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Evaluations of Morphometric Traits and Body Conformation Indices of Horse Ecotypes Reared in the Highlands of Bale Eco-Region, Ethiopia

Mesay Guyo | Melaku Tareke | Andualem Tonamo | Diriba Bediye | Girma Defar

Department of Animal Science, College of Agriculture and Natural Resources, Madda Walabu University, Bale-Robe, Ethiopia

Correspondence: Mesay Guyo (mesayguyo11@gmail.com)

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ABSTRACT

Background: Morphometric traits discrepancies are associated with production, reproduction, adaptation and behaviours in horses. It also determines the design of harnessing implements, physical injury level and working performance of the native horses. Thus, the study was conducted to evaluate morphometric traits and body conformation indices of horse ecotypes reared across four districts of Bale Zone, Ethiopia.

Methods: Data of croup height, croup length, hip height, mid-back height, wither height, hip width, thoracic depth, chest width, body length, sternum height, thorax perimeter and cannon perimeter were measured in 500 horses (294 male and 206 female). Using those traits, 17 body conformation indices were calculated to define the horses for multi-faceted performances.

Results: The study revealed that croup height, hip height, wither height, hip width, croup length, body length, thorax perimeter and sternum height were significantly ($p < 0.0001$) different among the studied districts. The district effect was also significant at $p < 0.05$ for mid-back height, thoracic depth, chest width and cannon perimeter. The sexual dimorphism effect was statistically significant for all measured traits; however, females were inferior to males except for cannon perimeter. Body conformation indices of pelvic index, body index, transversal pelvic index and weight were highly significant ($p < 0.0001$) among the studied districts. The sex dimorphism effect was significant ($p < 0.001$) for dactyl-costal index, pelvic index, longitudinal pelvic index, transversal pelvic index, weight, tare index 1 (trot or gallop), tare index 2 (walk) and riding comfort degree, while non-significant ($p > 0.05$) for the remaining indices. The studied horses were classified as mediline, elipometric, light, small and suitable riding ecotypes with a medium-conforming body structure and good capacity for carrying loads on carts and backs for functional effectiveness. The correlations of body conformation indices ranged from very high to low, with positive and negative associations for functional capabilities.

Conclusion: Therefore, selection for improvement needs to rank morphometric traits and body conformation indices in correlation to developing racing and modern sport horses in the highlands of the Bale eco-regions. Further, molecular studies will be essential to determine whether the predominated phenotypic multiplicity is genetic or environmentally progressed.

1 | Introduction

Numerous indigenous horses (*Equus caballus*), including highlands of the Bale eco-region ecotypes, are reared among different topography of Ethiopia. They have evolved and ecologically adapted to various production scenarios over the past decades (Effa et al. 2021). They are the most important animal species in the daily lives and agricultural practices of rural and urban societies. Horse selections are influenced by the owner's handling and management practices to improve working performances at the farmer's level. They are managed according to the owner's requirement for daily occupation, training, welfare and behavioural handling reimbursement (Tennah et al. 2014; Górniak et al. 2020).

Horses raised across different ecological regions have distinct phenotypic characteristics that allow them to adapt to their environments (Mousavi et al. 2023). Hence, the differences in management conquer the diversity of morphometric appearances persist to this day in horse populations (Gómez et al. 2012; Bonow et al. 2024). They also maintain various reproductive and productive performances via proceeding morphometric physiognomies in shifting production environment adaptability (Ablondi et al. 2020; Krebs et al. 2021). In popular horse marketing approaches, dealers set marketing prices on phenotypic appearances of morphology, management, care level and welfare aspects of handling for dispositions. Thus, price tagging reflects the body conformation scores attained during evaluations for the rider and handler's welfare during the marketing period as well as risk behaviours noticed (Fenner et al. 2020).

Given that, horse ecotypes originated in the highlands of the Bale eco-region and have been maintained for decades under traditional management practices. They play a crucial part in agricultural livelihood practices in the terrain of Bale Mountains where infrastructure has not yet been established. They are resourcefully used in day-to-day agricultural practices, transportation, carrying loads on backs, and pulling carts and wagons. Their role is not only limited to daily livelihoods but they are also employed in leisure events and cultural competitive sports of Arsi-Bale Oromo people. Moreover, they play a great role in Oromo political movements for the impartiality of Oromo societies in the country for a long (Effa et al. 2012). Most of the horses are named in Ethiopia based on their place of origin, and the ethnic societies that kept them similarly horses in the Bale highlands are named Arsi-Bale horses (Asfaw and Tadesse 2020; Kebede 2023).

Regardless of multi-economic influences on rural and urban communities and the ethno-political role they have played under traditional husbandry practices, no outlook attention is present for evaluations of phenotypic performances using morphometric traits for further genetic upgrading and performance improvements in the study area. Except for keeper's interventions during cross-breeding, and selection for elite morphometric traits, they have not been scientifically improved for instantly recognizable employment. So they are kept for a long without any genetic modifications except the owner's selection for some traits.

Additionally, there is a lack of comprehensive documentation regarding their useful morphometric traits and body conformation indices. Over decades, uncontrolled breeding practices and natural selection led to the acquisition of diverse body conformations. Thus, they are recognized for inconsistencies in morphological appearances, and body condition scores under current climatic scenarios and owners' monitoring levels (Bukhari et al. 2021). Management level determines body condition scores of working horses as an essential part of maintaining the adaptations they experience (Schork, de Azevedo, and Young 2018). Because of inherited and environmental influences, native horses have developed variable body conformation scores and genetic performances within and between breeds (McManus et al. 2008; Sánchez-Guerrero et al. 2016). However, inadequate management overshadows genetic achievements and undervalues long-lasting conformations (Zuluaga-Cabrera et al. 2021). Although body conformation indices play a significant part in the selection of productive and reproductive trait preferences for hard work, the most indispensable aspects are function, aptitude, disposition and training (Folla et al. 2020).

