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Multivariate analysis of morphometric traits of the horse ecotypes reared in highlands of Bale Zone, Ethiopia

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A R T I C L E I N F O

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A B S T R A C T

This study was conducted to evaluate morphometric traits of horse ecotypes reared in four districts of the Bale highlands, southeastern Ethiopia. Twenty-seven morphometric traits were measured from 500 horses (294 males and 206 females) of both sexes. Data were analyzed using SAS 2012. This study revealed that certain traits, such as head length, loin length, bi-ischial width, and sternum height of horses were similar. However, significant differences ($p < 0.0001$, $p < 0.01$, $p < 0.05$) were observed in other traits across the districts. All traits were affected by age ($p < 0.05$) except rump width and canon perimeter. All 27 morphometric traits were subjected to STEPDISC analysis, of which 21 had the best discriminating power. The uppermost distances of 32.2 and, 28.8 were reported between the Agarfa and Dinsho and, Agarfa and Sinana horse populations, respectively. Mean separation distance among districts ranges from -1.75 to 3.57, -2.42 to 2.43, and -1.61 to 0.92 for CAN1, CAN2 and CAN3, respectively. The quadratic discriminate function classified 95.2, 94.4, 96.0, and 96.8 % of the sampled horses into source populations of the Dinsho, Agarfa, Sinana, and Goba districts, respectively. In addition, the cross-validation summary revealed reduced consistency of membership among each districts with 5 % average success rates and 4, 8, 4, and 4 % for the Dinsho, Agarfa, Sinana, and Goba districts, respectively. Therefore, the presence of variation in morphometric traits within the Bale Highland horse ecotypes has the potential for selection and further genetic interventions.

Introduction

Nearly all horse populations found in Ethiopia are genetically native, except the Balidras breed imported from Britain for breeding purposes during Emperor Haile Selassie I (Lemma et al., 2015). Likewise, Effa et al. (2012) documented that eight native horse ecotypes found in different parts of the Ethiopia. There are around 2.15 million horse populations found in the country (CSA, 2021). These include the Abyssinian horse (Semien Mountain), Bale horse (Bale zone), Borana horse (Boran lowlands), Kafa horse (rain-forests of the Sheka and Keffa zones), the oldest Kundudo or Feral horse in Africa (Kundudo mountain), Ogaden or Wilwal horse (Somali region), and Selale horse (Shewa Oromo horse). With the exception of Effa et al. (2021) studied on horse genetic diversity; none of them has been acknowledged for performance qualify traits for production criteria and effective employment. These horses are commonly called/named based on their place of origin, the community raised them, and the ethnic group that uses them for daily livelihood (Asfaw & Tadesse, 2020). According to The BROOKE Ethiopia (2021) investigation, approximately 250,000 cart horses serve millions of people across different parts of the country. They are kept and used under traditional husbandry practices, with restrictions on their access to sufficient food, water, shelter, and health care (Cunha, 2012).

Over 50 % (1.30 millions) of the country's horse population be present in the Oromia region (CSA, 2021). Thus, in Oromo villages, rural horse husbandry traditions date back as far as cattle reared. They played a key role in the Oromo uprisings' combat against the monarchs that ruled modern Ethiopia prior to the Derge regime to establish democracy and ethnic impartiality. Moreover, horseback riding is a recreational and competitive activity among Oromo ethnic groups at cultural gatherings and festivals (Lemma et al., 2015). Correspondingly, horse ecotypes dispersed in highlands of Bale eco-region plays the same roles for the Arsi–Bale Oromo society until today. They are efficiently used for cultural rites, such as weddings, festival days, cultural sports, and funerals. Moreover, they plays a crucial part in agricultural livelihoods that occur in Bale terrain topography where infrastructure has not yet been established.

Despite the diverse indigenous horse populations and their significance in agriculture, culture, and societal values, they are neglected for

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genetic improvements across various production ecologies. Also, absence of phenotypic description in various production scenarios is a major problem that prevents further conservation initiatives and genetic interventions (Assefa et al., 2021). Additionally, inbreeding, selection pressures and traditional husbandry practices hurt genetic diversity without being conserved for future genetic exploitations (Van Marle-Köster et al., 2021). Also, no efforts have been undertaken in the area to benefit local farmers from their elite genetic resources (Abayneh et al., 2002).

Correspondingly, horses distributed in highlands of the Bale area has not yet been scientifically studied for conservations, despite hereditary presentations being subject to various selection pressures (e.g., farmers and environment). Thus, characterization and documentation of phenotypic traits, particularly morphometric traits are essential when selecting horses for employment, productive and reproductive performances (Perdomo-González et al., 2022; Souza et al., 2018; Staiger, 2015). Moreover, specific physical attributes should be evaluated for genetic interventions, primarily for crossbreeding program (Ducro, 2018). However, seasonal variations, one time linear body measurements, supervision level of owners, workload, and the effects of sexual dimorphism all have significant influences on the morphometric traits measurement and body conformation scores. Thus, agricultural societies assigned standards for selection when marketing and breeding according to the suggested employment and importance of morphometric traits in packing and loading carts and wagons, mainly in daily agricultural activities, saddle, riding purposes (Djukic et al., 2018; Recht, 2022). These has made selection and breeding improvements push for considerations of key morphometric traits. This will help to implement conservation policies and increased economic benefits through implementing horse breeding associations. As a result, the study aimed to evaluate morphometric traits that revealed the existence of phenotypic diversity in the horse population distributed in the highlands of the Bale zone of the Oromia region, Ethiopia.

