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Research Article

Conformation Traits and Structural Indices of Indigenous Goat Types In Benshangul Gumuz Region, Western Ethiopia

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Abstract: *The objective of this study was to assess the structural indices of indigenous goats in three districts (Homosha, Kumuruk and Bambasi) of Assosa Zone, Benishangul Gumuz Region, Ethiopia. Quantitative data were collected from 600 head of goats selected to characterize conformation traits and estimate structural indices. The measurement data on conformation traits and calculated structural indices were analyzed separately using the general linear model procedure of R software. Location had a significant effect on rear udder height, rear udder width, udder width and udder circumference of does while age had a significant effect on all udder and teat measurements except udder depth. In addition, location had a significant effect on Body index, Proportionality index, Pelvic index, transversal and longitudinal pelvic indices, dactyl thoracic index, compact index 1, Width slope and over increase index in does. In bucks, location had a significant effect on body index, Pelvic index, Transverse pelvic index, longitudinal pelvic index, Dactyl thoracic index, Thoracic development, relative cannon bone thickness index, compact index 1 and width slope. In both sexes, strong and positive correlations (P<0.001) were observed between over increase index and height slope (r = 0.98, for both sexes), thoracic development and Baron and Crevat (r =0.87 for does; r= 0.82 for bucks),weight 2 and Baron and Crevat index (r = 0.80 for does; r = 0.70 for bucks), areal index and weight 2 (r=0.77 for does and r = 0.79 for bucks), Baron Crevat and weight 2 (r = 0.80 for does; r = 0.70 for bucks). Conversely, perfect negative correlations (P<0.001) were observed between proportionality index and length index (r=-1.00 in does and r=-0.99 in bucks) and over increase weight and height slope (r=-0.98 in both does and bucks) in both sexes. Besides, strong negative correlations (P<0.001) were observed between body ratio and height slope (r= -0.99 for does; -0.90 for bucks). The structural indices of this study suggest that the goat population possesses characteristics of a dual-purpose production type, with a tendency toward dairy aptitude. Moreover, the results suggest that conformation traits and structural indices can serve as useful tools for the characterization, selection, and sustainable improvement of indigenous goat populations in the study area.*

Keywords: Structural indices; body conformation traits; indigenous goats; phenotypic characterization; Benishangul-Gumuz Region

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1. Introduction

Morphological differences between and within the Ethiopian indigenous goat population have important economical and socio-cultural values to the Ethiopian communities. However, Ethiopian indigenous goats are accused of less productive and are subject to replacement and crossbreeding with imported goat breeds before proper characterization, evaluation, and conservation of unidentified indigenous goat populations. This results in genetic erosion, loss of genetic diversity, and reduction of adaptive value and opportunities for efficient utilization of the existing adapted goat genetic resources (Halima et al., 2012). Besides, goat production in Ethiopia is constrained by many biological, environmental, and economic factors and is subjected to low productivity (Zewdie and Welday, 2015). Therefore, identification of livestock breeds, documentation of their common uses, and description of the management systems in which they are maintained are the first information to be addressed (FAO, 2011).

Conformation traits refer to the structural and physical characteristics that support an animal’s functional performance. Appropriate conformation is considered important for animal productivity, longevity, and disease resistance potential (Valencia-Posadas et al., 2017). In goats, conformation traits encompass linear type traits quantified on continuous, dimension-specific scales that capture variation between defined phenotypic extremes as well as structural and functional characteristics that determine skeletal robustness and biomechanical efficiency. These traits collectively exert significant influence on the animal’s reproductive performance, longevity, and overall productive capacity (ADGA, 2014).

Structural indices calculated from the morphometric measurements of animals are ratios of phenotypically correlated traits. They are useful for accurately estimating an animal's conformation and for better assessing its type, weight, and function compared to relying solely on individual morphological measurements (Putra and Ilham, 2019). The indices provide a more realistic indicator of which a particular livestock breed was developed or selected and therefore provide a directional approach for their further improvement (Mwambene et al., 2012).