Horse performances are described using body conformation indices depending on how they are interpreted and assessed from various angles, as well as behavioural changes alongside age. Such body conformation analysis is suggested as an indirect performance indicator and signifies an important consideration during purchasing and breeding of modern sport horses (Sanchez-Guerrero et al. 2016; Gómez et al. 2021). There are convinced body conformations and dimensions that are deemed attractive to improve one's competency for employment, jumping and riding in modern sports (Sánchez-Guerrero et al. 2019). So linear and circular morphometric measurements of various horse body parts have been used to study body condition scores and functional effectiveness from the perspective of farmers and researchers (Silva et al. 2002; Falaschini, Rizzi, and Pasquini 2003; McManus et al. 2008; Gómez et al. 2012; Komosa et al. 2013; Sole et al. 2014; Padilha et al. 2017; Kawareti et al. 2017; Souza et al. 2017; Bussiman et al. 2018; Popova, Nikolov, and Krastev 2019; Gómez et al. 2021; Lemos et al. 2021; Ribeiro et al. 2024; Bonow et al. 2024). Therefore, body conformation indices have been used in determining the degree of suitability for specific services like traction, riding, resistance and velocity because of their distinctive morphometric characteristics, proficiencies and aptitudes (Gómez et al. 2012). However, seasonal variations, management style, workload and the effects of sexual dimorphism all have significant impacts on the body conformation index.

Consequently, objectively pooled morphometric trait narratives that comprehend structure and functions are important ways to describe phenotypic performances. It is a more resourceful methodological approach to reduce misrepresentation of breed and avoid bias in selection decisions using unit morphometric traits for further conservations and upgrading. Additionally, comparative analyses of body conformation indices help to provide evidence for genetic diversity and racial classification (Silva et al. 2002; McManus et al. 2005). This enables the straightforward comprehension of animal performances for selection, breeding initiatives and conservation strategies of farm animal genetic resources in production scenarios. Therefore, this study was undertaken to evaluate morphometric traits and body conformation indices that revealed phenotypic diversity among the horse ecotypes found in the highlands of Bale eco-regions, South-Eastern Ethiopia.

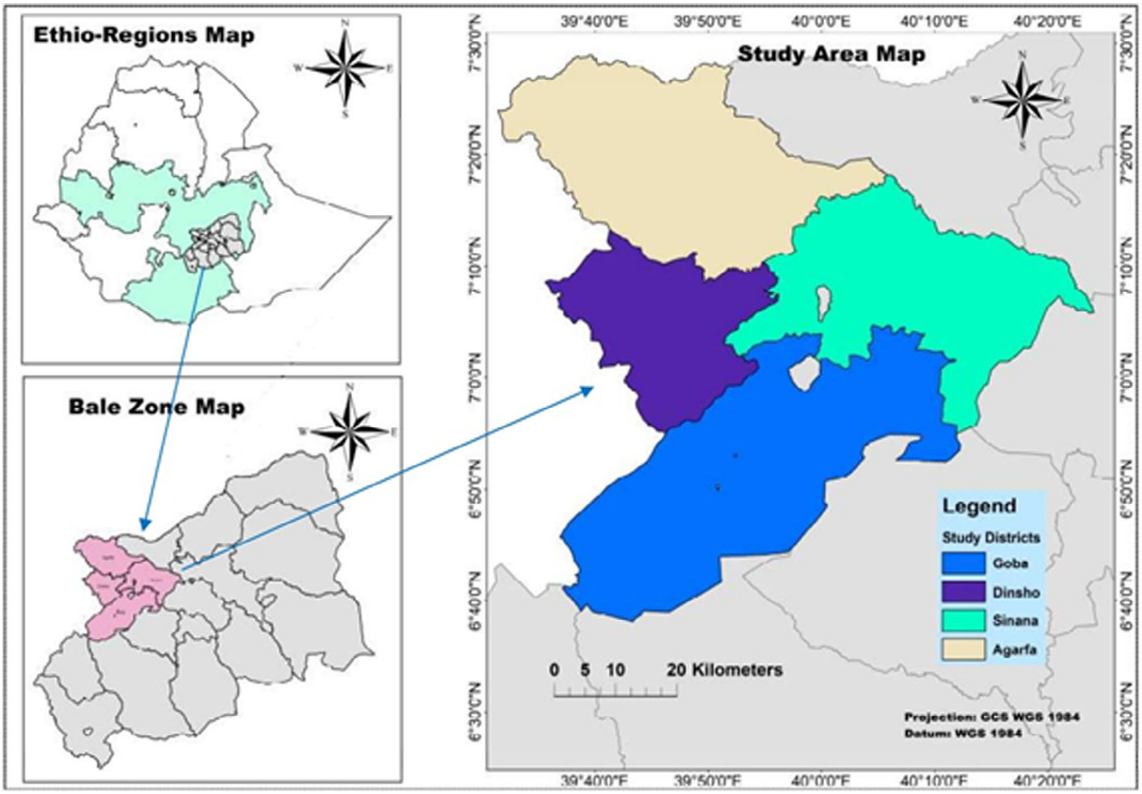

FIGURE 1 | Map of the study area.

TABLE 1 | Altitude and annual average temperature and relative humidity (RH) of the study districts.

Districts	Altitude (m)	Minimum and maximum temperature (°C)	Minimum and maximum RH (%)	Climatic condition
Dinsho	3207	3–17	53–80	Tropical Afro-Alpine
Goba	2705.1	5–18	59–69.3	Tropical wet and dry
Agarfa	2466.8	8.6–18.6	47.9–58.1	Tropical wet and dry
Sinana	2424	9.5–21	45–56	Sub-humid to cool mild

Source: Bale Zone Livestock Office (2020).