Materials and method

Description of the study area

The study was conducted in four (4) districts of the Bale zone of Oromia region, Ethiopia between November 2022 and June 2023. Geographically, the area lies between 5^{0}11′03’’N-8^{0}09′27’’N latitude and 38^{0}12′04’’ ‘E-42^{0}12′47’’E longitude (Fig. 1). They area has an elevation range of 2424–3207 meters above sea level as well as described for climatic conditions (Table 1). The area is well known for both crop cultivation (wheat and barley) and livestock production, where horses are extensively populated and effectively employed in agricultural practices.

Sampling procedures

The research sites of the Dinsho, Goba, Agarfa, and Sinana districts and *kebeles* (smallest administrative unit) were selected using purposive sampling procedures, acknowledging high horse populations. Among the study districts, two (2) *kebeles* were selected besides three (3) towns where the commercial exploitation of horses was prevalent. But, only two (2) *kebeles* were selected from the Dinsho district of high productive and reproductive areas. The study horse populations were selected randomly among *kebeles* and towns. Thus, a total of 500 horses (294

Table 1
Altitude and climatic conditions of the study districts.

Districts	Altitude	Annual temperature	Annual precipitation (%)	Climatic condition
Agarfa	2, 466.8	8.6–18.6 °C (14.4)	47.9–58.1 %	Tropical wet and dry
Dinsho	3, 207	3–17 °C (12.4)	53–80 %	Tropical afro-alpine
Goba	2, 705.1	5–18 °C (14.3)	59 - –69.3 %	Tropical wet and dry
Sinana	2, 424	9.5–21 °C (15.2)	45–56 %	Sub-humid to cool mild

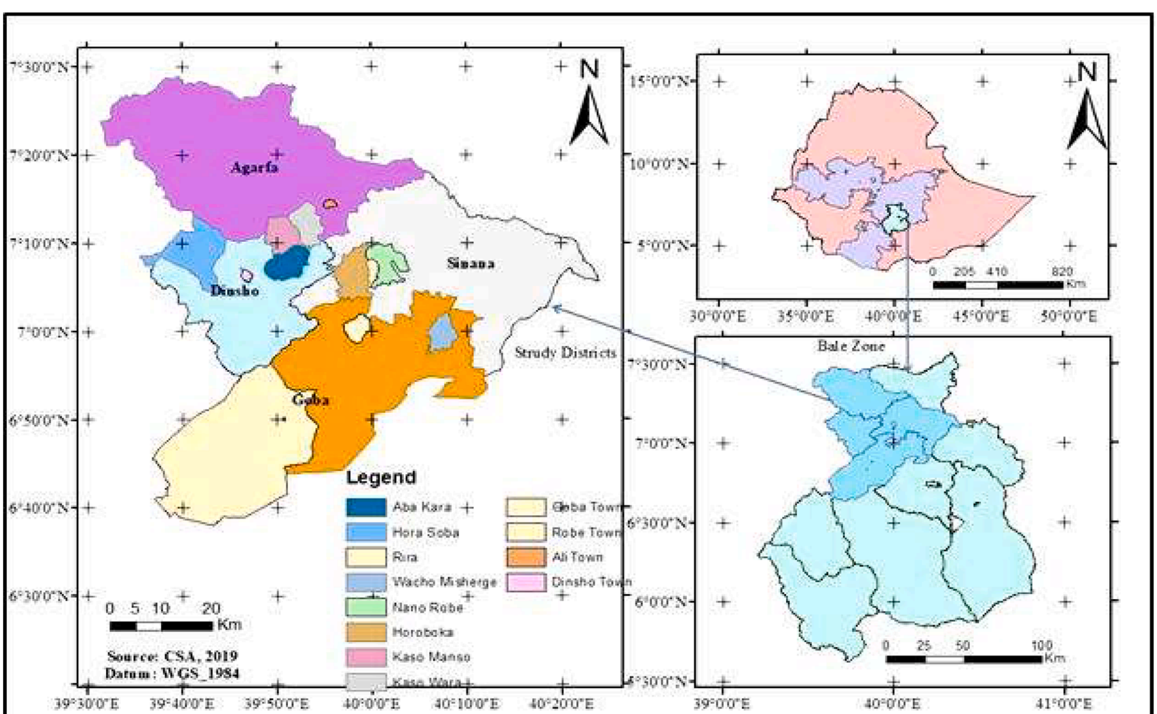

Fig. 1. Map of the study districts, *kebeles*, and towns.

males and 206 females) were selected for data collections across study sites (125 from each district) (Table 2). Age of horse were determined using the recall method of the owners and the dentition methodology for age-proofing (Elbeltagy et al., 2016). The age of selected horses were clusters in to three major groups as per distribution of Lewczuk (2015). Ages from 3 to 5 years old (123) termed as best age of first foal or birth period of female horse (filly) begins and male horses (colts) sexual maturity; >5–8 years old (261) at which mare and Stallion's performance culminates maximum and; >8–10 years old (116) at which they acquired good temperament, conformation, bloodlines and talent (efficient and effective working age). However, horses become either stagnates or/and decreases in performances when aged above 11 years in the study area.