Regardless of the above benefits, studies on structural indices of goats in Ethiopia is very limited except Mezgebu et al. (2022) for goat types in East Gojjam Zone, Hankamo et al. (2020) for local goats in Sidama Zone, Dea et al. (2019) for local goats in Gamo Gofa Zone and Chiemela et al. (2016) for Boer, Central highland, and their F1 crossbred goats in South Wollo Zone. Similarly, there is limited information on structural indices of the goat population in the study area. The objective of this study was to evaluate structural indices and associate these traits to goats’ adaptability, longevity, and productivity, so that to understand the production purposes of indigenous goats in the study area. The study will serve as baseline information for further studies, important for breeders to design an appropriate breeding program that suite with the available goat types and farmers breeding objectives, to aid selective breeding in the area, and to effectively conserve the indigenous goat types in the natural production system in which they are kept.

2. Materials and Methods

2.1. Description of the study area

The study was carried out in three districts of Assosa Zone Benshagul Gumuz region, namely Homosha, Kurmuk and Bambasi districts. The districts were selected purposively based on goat production potential and accessibility. From each of the selected districts, three peasant associations (PAs) were selected purposively based on concentration of goats, their suitability for goat production and accessibility to market and road. The study areas are briefly described as follows (ASARC, 2011).

Homosha district is one of the 22 districts of Assosa zone, the Benishangul Gumuz region of Ethiopia. It is bordered by Assosa on the South, Kurmuk on the Northwest and Menge on the East. The district is found 38 km away from Assosa town which is the capital city of the region and located between 10° 6444'N latitude and 34° 370.92'E longitude. It receives an average rainfall of 700-1200mm annually and the average annual temperature is 28.8°C with the hottest season occurring during March and May (District data, 2021). The district is characterized by diverse topography with an altitude of 1373 m.a.s.l., a long rainy season (June-September), a short rainy season (February/March to April/May), and a dry season (October-January) (ARC, 2011). The district is bordered by Menge district in the North, Oura district in the East and South and Abrahamo in the West.

Kurmuk district is classified as lowland plain, Kola type agro-climatic condition. It is located approximately 95 km in the Western part of the region. The district is bordered by Menge District in the East, Sudan, and South Sudan in the West, Sherkolle district in the North, and Komosha district in the Southeast. The climatic conditions of the district are arid and semi-arid desert with 1000 to 1500mm annual rainfall and 28°C to 42°C temperatures. Its altitude ranges from 650 to 1337m above sea level. Mean annual rainfall ranges from 800 to1200 mm and the maximum rainfall occurs in summer season (i.e., between June and August). Mean annual temperature varies from 25 ^{0}C to 33 ^{0}C. The number of sheep, cattle and mule is relatively less due to agro ecological condition which favours different diseases of farm animals such as Peste des petits ruminants (PPR) in sheep, Trypanosomiasis in cattle and Epizootic lymphangitis (EL) in mules. Goats are the predominant farm animals in the area because they are hardy and tend to survive diseases better in lowland environments than many other livestock species due to evolutionary adaptation and physiological mechanisms than enable them to withstand harsh environmental conditions.

Bambasi district is one of the 22 districts of Assosa zone, in the Benishangul Gumuz region of Ethiopia. It is found 618km away from Addis Ababa and is located to South-eastern part of Assosa at 45km. The district is bordered by the Mao-Komo special district on the Southwest, Assosa in the Northwest, Oda Buldiglu in the Northeast, and by the Oromia Region in the Southeast (Bambasi district administration office, 2022). The district has annual mean rainfall of 1000mm, a mean temperature of 23.60C, altitude of 1,668 m.a.s.l, latitude of 90 45' N and longitude of 340 44' E. The Total number of livestock and human population in each of the three districts is shown in Table 1.

Table 1. Total number of households and livestock population in the study districts.

No	District	Household	Cattle	Goats	Sheep	Equine	Chicken	Bee Hives
1	Bamabsi	14,521	62352	1020	8862	14,352	32,965	1408
2	Homasha	20,438	116800	4902	2115	22586	117372	1118
3	Kurmuk	16,405	139243	5301	1966	31120	93374	1435

Source: Districts' Agriculture and Rural development Offices (2021/22, Unpublished).

