2 to separate the horse populations. This shows the separation of Gesha and Masha horses from Telo horses while differences also occur between Gesha and Masha populations. However, the distances showed only the relative size differences between each population. Such differences might not necessarily be due to breed (genetic) differences (Zechner *et al*, 2001). Therefore, a diversity study through further genetic characterization is recommended to design conservation and breeding programmes.

Qualitative characteristics

Besides their aggressiveness and top-riding ability, the examined qualitative characteristics clearly differentiated the Gesha horse population from the other studied populations. The majority of Gesha horses possess red body colour, red and white-striped red head colour, striped dorsal body, slightly convex face and long mane while some similarities were observed with the adjacent Masha horses. A slight effect of sex and age on the qualitative characteristics was observed. Shorter hair, a slightly convex face and a straight-back profile were observed predominantly in stallions than mares.

The current study revealed the level of relationship between age and body colour. As age advanced, the proportion of horses with white (body, head and tail) colour increased while the proportion of horses with grey and brown colours decrease, which might be due to the progressive depigmentation of the coat's hairs (Locke *et al*, 2002). At birth, grey horses may have any colour but over time, white hairs begin to appear and become gradually more dominant as white hairs become intermixed with hairs of other colours. At a later age, most horses of this type ultimately become completely white, though some retain intermixed light and dark hairs (Locke *et al*, 2002). This is due to the presence of a greying allele of the KIT gene, which inhibits the hair follicles from producing melanin. The coat takes on a 'dappled' pattern that increasingly becomes white. However, grey horses with a totally white coat can be distinguished from white horses by their underlying black skin, particularly around the eyes, muzzle, and genital area (Locke *et al*, 2002).

Conclusion

The studied phenotypic traits (morphometric measurements and qualitative characteristics) had produced reliable information in characterizing and differentiating Gesha, Masha and Telo horse populations. Gesha horses were the tallest, longest and largest among the studied horse populations. Besides their size, the most important characteristics of Gesha horses are their aggressiveness, top-riding ability, red-dominated body colour, white-striped red head colour and slightly convex face. These results were also supported by the multivariate analysis, which differentiated the Gesha horse population from the Masha and Telo horse populations, and showed a relatively higher relationship with Masha horses. Further genetic characterization is recommended to confirm the above results and design conservation and breeding programmes.

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Author contributions

All authors contributed to the study conception and design. Material preparation and data collection were performed by Amine Mustefa, Aweke Engdawork, and Seble Sinke. Amine Mustefa performed the data analysis and wrote the first draft of the manuscript. All authors commented on previous versions of the manuscript, and read and approved the final manuscript.

Conflict of interest statement

The authors declare that they have no conflict of interest.

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