Data collection

Tape meter and measuring stick were used to collect data on horse morphometric traits in line with ethical guidelines for animal ethics and experiment (Madda Walabu University Animal welfare and ethics committee, 2008) in animal research (ref. no RPEED/012/2015). Moreover, before data collection, researchers verbally obtain the approved consent of the horse owner's agreement. Data was collected by measuring neck length (NL), neck circumference (NC), head length (HDL), head width (HDW), croup height (CorpH), hip or quarter height (hipH), height at buttock (HBU), height at dock or thigh (HDO), height at hock (HHO), height at wither (HW), rump width (RW) or hip width (hipW), rump length (RL) or croup length (CorpL), thoracic depth (ThD), thoracic width (ThW) or shoulder bone length (SBL), chest width (ChW), back width (BaW), back length (BaL), mid back height (MBH), loins length (LoL), loin width (LoW), bi-ischial width (BiW), body length (BL), thoracic girth (TGi) or thorax perimeter (TP), sternum height (SH), shin bone perimeter (SBP) or cannon circumference (CC) also called canon perimeter (CP), hind leg length (HLL), and fore leg length (FLL) as described by Cabral et al. (2004) and Sanchez-Guerrero et al. (2016), Costa et al. (1998), Miserani et al. (2002). Pregnant mares (females) were excluded to avoid misleading information's. The data was gathered early in the morning, before the horses were let out to be fed and worked.

Data analysis

Data were analyzed using descriptive statistics to determine means followed by ANOVA to test the effect of districts, sex, and age group on morphometric traits (SAS, 2012 Vr. 9.4). Duncan's multiple range test was used to differentiate the means when the F-test deemed significant. The model used for data analysis:

Y_{ijk}: $\mu + S_i + B_j + D_k + e_{ijk}$

Where:
$Y_{ijk:}$ the response of the observed variables,
μ: the overall mean
S_i: fixed effect of the i^{th} district (1: Dinsho, 2: Goba, 3: Agarfa, 4: Sinana);
B_j: fixed effect of the j^{th} sex (1: Male, 2: Female) and;
D_k: fixed effect of the k^{th} age group (1: 3–5, 2: >5–8, 3: >8–10); e_{ijk}: random error.

Furthermore, the diversity of the studied horse ecotypes was determined using a multivariate analysis. The STEPDISC technique was first applied to identify morphometric traits to determine discriminating power. Then, traits that displayed discriminating power were examined using cluster canonical and quadratic discriminant functions. Homogeneity of variances was examined using chi-square test. The canonical (CAN) variables were shown in a scatter graph using the TEMPLATE and SGRENDER techniques for visual explanation. The studied horse populations were assigned to source populations using DISCRIM analysis and the likelihood of membership was determined using distance intervals and overlaps among the studied districts.

Table 2
The study district horse population, target *kebeles*, towns and sampled size.

District	Horse population	*Kebeles* and Towns	Sample size
Dinsho	19,376	*Aba Kara and Hora Soba*	125 (M: 46, F: 79)
Goba	28,598	*Rira, Wacho Misherge and Goba town*	125 (M: 53, F: 72)
Agarfa	16,062	*Kaso Wara, Kaso Manisoand Ali town*	125 (M: 85, F: 40)
Sinana	19,401	*Nano Robe, Horeboka, and Robe town*	125 (M: 110, F: 15)

Source: Bale Zone Livestock Agency, 2020.

Results

Descriptive statistics

Summarized descriptive statistics results of the morphometric traits of horse ecotypes distributed in the highlands of the Bale Zone are shown in Table 3. The results demonstrated a highly significant differences ($p < 0.0001$) among the study districts for HBU, HW, BL, and TP. In comparison, HBU in Sinana had the highest measurement, whereas the lowest in the Dinsho district. In addition, high values of TP, BL, and HW were recorded in Sinana and Agarfa districts, whereas the lowest values noted for the remaining districts. In addition, the study showed that the NC, CorpH, HDO, MBH, RW, CorpL, ChW, BaL, CP, HLL, and FLL traits were significantly different ($p < 0.01$) among the study districts. NC, CorpL, HDO, MBH, RW, CorpL, ChW, BaL, SBP or CP, FLL, and HLL were the lowest for Goba and Dinsho and highest for the Sinana and Agarfa districts. Furthermore, there were significant ($p < 0.05$) differences in the morphometric measurements of NL, HDW, HHO, ThD, ThW, BaW, and LoW. However, HDL, LoL, BiW, and SH were non-significant ($p > 0.05$) across the study districts. Similarly, there were no significant differences ($p < 0.05$) in the morphometric traits of RL, ThD, TP, ThW, and ChW for the horse populations in the Dinsho and Goba districts. The highest values were recorded for BaW, WH, TP, CorpH, BL, HDL, NL, FLL, and HLL in Agarfa and Sinana compared to the Goba and Dinsho district horse populations. However, the lowest values were reported for CorpH (124.7), hipH (105.2), HBU (94.3), ChW (28.2), BaW (30.4), and LoW (18.1) in Dinsho, and for RW (36.1) and TP (134.6) in Goba District (Table 3).

The sex effect was highly significant ($p < 0.0001$) for traits of NC, HDL, CorpH, hipH, HBU, HDO, MBH, WH, ChW, BaL, BL, TP, SH, HLL, and FLL. In addition, the sex effect was significantly different ($p < 0.01$) for NL, HHO, BaW, LoL, and LoW while significant at ($p < 0.05$) for HDW, RW, CorpL, ThW, ThD, BiW, and CP. The study shows that a record number of measured traits was advanced in males across ages. This might be due to a large proportion of male horse sample size. In contrary, females advanced at the age of >5–8 year-old. This was due to a large number of females at this age. On the other hand, comparable results were obtained for RW, CorpL, ThD, ThW, BiW, and CP traits for males and females (Table 3).