2.2. Sampling Technique and Sample Size Determination

In this study, a multi-stage purposive sampling technique where the sample is selected in two or more stages was used to identify the sampling sites. Districts and PAs were selected purposively based on the information collected from preliminary field surveys and discussions with districts agriculture and rural development bureau experts, development agents and farmers who live in the study area. Accordingly, three districts and three PAs from each district were purposively selected based on goat population and accessibility of the area.

Morphological measurement was done on mature/adult animals since young animals may not have acquired the features that are typical of adult animals. For conformation traits characterization, sample mature goats were purposively selected from each sampling site. Goat's dentation (≥1PPI), health condition (healthy), and physiological state (lactating for females and un-castrated for males) were considered as selection criteria. After the total sample size is determined using Cochran (1977) sample size determination formula, samples from each PA were taken proportionally based on the goat population size in each PA as suggested by FAO (2012). Summary of the total number of samples in each district is shown in Table 2.

The formula used to determine the sampled goat population to study conformation traits was:

$n=\frac{z^2pq}{e^2}$ ………… (Equation-1), then adjusted n_0 can be calculated as:

$n_0 = \frac{n}{1+\frac{n-1}{N}}$……………Where;

n = required sample size

z = z-value for the confidence level (1.96)

p = estimated proportion of the sample that will respond a given way to a survey question=0.7

q=1-p =0.3

e= margin of error (for this study 0.06 was considered)

n_0=adjusted sample size for finite population

N= Total population size

Table 2: Summary of the total number of samples in each district.

District	Number of goats sampled		
	Male	Female	N
Bambasi	40	137	177
Homosha	40	179	219
Kurmuk	40	164	204
Total	120	480	600

2.3. Data Types and Methods of Data Collection

2.3.1. Structural indices characterization

Structural indices characterization data were collected from a total of 600 heads of goats comprising 177 from Bambasi (137 does and 40 bucks), 219 from Homosha (179 does and 40 bucks) and 204 from Kurmuk (164 does and 40 bucks) districts. The sampled goats were selected based on the selection criterias indicated above to characterize conformation traits and to calculate structural indices. Measurements were undertaken following the reference points and procedures specified by ICAR (2017) and FAO (2012) for conformation traits recording of dairy goats and phenotypic characterization of animal genetic resources, respectively. For conformation traits measurements, a linear measurement scale (textile measuring tape) was used and live body weight was measured using weighting balance having 120kg capacity and 0.2kg precision. Measurements were taken in the morning to avoid the effect of feeding and watering. Qualitative information on loin strength, rump angle, angularity, rear legs set side view from both sexes and central ligament, fore udder attachment, teat placement rear view, teat placement side view, and teat form for female goats were collected by observation and judgments based on the specifications set by ICAR (2017).

Structural indices were calculated from morphometric measurements of conformation traits based on Olaniyi et al. (2018), Chiemela et al. (2016), Khargharia et al. (2015), Salako (2006) and Alderson (1999) indexes calculation methods to assess the type and function of the indigenous goat types in the study area. Accordingly, the following structural indices were calculated by using the respective index calculation formulae indicated below.

- Height Slope (HS) = Hip height – Wither height
- Body Index (BI) = (Body length/ Heart girth) x 100. When this value is > 0.90, the animal is longiline, between 0.86-0.88 is medigline and less than 0.85 is brevigline
- Proportionality Index (PrI) = (Wither height / Body length) x 100