2 | Materials and Methods

2.1 | Description of the Study Area

The study was undertaken in the highlands of the Bale eco-region of the Oromia region, Ethiopia. Geographically, the area lies between 5°11′03″N–8°09′27″N latitude and 38°12′04″E–42°12′47″E longitude (Figure 1).

The study districts are found in the altitude range of 2424–3207 m above sea level for geographic locations and climatic conditions (Table 1). The agroecology has potential for both livestock and crop cultivation for worthy climatic conditions. Livestock (cattle, small ruminants, equines) herding and crop cultivations (wheat, barley, maize) are among the major livelihood activities. Hence, horses are helpfully used in agricultural activities of everyday works in the terrain topography of Bale Mountains, especially for transporting, threshing and harvesting crops while, in urban and peri-urban for transportation, water fetching, and carrying of marketing goods, and grains to milling plants and woods besides daily income sources.

2.2 | Sampling Procedures

The study's districts, namely, Goba, Dinsho, Agarfa and Sinana were selected for their potential to have large horse populations in the Bale Zone of Oromia region (Figure 1). Accordingly, a total of three towns and eight kebeles were selected among the study districts. The districts of Dinsho, Goba and Agrafa were the most experienced in horse breeding and husbandry practices among Bale Zone districts. In addition, horses were resourcefully and effectively used ranking first, second and third in Sinana, Goba and Agarfa, respectively, for daily financial support of most rural and urban households (BZLD, 2020). Thus, over 500 horses (294 males and 206 females) aged 3–10 years were selected randomly among the study districts (125 horses from each district) (Table 2).

TABLE 2 | Study district horse population size, kebeles and sampled population.

District	Horse population	Rank	Kebeles and towns	Sample size
Dinsho	19,376	4th	*Aba Kara*; Hora Soba	125 (M: 46, F: 79)
Goba	28,598	1st	*Rira*, *Wacho Misherge*; Goba town	125 (M: 53, F: 72)
Agarfa	16,062	2nd	*Kaso Wara*, *Kaso Maniso*; Ali town	125 (M: 85, F: 40)
Sinana	19,401	3rd	*Nano Robe*, *Horeboka*; Robe town	125 (M: 110, F: 15)

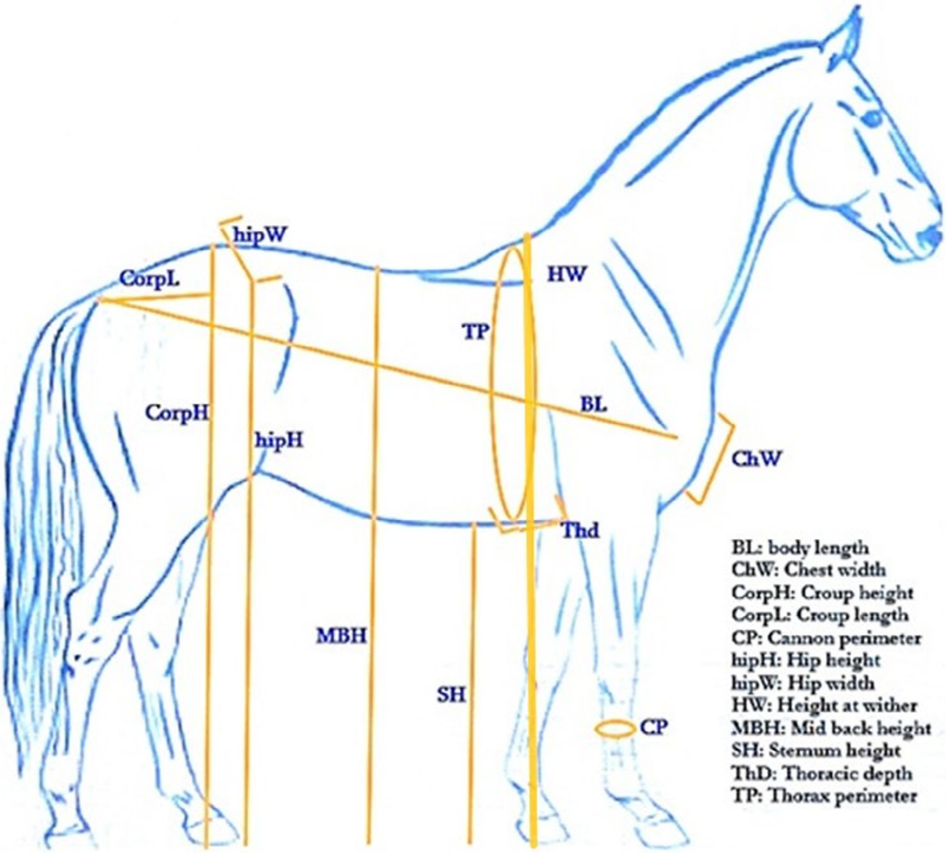

FIGURE 2 | Model of anatomical point measurement of morphometric traits in horse.

2.3 | Data Collection

Measurement data were collected using a tape metre and measuring stick (in centimetres) in line with ethical guidelines for animal experiments. Additionally, researchers obtained verbally approved consent from the horse owners before data collection. Measurements were done in the morning before the horses were released for feeding. Pregnant mares were snubbed for data collection. Data of croup height (CorpH), croup length (CorpL), hip height (hipH), mid back height (MBH), height at wither (HW), hip width (hipW), thoracic depth (ThD), chest width (ChW), body length (BL), sternum height (SH), thorax perimeter (TP) and cannon perimeter (CP) were measured as described by Costa et al. (1998)), Miserani et al. (2002), Cabral et al. (2004), and Kawareti et al. (2017) as shown below Figure 2.

From measured morphometric traits, 17 body conformation indices listed below were calculated following cited references.

BARON and CREVAT (BC): TP^2/HW; The greater the index, the closer the animal is to a traction type, the lower the index the weaker used for riding, and packing type of work, also called the conformation index (McManus et al. 2008).