The morphometric traits of NL, NC, HDL, CorpH, hipH, HDU, HDO, MBH, WH, BaL, LoL, LoW, BL, TP, SH, FLL, and HLL were significantly ($p < 0.0001$) affected by age differences. Similarly differences across age groups had a significant effect on morphometric traits of HDW, HHO, CorpL, ThD, ThW, ChW, BaW, and BiW. However, non-significant ($p > 0.05$) for RW and CP. Moreover, within age groups, variations were higher for BaL and MBH, while non-significant ($p > 0.05$) for LoL and BiW traits (Table 3).

Table 3
Measurements of morphometric traits of the horse ecotype distributed in the highland of Bale Zone.

Traits	NL	NC	HDL	HDW	CorpH	hipH	HBU	HDO	HHO	MBH	WH	RW	CorpL	ThD	ThW	ChW	BaW	BaL	LoL	LoW	BiW	BL	TP	SH	CP	HLL	FLL
Mean	51.4	69.6	47.3	16.7	128.2	115.1	108.8	110.8	50.5	126.1	128.4	38.7	36.9	46.4	26.7	31.7	33.8	78.2	25.8	22.2	30.5	123.8	140.5	68.0	14.6	84.8	79.9
District	*	**	ns	*	**	**	***	**	*	**	***	**	**	*	*	**	*	**	ns	*	ns	***	***	ns	**	**	**
Dinsho	49.3	67.8	46.5	15.8	124.7	105.2	94.3	113.7	49.5	121.8	123.1	38.2	35.5	43.9	24.5	28.2	30.4	76.1	25.0	18.1	29.8	119.0	139.9	68.2	16.0	83.5	76.8
Goba	51.6	68.0	46.7	16.1	127.1	116.4	110.3	108.4	49.1	123.9	122.4	36.1	35.3	47.2	27.5	28.6	34.7	75.4	25.3	21.4	31.1	120.9	134.6	66.6	14.7	83.2	77.6
Agarfa	50.7	72.3	47.3	17.2	127.3	119.5	111.4	110.1	51.4	128.2	133.1	40.8	38.3	46.7	28.3	31.8	35.1	80.7	25.5	24.1	31.6	128.3	145.2	67.7	16.4	84.6	80.9
Sinana	52.1	71.4	48.8	17.5	131.5	118.1	119.2	110.5	52.1	127.9	132.8	38.6	38.5	46.1	26.8	31.6	35.0	79.2	27.1	23.8	28.9	127.4	144.2	70.0	16.2	87.9	83.7
Sex	**	***	***	*	***	***	***	***	**	***	***	*	*	*	*	***	**	***	**	**	*	***	***	***	*	***	***
Female	49.5	65.9	45.4	15.5	124.3	110.4	102.6	107.4	48.8	121.9	122.5	37.5	37.7	45.1	26.2	34.2	32.5	75.3	24.6	20.36	31.8	119.5	134.9	65.6	15.1	82.4	76.1
Male	52.2	73.7	51.3	17.4	130.1	119.1	114.5	112.1	51.7	128.1	132.9	39.9	36.4	46.9	27.6	38.0	35.2	79.6	26.5	23.28	30.1	127.1	146.3	69.4	16.9	86.2	82.2
Age	***	***	***	**	***	***	***	***	**	***	***	ns	**	**	**	**	**	***	***	***	**	***	***	***	ns	***	***
3–5	48.8	67.9	45.5	15.5	124.1	112.6	101.7	108.4	49.6	121.3	124.2	38.3	37.8	44.2	25.1	29.3	31.1	74.8	23.8	20.1	29.8	117.7	135.7	66.0	14.9	81.6	78.4
>5–8	51.4	69.6	47.7	16.8	128.8	118.5	109.9	112.1	50.6	127.1	129.5	38.7	36.6	46.9	27.6	30.8	34.8	79.6	26.2	22.3	30.4	125.8	142.4	68.9	14.9	85.7	80.2
>8–10	53.1	71.4	48.2	17.5	130.9	121.4	113.1	109.7	51.5	128.9	130.5	38.9	36.9	47.5	26.3	31.4	34.6	77.7	26.7	23.1	31.6	125.8	141.0	68.3	14.8	86.2	80.8

*** significant at $p < 0.0001$, ** significant at $p < 0.01$, * significant at $p < 0.05$, ns: not significant at $p > 0.05$; NL: neck length; NC: neck circumference; HDL: head length; HDW: head width; CorpH: croup height; hipH: hip height; HBU: height at buttock; MBH: mid back height; HW: wither height; RW: rump width, CorpL: croup length; ThD: thoracic depth; ThW: thoracic width; ChW: chest width; BaW: back width; BaL: back length; LoL: loin length; LoW; loin width; BiW: bi-ischial width; BL: body length; TP: thoracic perimeter; SH: sternum height; CP: cannon perimeter; HLL: hind leg length; FLL: fore leg length.

Stepwise discriminate analysis

Per study, out of the twenty-seven (27) morphometric traits that were analyzed using STEP DISC analysis, 21 had the best discriminating power (Table 4). The results showed that the morphometric trait variability in the sampled population's was much higher ($p < 0.0001$). Similarly, the Wilks' Lambda tests for within variance to total variation for the traits of ChW, LoW, RL, HBU, CP, and CorpH contributed the strongest discriminating power with 61.3, 36.6, 26.0, 17.7, 13.2, and 12.8 %, respectively. Additionally, with reduced variances throughout the Dinsho, Agarfa, Sinana, and Goba districts, TGi/TP, ThW, ThD, BaL, LoL, HHO, BaW, NC, HDL, hipH, FLL, RW, BiW, BL, and HDO were included as the least discriminating power traits, with a tolerance of <0.1. This demonstrates that the differences in population living in comparable areas were not as substantial as those between districts. Thus, all traits accept SH, NL, HDW, MBH, LoW, HW, FLL, and HLL had discriminate power across populations in the study area. Therefore, the most essential traits for easily identifying the study population among districts were ChW, LoW, RL, HBU, CP, CorpH, TP/TGi, ThW, ThD, BL, and BaL, as evidenced by their partial discrete R^2 values. However, RW, BiW, and HDO were comparable among studied districts (Table 4).

Cluster analysis

Based on the cluster analysis, the horse population raised in four districts of the Bale zone can be divided into two main groups with an average distance of 3.6 between each group. Therefore, cluster 1 has populations from the Dinsho and Agarfa districts separated by a mean square distance of 0.58. The horse populations in the Sinana and Goba districts were classified in to cluster 2 with a mean square distance of 1.6 even with disparate morphometric traits and geographical locations. In addition, four (4) sub-clusters were clearly seen in the horse population throughout the four districts. Consequently, the Goba and Sinana horse populations shared a portion of the admixture population. Furthermore, Goba and Dinsho horse populations were diversified as can be seen in Figure below (Fig 2).

Canonical discriminate analysis

Table 5 displays the Mahalanobis distance and area of mean separation among the four districts of the study population. The uppermost distances; 32.2 and 28.8 were reported between Agarfa and Dinsho and, Agarfa and Sinana horses, respectively. In addition, average distances of 24.4 and 24.2 were observed between Dinsho and Sinana and, Agarfa and Goba, respectively, while the lowest distances reported between Goba and Sinana and,Dinsho and Goba districts with respective of 13.8 and 10.2 generalized squared distance. The distance of the studied horse population among four districts were highly significant ($p < 0.0001$). For measured traits, the separation mean among districts shows CAN1′s distance ranged from -1.75 to 3.57 (average of 4.32), CAN2 ranges from -2.42 to 2.43 (average of 4.85), and CAN3 which ranges from -1.62 to 0.92 (average of 2.53). This indicates that the morphometric traits used for classification among districts had a lower pairwise squared distance among groups for CAN2. However, the distinctions were lower within the population of districts (Table 5).

The graphic elucidations of differences in CAN variables of the studied horse populations are clearly shown in a scatter graph (Fig 3).

Table 6 displayed the canonical variables (CAN) that identify the relationships between CAN1, CAN2, and CAN 3 with eigenvalues and likelihood ratios. The morphometric traits assigned to the CAN1 exhibited the highest squared and adjusted canonical correlations among the examined traits. The study revealed three canonical variables (CAN) of CAN1, CAN2, and CAN3 that had likelihood ratios of 0.02, 0.12, and 0.51 and significantly different ($p < 0.0001$) those proportionally account for 82.0, 76, and 49 % of the total variations, respectively (Table 6).

Table 4
Summary of stepwise discriminate analysis of variables.

Step	Variables	Partial R^2	F value	Pr > *F*	Wilks' Lambda	Pr < Lambda	ASCC	Pr > ASCC
1	ChW	0.3873	88.72	<0.0001	0.61267402	<0.0001	0.12910866	<0.0001
2	LoW	0.4031	94.55	<0.0001	0.36569059	<0.0001	0.25651139	<0.0001
3	RL	0.2890	56.78	<0.0001	0.25999582	<0.0001	0.33389340	<0.0001
4	HBU	0.2559	47.81	<0.0001	0.17770604	<0.0001	0.43763115	<0.0001
5	CP	0.2361	42.86	<0.0001	0.13165575	<0.0001	0.48992685	<0.0001
6	CorpH	0.1940	33.30	<0.0001	0.12812601	<0.0001	0.50858059	<0.0001
7	TP/TGi	0.1611	26.49	<0.0001	0.06805916	<0.0001	0.53626495	<0.0001
8	ThW	0.1399	22.39	<0.0001	0.05853974	<0.0001	0.56056790	<0.0001
9	ThD	0.1364	21.69	<0.0001	0.05055468	<0.0001	0.59106394	<0.0001
10	BL	0.1248	19.53	<0.0001	0.04424671	<0.0001	0.61053817	<0.0001
11	LoL	0.0899	13.50	<0.0001	0.04026940	<0.0001	0.62096592	<0.0001
12	HHO	0.0976	14.75	<0.0001	0.03633777	<0.0001	0.63131654	<0.0001
13	BaW	0.0786	11.60	<0.0001	0.03348187	<0.0001	0.64127589	<0.0001
14	NC	0.0839	12.43	<0.0001	0.03067189	<0.0001	0.64907402	<0.0001
15	HDL	0.1076	16.32	<0.0001	0.02737189	<0.0001	0.65957128	<0.0001
16	hipH	0.0823	10.52	<0.0001	0.02539335	<0.0001	0.66655176	<0.0001
17	FLL	0.0663	9.56	<0.0001	0.02370981	<0.0001	0.67710954	<0.0001
18	RW	0.0857	12.60	<0.0001	0.02167734	<0.0001	0.69014536	<0.0001
19	BiW	0.0918	13.54	<0.0001	0.01968799	<0.0001	0.70256671	<0.0001
20	BL	0.0541	7.64	<0.0001	0.01862307	<0.0001	0.70580154	<0.0001
21	HDO	0.0415	2.77	0.0007	0.01785051	<0.0001	0.71231216	<0.0001

ASCC: Average squared canonical correlation.