Body index (BI): BL × 100/TP; if BI > 0.90, they are longiline, suited for speedy animals; between 0.86 and 0.88, mediline with midway ratios has intermediate abilities and <0.85, breviline, more apt for force or strength (Cabral et al. 2004).

Body ratio (BR): HW × 100/CorpH; if the WH's are lower than CropH, the animal is low in front and vice versa considered as defects. This inequality in heights may hinder both gait and resistance (Rezende et al. 2015).

Compact index 1 (CI1): (W/HW)/100 indicates how compact the horse is. Animals used as saddle horses have CI1 < 2.20; animals suited for light traction have 2.60 ≤ CI1 ≤ 3.15 and horses used for heavy pulling/traction have CI1 > 3.15 (Cabral et al. 2004).

Dactyl thorax index (DTI): CP × 100/TP; the DTI > 0.105 for light small horses, up to 0.108 in intermediary horses, up to 0.110 in light traction animals and up to 0.115 in heavy traction and riding horses. This index also indicates thoracic development (Cabral et al. 2004).

Dactyl-costal index (DCI): CP × 100/ChW indicates balanced bone development for excellent sport performance due to its lightness in horses. Long, light and thin limbs (minimum bone and tendon, and no muscle at all) with proportional inner and outer ChW are qualities of horse gaits and practical predispositions. This allows the horse to swing its limbs back and forth quickly during competitions with a minimal expenditure of energy.

Longitudinal pelvic index (LPI): CorpL × 100/HW shows the size of the croup. The higher the value, the better is its conformation for meat production (Alberti et al. 2008).

Pectoral index (PI): MBH/SH; when the back height is less than the space under the horse, the animal is considered 'far from ground' a trait that favours speed due to relatively long legs (C. McManus et al. 2005; McManus et al. 2008).

Pelvic index (PVI): hipW × 100/CorpL; PVI ≥ 1 indicates wide pelvic bones (ilium, ischium and pubis) supporting parturition where there is no difficulty of dystocia in a female horse while PVI < 1 indicates higher occurrence of the dystocia (Gómez et al. 2012).

Relative proportionality of thorax index (RPTI): ThD/HW indicates RPTI with values ≥50% shows breed with good thoracic development as the higher values are linked to greater depth (Gómez et al. 2012).

Relative body index (RBI): BL × 100/HW indicates useful indices in assessing functionality in horses. If >110 in RBI, they are fatty with poor gait and lower than <90 poor gaits and emaciated muscular appearances (Hill et al. 2020).

Riding comfort degree (RCD): MBH–(HW + CorpH)/2 indicates the back inclination of the animal where the saddle is seated (McManus et al. 2008).

Tare index 1 (trot or gallop) (TI1): TP^2 × 56/HW indicates weight in kilograms the animal can withstand without excessive stress on the back, which can be carried working at a trot or gallop.

Tare index 2 (walk) (TI2): TP^2 × 95/HW indicates weight in kilograms the animal can be carried at walking step endure without excessive stress on the back, working at a walking speed (McManus et al. 2008).

Thoracic development (TD): TP/HW; the values >1.2 indicate animals with good TD or massiveness. Poor TD is associated with a lack of good musculature and deficiencies in the cardiovascular system. A horse with an excessively large thorax is also not desirable as the centre of gravity moves to the front of the horse (McManus et al. 2008).

The relative thickness of cannon bone index (RTCI): CP × 100/HW; the higher values indicate the harmony between the body conformation and bone development and vice versa (Cabral et al. 2004).

Transversal pelvic index (TPI): hipW × 100/HW; this shows the size of the croup relative to body height. The higher the value, the better is its conformation for meat production (Alberti et al. 2008).

Weight (W) (kg): TP^3 × 80; weight ≥ 550 kg corresponds to large or hypermetric horses, between 350 and 550 kg medium or eumetric horses and ≤350 kg small or elipometric/hypometric horses (Cabral et al. 2004).

2.4 | Data Analysis

Measured data were entered into a Microsoft Excel spreadsheet for the statistical analysis using general linear model (GLM) procedures (SAS 2012 vr 9.4). Analysis of variance was used to determine means for linearly measured morphometric traits and body conformation indices among the study districts and sexes. Duncan's multiple range tests were used to differentiate means when the F-test was declared significant. The model used for the analysis was:

$$Y_{ij} = \mu + S_i + P_j + e_{ij},$$

where

- Y_{ij} = morphometric traits and body conformation indices among fixed factors
- μ = the overall mean
- S_i = fixed effects of the *i*th district (1 = Dinsho, 2 = Goba, 3 = Agarfa, 4 = Sinana)
- P_j = fixed effect of the *j*th sex (1 = Male; 2 = Female)
- e_{ij} = random error

The CORR procedure was applied to determine associations of body conformation indices. The correlation (R^2) measures the proportion of variation, where r represents the correlation coefficient between the fitted body conformation indices. The R^2 values were classified: as very low ($R^2 < 0.20$), low ($R^2 > 0.20$ to < 0.40), moderate ($R^2 > 0.40$ to < 0.60), high ($R^2 > 0.60$ to < 0.80) and very high ($R^2 > 0.80$ to < 1.00).

3 | Results

3.1 | Morphometric Traits

The influences of the study district and sexual dimorphism on morphometric traits of horse ecotypes reared in the highlands of Bale eco-regions are shown in Table 3. The overall coefficients of variations among measured morphometric traits range from 4.4% to 11.4%. The effect of study districts was significantly ($p < 0.0001$) different on CorpH, hipH, HW, hipW, CorpL, BL, TP and SH. The effects of the district were also statistically significant ($p < 0.001$) for MBH and ThD, whereas it had a significant effect ($p < 0.05$)

TABLE 3 | Mean values of morphometric trait measurements (in centimetres) of horse ecotypes reared in highlands of the Bale eco-region.