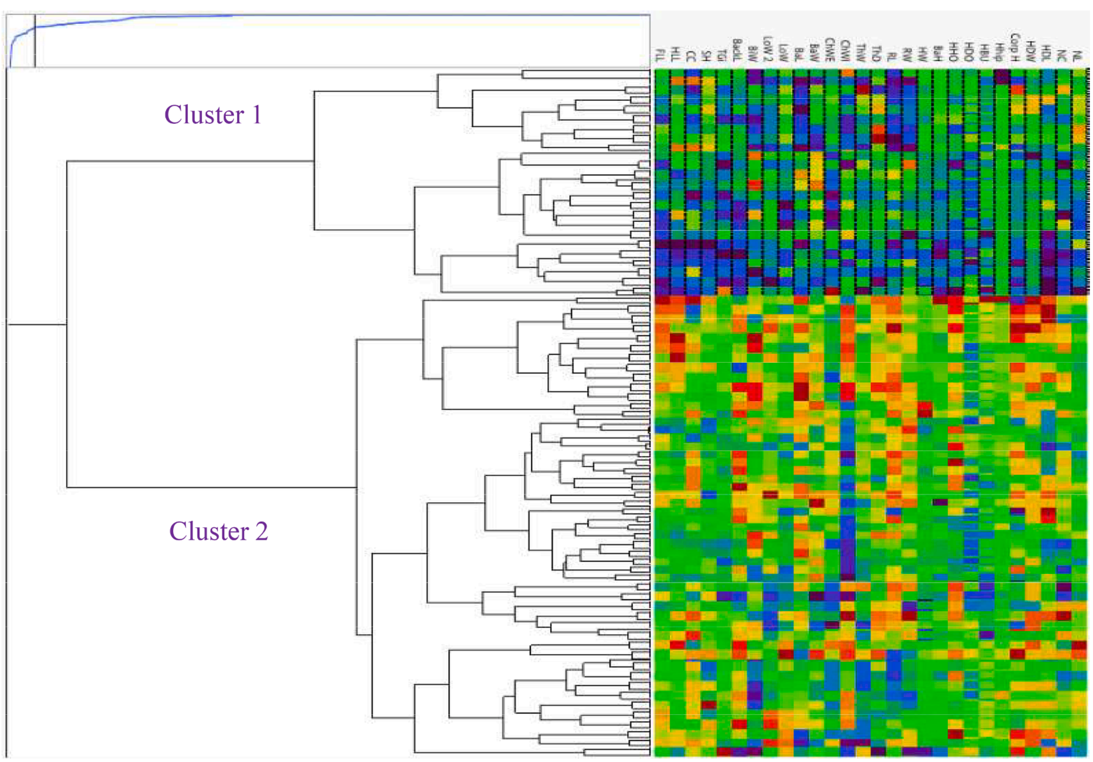

Fig. 2. The Dendrogram constructed using average linkage values between groups of four district horse populations.

Table 5
Mahalanobis squared distance matrix and mean separations for horse population among the four districts of Bale Zone.

Districts	Agarfa	Dinsho	Goba	Sinana	Separation means		
					CAN1	CAN2	CAN3
Agarfa		32.3	24.2	28.8	3.57	-0.47	0.09
Dinsho	<0.0001		13.8	24.4	-1.75	-2.42	0.60
Goba	<0.0001	<0.0001		10.3	-0.95	0.46	-1.61
Sinana	<0.0001	<0.0001	<0.0001		-0.87	2.43	0.92

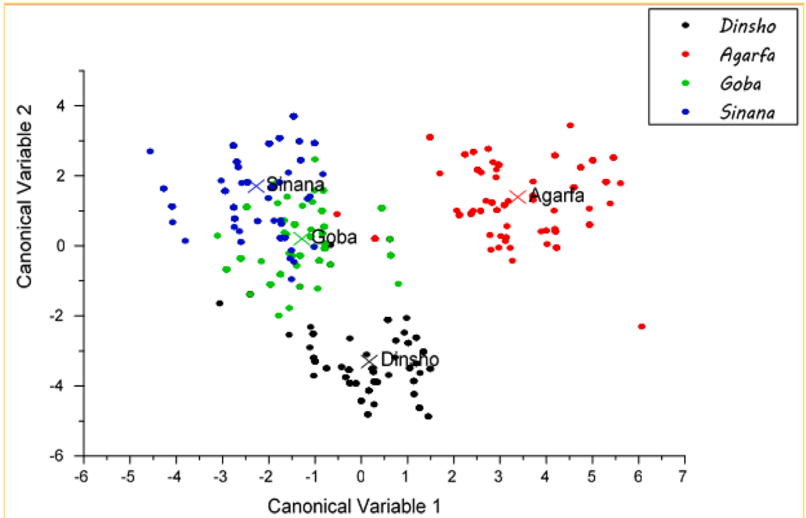

Fig. 3. Summary of morphometric traits canonical illustrations of horse populations among four studied districts of Bale Zone.

Table 6
Summary of the canonical variable correlations, eigenvalues, and likelihood ratios.

Variables	ACC	SCC	Eigenvalue	Proportion	Cumulative	Likelihood ratio	Approximate F Value	Num DF	Den DF	Pr > *F*
CAN1	0.90	0.82	5.25	0.52	0.52	0.02	42.02	84	1403.9	<0.0001
CAN2	0.86	0.76	3.55	0.37	0.89	0.12	31.73	54	940	<0.0001
CAN3	0.68	0.49	1.15	0.12	1.00	0.51	17.29	26	471	<0.0001

CC: canonical correlation, ACC: adjusted canonical correlation, CAN1: canonical variable 1, CAN2: canonical variable 2, CAN3: canonical variable 3, SCC: squared canonical correlation.

Quadratic discriminate analysis

Quadratic discriminate functions assessed the heterogeneity of horse populations distributed among the four districts, proving great differences ($p < 0.0001$) among districts. Therefore, the null hypothesis, which holds that variances are equal, is rejected by the covariance matrices. The discriminate functions classified 95.2, 94.4, 96, and 96.8 % of the sampled horses into their origin/dwelling districts of Dinsho, Agarfa, Sinana, and Goba, respectively. Hence, the population was precisely categorized with a lower average error rate of 0.04 besides, 0.04, 0.05, 0.06, and 0.03 for Dinsho, Agarfa, Sinana, and Goba districts, respectively. Additionally, the cross-validation summary revealed reduced consistency of membership, with 5 % average success rates among studied districts and 4, 8, 4, and 4 % for the Dinsho, Agarfa, Sinana, and Goba districts, respectively. The overall misclassification error count level was 0.05 (5 %) within the four districts (Table 7).

Table 7
Classifications and re-substitution summary of the horse population reared in Bale zone.

Classification Districts	Dinsho	Goba	Agarfa	Sinana	Total
Dinsho	119 (95.2)	6 (4.6)	0 (0.0)	0 (0.0)	125 (100)
Goba	2 (1.6)	118 (94.4)	1 (0.8)	4 (3.2)	125 (100)
Agarfa	2 (1.6)	0 (0.0)	120 (96.0)	3 (2.4)	125 (100)
Sinana	0 (0.0)	4 (3.2)	0 (0.0)	121 (96.8)	125 (100)
Total	24.2	24.6	25.6	25.6	500 (100)
Rate priors	0.04	0.048	0.056	0.032	0.044
Re-substitution					
Dinsho	115 (92)	10 (8)	0 (0.0)	0 (0.0)	125 (100)
Goba	1 (0.8)	120 (96)	1 (0.8)	2 (1.6)	125 (100)
Agarfa	2 (1.6)	0 (0.0)	120 (96)	3 (2.4)	125 (100)
Sinana	1 (0.8)	4 (3.2)	0 (0.0)	120 (96)	125 (100)
Error count rate	0.04	0.08	0.04	0.04	0.05
Prior	0.25	0.25	0.25	0.25	0.25

Discussion

Horse phenotypic characteristics are typically employed to assess performance in predictable everyday job engagement for the benefit of a business (Duensing et al., 2014). Therefore, the current study was conducted to evaluate morphometric traits of the horse ecotypes dispersed in the highlands of the Bale zone for the effects of district, sex, and age group as illustrated in Table 3. The study revealed presence of variations in morphometric traits of the studied horse ecotypes. Variations in phenotypic traits are mostly the results of multiple genes, whereas outside influences are significant in determining genetic variance and the shape of body conformations (Borowska & Lewczuk, 2023). Horse statures were considered when ascertaining morph-functional capabilities throughout classifying a horse ecotype to define breed superiority (Gómez et al., 2021; Perdomo-González et al., 2022). Accordingly, horses can perform differently when subjected to endurance, jumping, running, carrying heavy loads, pulling wheels, riding, and pack transport (Wilson, 2007). Moreover, types of job, economic status of owners, local weather, and breed type must be considered when selecting horses (Willekes, 2013). Farmers are therefore concerned about the welfare of morphology and health of the front (facial, skull, and neck), middle (thoracic and lumbar), and rear or distal (sacral and caudal) body sections of horses, as well as the front and hind legs at selections. Therefore, to increase production and reproduction, certain qualitative and quantitative traits of horses are visually evaluated to judge strength, durability, and attractiveness (Swart, 2010). Horses be different morphologically due to management routines, environmental adaptations, and breeding interventions projected by objectively enhancing performance (Kjöllerström et al., 2015). Therefore, the first step in horse breeding initiatives would be better served by economically well-organized selections of morphometric traits and the best fit for the background history of equestrian measures (Ali, 2022).