Traits	No.	CorpH	hipH	MBH	HW	hipW	CorpL	ThD	ChW	BL	TP	SH	CP
Mean	500	128.2	117.7	126.1	128.4	38.7	36.9	46.4	31.7	123.8	140.5	68.0	15.6
CV	%	4.6	6.7	4.7	4.4	11.4	9.7	11.1	8.3	5.5	9.3	7.6	9.2
District	*p*-value	***	***	**	***	***	***	**	*	***	***	***	*
Dinsho	125	125.6[c]	113.7[d]	123.9[b]	125.5[c]	38.2[b]	35.5[b]	43.9[c]	28.2[b]	119.0[b]	139.2[b]	68.2[b]	16.0[a]
Goba	125	127.6[b]	116.4[b]	124.8[b]	127.0[d]	36.1[c]	35.3[b]	47.2[a]	28.6[b]	120.9[b]	134.6[c]	66.4[c]	14.7[b]
Agarfa	125	128.3[b]	118.1[b]	127.6[a]	129.0[b]	40.8[a]	38.3[a]	46.7[a]	31.8[a]	128.3[a]	145.3[a]	67.7[b]	16.4[a]
Sinana	125	131.2[a]	122.7[a]	128.0[a]	132.2[a]	38.6[b]	38.5[a]	46.1[ab]	31.6[a]	127.4[a]	144.6[a]	70.0[a]	16.2[a]
Sex	*p*-value	***	***	***	***	*	*	*	***	***	***	***	ns
Female	206	124.3	114.3	123.3	124.7	37.5	37.7	44.8	34.2	119.7	135.4	66.1	15.1
Male	294	130.1	120.1	128.1	131.0	39.9	36.4	47.5	38.0	127.7	144.0	69.5	16.9

Abbreviations: BL, body length; ChW, chest width; CorpH, croup height; CorpL, croup length; CP, cannon perimeter; hipH, hip height; hipW, hip width; HW, height at wither; MBH, mid back height; ns, non-significant; SH, sternum height; ThD, thoracic depth; TP, thorax perimeter.

*$p < 0.05$. significant

**$p < 0.001$.highly significant

***$p < 0.0001$.significantly very highly

on ChW and CP. Most of the morphometric traits were significantly higher among the studied districts for stallions regularly employed in daily livelihoods than reproductive mares (Table 3).

The sexual dimorphism effect was statistically significant ($p < 0.0001$) for CorpH, hipH, mid-back height, HW, ChW, BL, TP and SH. The sex difference had also a significant effect ($p < 0.05$) on hipW, CorpL and ThD, but it was non-significant ($p > 0.05$) for CP. Additionally, mares were inferior to stallions for utmost measured morphometric traits in this study (Table 3).

3.2 | Body Conformation Indices

Table 4 presents the study results of body conformation indices analysed from multiple linearly measured morphometric traits for the effects of district and sex. The study revealed that body conformation indices of BI, PVI, TPI and weight were significantly affected ($p < 0.0001$) among the studied districts. In addition, the effect of studied districts was significant ($p < 0.001$) for tare index 1, tare index 2 and RCD. Furthermore, the effect of districts was statistically significant ($p < 0.05$) for relative BI, DCI, PI, LPI and CI1. In contrast, the effect of studied districts was non-significant ($p > 0.05$) for DTI, RTCI, relative proportionality of thorax index, TD, BR and BC.

The sexual dimorphism effect was highly significant ($p < 0.0001$) for weight and tare index 1. The effect was also significant ($p < 0.001$) for LPI and tare index 2. Furthermore, the sexual effect was significant ($p < 0.05$) for the DCI, PVI, TPI and RCD. However, the sexual dimorphism effect was non-significant ($p > 0.05$) for BI, RBI, DTI, RTCI, PI, RPTI, TD, BR, BC and compact index 1 (Table 4).

3.3 | Correlations of Body Conformation Indices

Table 5 presents the correlations between body conformation indices of the horse ecotypes distributed in the highlands of Bale eco-regions. The study indicated that correlations between body conformation indices of BC and RTCI ($r = 0.85$), weight and TD ($r = 0.87$), tare index 1 and RTCI ($r = 0.96$), tare index 1 and B C ($r = 0.89$), B C and DTI ($r = 0.93$), tare index 2 and RTCI ($r = 0.96$), tare index 2 and BC ($r = 0.89$), tare index 2 and tare index 1 ($r = 1.0$), CI1 and TD ($r = 0.90$), and CI1 and weight ($r = 0.99$) were very high ($R^2 > 0.80$)—positive and highly significant ($p < 0.0001$). In addition, body conformation indices of LPI and RTCI ($r = 0.23$), BR and TD ($r = 0.26$), BC and BI ($r = 0.31$) had positive associations ($p < 0.0001$) with low correlations. Conversely, the study showed that negative correlations were identified between TD and BI, TD and DTI, weight and BI, weight and DTI, CI1 and BI, and CI1 and DTI with positive associations. Moreover, negative correlations were reported between conformation indices of RBI, PI, RPTI, TPI and BR with non-significant association ($p > 0.05$) (Table 5).

4 | Discussion

4.1 | Morphometric Traits

Diversity in the morphology of farm animals provides an outline for breeding goals and selection tactics focused on improving genetic performances (Von Borstel et al. 2013; Perdomo-González et al. 2024). The causes of modifications in phenotypic characteristics resulted in variations in the morphological, reproductive and productive performances of native horses enabling them to effectively implement ecological and adaptive adaptations (Jez et al. 2013). Moreover, interventions by the owner during breeding practices and selections for preference traits also had significant contributions to performance variations. The current investigation revealed notable differences in morphological appearances among study districts due to climatic conditions for the availability of feed resources in quality and quantity. These variations might also be long-time selections for improvements besides breed type and supervision levels of keepers. Moreover, the discrepancies could be due to the selective handling and feeding of more working stallions for daily occupations.

TABLE 4 | Mean values of body conformation indices of horse ecotypes reared in the highlands of Bale eco-region.

Body indices	№	BI	RBI	DTI	DCI	RTCI	PVI	PI	RPTI	LPI	TPI	TD	BR	BC	W	TI1	TI2	CI1	RCD
Mean	500	88.7	96.5	0.106	49.1	11.6	105.0	0.9	0.4	28.9	30.2	1.1	1.0	1.6	228.5	96.7	163.9	1.8	−2.2
CV	%	7.6	5.1	1.8	3.1	0.5	12.2	4.4	0.6	2.8	11.7	1.8	2.3	1.9	34.7	14.2	18.4	3.5	12.7
Districts	*p*-value	***	*	ns	*	ns	***	*	ns	*	***	ns	ns	ns	***	**	**	*	**
Dinsho	125	84.4^{d}	95.1^{c}	0.106	50.5^{a}	11.9	102.6^{c}	0.8^{b}	0.4	30.6^{a}	31.4^{b}	1.2	1.0	1.6	216.4^{c}	100.8^{a}	170.9^{a}	2.1^{a}	-1.6^{b}
Goba	89.9^{b}	95.2^{c}	0.109	50.3^{a}	11.5	106.9^{b}	0.9^{a}	0.4	30.2^{a}	32.2^{a}	1.1	0.9	1.6	196.8^{d}	95.5^{b}	162.0^{b}	1.6^{c}	-2.4^{c}	125	
Agarfa	91.9^{a}	99.3^{a}	0.106	47.9^{b}	11.4	102.4^{c}	0.9^{a}	0.4	27.6^{b}	28.0^{cd}	1.1	1.0	1.6	261.6^{a}	94.6^{c}	160.4^{c}	1.7^{bc}	-1.0^{a}	125	
Sinana	88.5^{bc}	96.4^{b}	0.104	47.6^{b}	11.4	108.2^{a}	0.9^{a}	0.4	27.2^{b}	29.1^{c}	1.1	1.0	1.6	239.2^{b}	95.8^{b}	162.5^{b}	1.8^{b}	-3.6^{d}	125	
Sex	Ns	ns	ns	*	ns	*	ns	ns	**	*	ns	ns	ns	***	***	**	ns	*	*P value*	
Male	88.9	96.1	0.110	50.8	11.9	104.2	0.9	0.4	30.3	31.5	1.1	1.1	1.6	234.2	99.1	167.9	1.6	−1.7	294	
Female	88.6	96.8	0.104	47.8	11.4	105.6	0.9	0.4	27.9	29.3	1.1	1.0	1.6	221.6	95.1	161.3	1.9	−2.5	206	

Abbreviations: BC, BARON and CREVAT; BI, body index; BR, body ratio; CI1, compact index 1; DCI, dactyl-costal index; DTI, dactyl thorax index; LPI, longitudinal pelvic index; ns, non-significant at $p > 0.05$; PI, pectoral index; PVI, pelvic index; RBI, relative body index; RCD, riding comfort degree; RPTI, relative proportionality of thorax index; RTCI, relative thickness of cannon bone index; TD, thoracic development; TI1, tare index 1 (trot or gallop); TI2, tare index 2 (walk); TPI, transversal pelvic index; W, weight.

*$p < 0.05$. significant

**$p < 0.001$. highly significant

***$p < 0.0001$. significantly very high

The appearance of symmetry and balance in dressage and racing horses indicated the presence of a good proportion of HWs, CorpH and BL for better conformation and performances (Solé et al. 2013). Per the study, the measured value of BL was nearly comparable to HW, MBH and CorpH among the studied districts. This indicates the studied horses had a balanced position of whole body parts to support health and comfort for heavy packing and riding in strenuous hikes of Bale Mountains. Moreover, whole body dimensions including lengths from the ground up to the saddle placement and chest to buttock points are used to control and transfer loads via chains, reins, halters and straps. Therefore, balanced body dimension and height from frontal, mid and distal body parts are important considerations in the selection of horses in modern sports when purchasing and breeding programmes (Gómez et al. 2021). Correspondingly, the studies of C. M. McManus et al. (2008), Souza et al. (2017), and Popova, Nikolov, and Krastev (2019) indicated that balanced body dimensions had positive possessions on connecting loads using harnessing straps and minimized physical injuries. This was due to balanced dimensions helping horses to effectively ride squarely using whole body parts. Conversely, the studies of Padilha et al. (2017) and Lemos et al. (2021) reported lower BL compared to the height of the body from the ground as of frontal (HW), middle (MBH) and distal (CorpH) parts. This has a significant impact on motor and racing performance (Sobczuk and Komosa 2012). They have flattened hindered body conformations due to comparable sizes of hipW and CorpL (Table 3). Therefore, the studied horses have satisfactorily massive and compact presentations comparatively. However, they have greater TP than WH and BL, which was similarly reported by Popova, Nikolov, and Krastev (2019) for the Karakachan horse breed. This was conferring to the selection criteria of wither height for efficient racers as published by Ribeiro et al. (2024), whereas the growth performances of these horses were negligible. This was because most of the horses were males and received poor feed in quality and quantity even though they were used for pulling carts and wagons in the study area. Moreover, females were grazed on poor feed resources of communal rangelands with zero supplementation.

The study also showed that Agarfa and Sinana horses were comparable for CorpH, MBH and HW that revealed front and hindquarter body portions are long. Similarly, they have equivalent MBH with CorpH indicating they have more appropriate straight backs that make the studied horses powerful for pulling carts. Conversely, horses in Goba and Dinsho districts were lower in frontal parts than distal indicating that they are preferably used for riding and packing on the back. This shows that they have exceptionally refined conformations in respective districts regardless of height variations. Additionally, horses of Sinana and Agarfa have wider chests suitable for easy harnessing of straps to associate cartloads from the hinder. Also, the horses have good bone development to carry well-muscled bodies. This remains because daily working horses offered supplementation (when available) resulting in the development of larger and more muscular body parts. However, poor ChW was described for the Dinsho and Goba districts that might be due to more number of reproductive females and young foals in the area. Overall, the reported ChW of the present study was lower than that reported by Padilha et al. (2017), Kawareti et al. (2017), Gómez et al. (2012), Krebs et al. (2021), and Lemos et al. (2021) for Brazilian sport horses, thoroughbred horses, Spanish heavy horse breeds, Campolina horse breed and Brazilian Fjord horse breeds, respectively.