In the same way, NL, NC, and HDW of the skull and neck revealed differences in parts of the head and neck where the halter should be placed for easy training and control (Table 3). In addition, the head, neck, and facials of horses are used for easy communication, accepting rituals, threats, and subjugation expressing sexual urges via "mating faces.'' Besides, NL is used for mutual grooming standing in opposite directions via nibbling at the base of neck and root of the tail (Kolter & Zimmermann, 1988). In this study, horses of Dinsho and Goba were recorded for reduced head and neck profiles. This is because the majority of horses in the Dinsho and Goba districts are females and young under poor feeding practices. In contrast, the horse populations of Agarfa and Sinana were carefully chosen males and used for pulling carts that have greater muscularity due to supplementary feeding.

Moreover, the study horse populations in the Sinana and Agarfa districts had wide thoracic perimeters, while Goba and Dinsho had the lowest measures. A wider TP helps horses achieve efficient heart and lung functioning, which enables them to run long distances at high speeds. Furthermore, ThD, ThW, and ChW measurements were higher in Sinana and Agarfa, however low in the Dinsho and Goba districts (Table 3). This was because the majority of horses in Sinana and Agarfa were morphometrically preferred for heavy works. These horses were employed for the daily labor tasks of pulling wagons and carts to transport commodities and grains from farmlands to homes and markets. As a result, a wide thoracic frame, shoulders, and deep chest are wider enough to accommodate straps and forward pulling forces, which are highly desirable traits in horse breeding and husbandry, as similarly reported by Harper (1913). Thus, it is equally important to evaluate the predictability of conformational traits observed in horses to ensure optimal morphometric traits in selection (De Oliveira Bussiman et al., 2018).

Horse riding and jumping sports require long, well-muscled, good standing and comfortable back points for experienced sports people (Brown et al., 2013). Saddle-staying thoracic area, lumbar, sacral, and caudal regions of horses indicated management efficiency of owners for well-developed body condition scores, while emaciated and outward ribs of thoracic and back pointed out poor diet consequences. Accordingly, horses from Agarfa and Sinana district developed good appearances for BaW, LoL, LoW, CorpL, hip quarter, BiW, and BL. However, poor conditions were assessed for BaW, LoL, and LoW traits in Dinsho horses. Similar conditions were observed for the Goba horses for LoL and LoW measurements, but medium for BaW and CorpL. The BaL and BL values of the Agarfa and Sinana horses were recognized as longer/taller which helps to carry bulky loads on the backs and easily pull forward loads on the carts and wagons. Moreover, long leg and body, wider backs parts are more suitable for harnessing implements with loads that implies to take care of harnessing. The morphometric appearances of horses are significantly impacted by management barriers from owners, which affects growth rate and functional performances (Williams & Tabor, 2017). These variations resulted from how horses cared for various environmental conditions, including varying climates, diets, and levels of supervision (Cunha, 2012; Thompson et al., 2015).

The study revealed that body measurements of CorpL, hipH, HBU, WH, TP, FLL, and HLL were higher in Sinana and Dinsho than Goba and Agarfa districts. However, HDO was higher in Dinsho while equivalent for other district horses. The lengths of MBH and HHO were similar among the studied horse population, however HHO was slightly higher in Sinana horses. The MBH of the studied horses were convex or lowered inward indicating poor presentations for modern sports. In the study area horses, leg and upper body parts have lengthy traits, including HW, HHO, HDO, HBU, hipH, and CorpH indicated specialized horse structures that make them efficient runners. In addition, the upright appearance sustained by its safe toes, tough, and curved hoof with lengthy legs are the preferred traits of horses in modern sports. However, toes are lightweight, carrying a minimum of bone and tendon and no muscle at all, making them efficient runners (Borowska & Lewczuk, 2023). A long leg produces a long stride, and a light leg allows it to swing its limbs back and forth quickly, with minimal energy expenditure. The back bone and legs should be straight, and the legs are not bowed or turned in as viewed from the front or back (Gmel et al., 2018). Moreover, whole body dimensions including height from the ground up to the saddle placement and chest to buttock points are used in controlling and transferring of loads via chains, reins, halters, and straps. These body parts are considerably reflected in the selection of horses in modern sports when purchasing for breeding programs (Gomez et al., 2021).

Conclusion

The study revealed that morphometric traits of head length, head breadth, croup height, hip point height, and croup length or height at the dock were varied in horse ecotypes distributed among the study districts. From 27 morphometric traits subjected to STEPDISC analysis, 21 showed the best discriminating power except LoW, BaL, LoL, and BiW traits. The uppermost distances were reported between Agarfa and Dinsho and, Agarfa and Sinana horses, respectively, while the lowest were reported between Goba and Sinana and Dinsho and Goba with generalized squared distances. Therefore, it is necessary to describe phenotypic diversity using multiple morphometric traits or body conformation indices to define functional capabilities and effectiveness. Further, genomic studies are needed to determine whether the observed morphometric merits are the result of genotype or environmental advancement under prevailing management practices.

Consent for publications

No.

Ethical clearance

The Madda Walabu University Animal Welfare and Ethics Committee authorized the research techniques and methods in 2008. The committee declared that all conditions had been met by approving with a certificate (ref. no RPEED/012/2015, 18 April 2022 or 10/08/2015 EC).

Availability of data

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CRediT authorship contribution statement

Mesay Guyo: Writing – review & editing, Methodology, Formal analysis, Data curation, Conceptualization. **Melaku Tareke:** Writing – review & editing, Formal analysis. **Andualem Tonamo:** Writing – review & editing. **Diriba Bediye:** Writing – original draft. **Girma Defar:** Writing – review & editing.

Declaration of competing interest

All authors declare no conflict of interest regarding the publication of this paper.

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