On the other hand, widely apprehended reproductive females in the Dinsho and Goba districts attain poor muscle mass and body conformations due to poor feedings on the rangelands. The changes in body conformation occur during the

TABLE 5 | Pearson's correlations between body conformation indices of the horses reared in highlands of the Bale eco-region.

	BI	RBI	DTI	DCI	RTCI	PVI	PI	RPTI	LPI	TPI	TD	BR	BC	W	TI1	TI2	CI1	RCD
BI																		
RBI	0.57***																	
DTI	0.51***	0.04^{ns}																
DCI	0.05^{ns}	−0.30***	0.65***															
RTCI	−0.01^{ns}	0.11**	0.75***	0.56***														
PVI	0.16***	0.03^{ns}	0.04^{ns}	−0.09*	−0.09*													
PI	−0.03^{ns}	−0.04^{ns}	−0.08*	−0.15***	−0.08*	−0.03^{ns}												
RPTI	−0.00^{ns}	0.06^{ns}	−0.03^{ns}	−0.01^{ns}	−0.02^{ns}	0.01^{ns}	−0.14***											
LPI	−0.07*	−0.07^{ns}	0.17***	0.11**	0.23***	−0.38***	0.02^{ns}	0.04^{ns}										
TPI	0.06^{ns}	−0.05^{ns}	0.19***	0.04^{ns}	0.14***	0.47***	−0.03^{ns}	0.07*	0.63***									
TD	−0.81***	−0.10**	−0.61***	−0.22***	−0.01^{ns}	−0.15***	0.03^{ns}	−0.01^{ns}	−0.05^{ns}	−0.17***								
BR	−0.05^{ns}	−0.15***	−0.08*	0.08*	−0.14***	0.00^{ns}	−0.01^{ns}	0.01^{ns}	−0.17***	−0.15***	0.26***							
BC	0.31***	0.02^{ns}	0.93***	0.65***	0.85***	0.02^{ns}	−0.07*	0.01^{ns}	0.07^{ns}	0.08*	−0.38***	−0.04^{ns}						
W	−0.83***	−0.25***	−0.68***	−0.23***	−0.16***	−0.11**	0.02^{ns}	−0.01^{ns}	−0.13***	−0.20***	0.87***	0.07*	−0.42***					
TI1	−0.03^{ns}	0.05^{ns}	0.73***	0.56***	0.96***	−0.06^{ns}	−0.08*	0.02^{ns}	0.10*	0.05^{ns}	0.01^{ns}	−0.06^{ns}	0.89***	−0.07*				
TI2	−0.03^{ns}	0.05^{ns}	0.73***	0.56***	0.96***	−0.06^{ns}	−0.08*	0.02^{ns}	0.10*	0.05^{ns}	0.01^{ns}	−0.06^{ns}	0.89***	−0.07*	1.00***			
CI1	−0.86***	−0.22***	−0.66***	−0.22***	−0.10*	−0.14***	0.02^{ns}	−0.02^{ns}	−0.08*	−0.18***	0.90***	0.04^{ns}	−0.42***	0.99***	−0.05^{ns}	−0.05^{ns}		
RCD	0.03^{ns}	0.19***	−0.01^{ns}	−0.15***	0.07^{ns}	−0.11*	0.19***	0.12*	0.16***	0.04^{ns}	0.13***	0.02^{ns}	−0.02^{ns}	−0.07^{ns}	0.03^{ns}	0.03^{ns}	−0.06^{ns}	

Abbreviations: BC, BARON and CREVAT; BI, body index; BR, body ratio; CI1, compact index 1; DCI, dactyl-costal index; DTI, dactyl thorax index; LPI, longitudinal pelvic index; PI, pectoral index; PVI, pelvic index; RBI, relative body index; RCD, riding comfort degree; RPTI, relative proportionality of thorax index; RTCI, relative thickness of Cannon bone index; TD, thoracic development; TI1, tare index 1 (trot or gallop); TI2, tare index 2 (walk); TPI, transversal pelvic index; W, weight.

*$p < 0.05$. significant

**$p < 0.001$. highly significant

***$p < 0.0001$. significantly very high

^{ns}non-significant at $p > 0.05$.

reproductive periods for the entire morphology in the female consort with inadequate nutrition before, during and post-pregnancy. Additionally, in most seasons, females are allowed to graze on inadequate and poor-quality feed resources. However, stallions were supplemented with comparatively nutritionally worthy feed resources.

4.2 | Body Conformation Indices

On the basis of the average BI (88.7), they are categorized as mediline horse type with intermediate aptitude. These horses exhibit equal standing in the frontal and hind parts due to equivalent WH and CorpH that makes them efficient runners with slight speed and suitable for carrying loads using a wagon as previously reported by Souza et al. (2017) for Mangalarga Marchador horses. Furthermore, these horses acquired a body weight of <350 kg that is a small or elipometric type compared to the weight of the Pantaneiro horses as reported by C. M. McManus et al. (2008). However, the Dinsho horses were classified as brevigline or short type and exhibited significantly developed pelvic space (PVI), consistent with a horse-like reproductive type. However, the inferior TPI they possess may not allow them to take advantage of any employment choices. This might be due to inadequate management and handling of mares.

The TI1 of horses exhibit variations in tolerating loads on the back when standing and walking despite being small or elipometric/hypometric horses. Hence, the Dinsho horses were chosen to carry the weight on their backs. This resulted from inadequate TP muscles for easily transitory straps for workload and lower pulling ability of heavy objects. However, the remaining horses were used to pull carts and wagons. These horses have concave and convex back inclinations that make saddle seating challenging for them. Mostly, they are employed as a remedy for overloads that cause the backbone to distort riding to a comfortable degree.

Additionally, they developed poor bone and muscles besides middling DTI (0.106) that makes them suited for light work. They have also comparable heights of the sternum or back height that subsidize them to have intermediate speed when working. Because of this, they are either saddle or riding horses due to their poor massiveness with shrunken muscles (light small to intermediary horses, >0.105 to 0.108) compared to heavy traction and riding horses of the Mangalarga Marchador race (Cabral et al. 2004) and the Brazilian Fjord (Lemos et al. 2021).

The BR (1.0) shows that WH and CorpH were balanced for any movement patterns. These qualities help them to develop an efficient breathing system and increase flexibility during lengthy and arduous treks. However, imbalance may suggest a tendency for issues with the anterior and posterior limb joints, which might be detrimental to the skeleton (Zamborlini 1996; McManus et al. 2008). On the contrary, a strangely big thorax is likewise undesirable, as it causes the horse's centre of gravity to shift to the front. So the corresponding hipH and shoulder heights are important body parts taken into justification when selecting and developing breeding programmes for improvement. Additionally, the rider might feel comfortable when ChW is in the optimal range to avoid certain body lesions from harnessing (Ribeiro et al., 2024). Moderate body conformation reduces the likelihood of occupational-related injuries resulting from imbalanced harnessing devices and facilitates easier harnessing (Carpenter et al. 2020). Therefore, modern sport horse buyers and breeders place a premium on body conformation with dependable performances for horses' grace and attractiveness that keepers' oversight for deliberate selection (Warriach et al. 2014; Folla et al. 2020). Additionally, evidence confirms that nearly all recreational riders exhibit violence when riding young horses (Grandin and Shivley 2015). Behavioural changes improved when maturity enhanced across increasing age and training. Thus, horses are gentle when they are aged (Hausberger et al. 2008). Correspondingly, Duensing, Stock, and Krieter (2016) indicated that body confirmations are used to identify behaviours enabling a competitive and durable riding horse to be selected using detailed direct approaches. Therefore, an eternal grasp of the horses under inquiry was made possible via testing angular and linear dimensions in conjunction with body conformation and behaviour in selection, conservation and breeding interventions.

As per the present study, body conformation scores described the entire achievement of growth under the prevailing husbandry practices (restrictions on nutrition, hydration, breeding and adaption), where the management techniques are key components in achieving acceptable standard results (Willekes 2019; Librado and Orlando 2021). Thus, body conformations are considered aimed at improving the market price caps and selections (Thiruvenkadan, Kandasamy, and Panneerselvam 2009; Gómez, Valera, and Molina 2010).

Consequently, breeders and farming societies assigned standards for selection during marketing and breeding for suggested employment and health status of the horses. This allows selection for very high to moderate body conformation indices (Jönsson et al. 2014). Per the study, among the most associated body conformation indices were those between BC and RTCI, TI1; TI2 and DTI, RTCI, TI1; W and TD, CI1; TI1 and RTCI; and CI1 and TD with positive correlations (Table 5). Thus, advanced interventions can be made easier by taking into account for highly associated body conformation indices throughout the selection process employing morphometric traits used in body conformation analysis (Ribeiro et al. 2024; Guyo et al. 2024). Therefore, selections of morphometric traits employed for BC, W, and TI1 and TI2 analysis might favour an increase in improvements for breeding programmes. So selections of morphometric traits like thoracic perimeter, HW, ThD, thoracic width, canon perimeter, and length and width croup can improve muscle mass, with good skeletal standing of horses for ringing, racing and drawing of carts and wagons under intensive management conditions (McManus et al. 2008; Gómez et al. 2021; Bonow et al. 2024). Additionally, morphometric traits associations were weighed for harnessing assistance during riding, packing, and loading carts and wagons to link loads via straps (Recht 2022). Thus, rating for predicted improvement interferences relayed for highly associated and positively correlated body conformation indices. Furthermore, correlation standards indicate the relationship is strengthened via assortment selection and interaction for considerations of highly correlated traits (Gómez et al. 2021). This helps in selections for subjective- and objective-centred breeding interventions for the application of desirable characteristics for intended performance (Martin et al. 1978).

5 | Conclusions and Recommendations

The study revealed that the studied horses varied in morphometric appearances among the study districts. The comprehensive morphometric descriptions of the studied horse also indicated they were diverse for body conformation indices except for DTI, relative thickness of cane bone index, RPTI, TD, BR and BC. Body conformation indices described that the studied horses were lighter and smaller that makes them more suitable for saddle-type horses. Body conformation indices were very high to low with positive and negative associations. In community-based breeding programmes, highly associated body conformation indices could be useful for selecting and improving the functional competency of the investigated horses. Further, genomic studies are needed to determine whether the observed morphometric merits are the result of genotype or environmental advancement under prevailing management practices.

Author Contributions

Mesay Guyo: conceptualization, methodology, writing–original draft, writing–review and editing, visualization, formal analysis, data curation, supervision. **Melaku Tareke**: conceptualization, writing–original draft, writing–review and editing, formal analysis. **Andualem Tonamo**: writing—review and editing. **Diriba Bediye**: writing–original draft, data curation, validation, visualization. **Girma Defar**: writing–review and editing, conceptualization, data curation, supervision.

Ethics Statement

The study follows ethical guidelines for animal experiments (Madda Walabu University Animal Welfare and Ethical Committee 2008). The committee declared that all conditions had been met by approving the study and issuing a certificate (ref. no RPEED/012/2015, 18 April 2022).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Ready when requested by the corresponding author.

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