- Pelvic Index (PI) = (Rump width/ Rump length) x 100
- Transverse Pelvic Index (TPI) = (Rump width/ Hip height) x 100
- Longitudinal Pelvic Index (LPI) = (Rump length/ Hip height) x 100
- Dactyl Thorax Index (DTI) = (Cannon bone circumference/ Heart girth) x 100; The DTI may not be more than 10.5 in light animals, up to 10.8 in intermediary, up to 11.0 in light meat animals, and up to 11.5 in heavy meat type animals.
- Thoracic Development (TD) = Heart girth/ Wither height; this indicates thoracic development of animals, with values above 1.2 indicating animal with good thoracic development (TD).
- Body Ratio (BR) = Withers height / Hip height
- Baron and Crevat (BC) or Conformation Index = (Heart girth) 2/ Wither height
- Compact Index 1 (CI1) = (Weight/ Wither height)/ 100; Compact index indicates how compact the animal is. Meat type animals have compact index values above 3.15. Compact index value close to 2.75 indicates that the animals are dual purpose type and values close to 2.60 indicate that the animals are more suitable for milk purpose.
- Area Index (AI) = Withers height x Body length
- Relative Cannon Thickness Index (RCTI) = (Cannon circumference/ Withers height)*100
- Weight 2 (W2) = (0.63 × Heart girth) – 19.5
- Over Increase Index (OII) = Hip height/ Wither height x 100
- Width Slope (WS) = Rump width/Chest width

2.4. Data Management and Analysis

The collected data were checked for its completeness and consistency and qualitative data were coded. All qualitative data were entered into Microsoft office excel worksheet, 2019 whereas all coded quantitative data were entered into R-software application for analysis. Before conducting the main data analysis, normality of the data was assessed using the Shapiro-Wilk test, while homogeneity of variances among groups was tested using Levene's test. Moreover, screening of outliers was employed. Then different statistical analyses were employed based on data types.

2.4.1. Observations and measurement of conformation traits

Observations on qualitative conformation traits of male and female goats from the sampled districts were analyzed using frequency distributions of R software. Chi-square (χ^2) test of independence was done between districts and the respective qualitative traits. Quantitative data from morphometric measurements of conformation traits on chest width, body depth, rump width, rear legs set rear view, body length, heart girth, paunch girth, wither height, hip height, cannon length, cannon circumference, neck circumference, neck length, rump length, body weight, rear udder height, rear udder width, udder width, udder depth, udder circumference, teat length, scrotal circumference, scrotal width, scrotal length and calculated structural indices were analyzed by using the general linear model (GLM) in R Software (using the lm() function).

Location and goat's dentation class were considered as fixed factors, whereas, morphometric measurements were analyzed for males and females separately. Conformation traits were considered as dependent variables for the analysis. Significance of the effect of the independent variables on dependent variables were checked by analysis of variance (ANOVA) and if significance is declared means were separated using Duncan multiple range mean separation test.

The statistical models used to analyze linear conformation traits and calculated structural indices in males were: $Y_{ij} = \mu + L_i + A_j + e$,

Where Yij = Conformation traits except rear udder height, rear udder width, udder width, udder depth, udder circumference, teat length (estimate of structural indices (height slope, length index, girth index, body index, proportionality index, pelvic index, transverse pelvic index, longitudinal pelvic index, dactyl thoracic index, thoracic development, body ratio, Baron and Crevat, cannon thickness indices, weight 1, weight 2, compact index1, areal index, width slope, over increase index)) in the ith location of the experimental goat and jth age.

Where, μ = overall mean

Li = effect of the ith location (i = Kurmuk, Bambasi and Homosha)

Aj=effect of jth age (dentation class) (j=1PPI, 2PPI, 3PPI, 4PPI) ei = random error term associated with each observation.

Whereas the model used to analyse linear conformation traits and calculated structural indices in females were: Yij = μ+ Li + Aj + e, Where Yij = Conformation traits except scrotal circumference, scrotal width, scrotal length (estimate of structural indices (height slope, length index, girth index, body index, proportionality index, pelvic index, transverse pelvic index, longitudinal pelvic index, dactyl thoracic index, thoracic development, body ratio, Baron and Crevat, cannon thickness indices, weight 1, weight 2, compact index1, areal index, width slope, over increase index)) in the ith location of the experimental goat and jth age.

2.5. Correlation Analysis

Pearson's correlation coefficients were calculated between structural indices of goats for both sexes separately. Stepwise multiple linear regression analysis was used to obtain models to predict body weight of both sexes from linear conformation trait measurements using regression analysis in R software.

3. Results and Discussion

3.1. Conformation traits of indigenous goats in the study area

3.1.1. Udder and teat traits measurements of does

The overall means (±SD) of udder and teat conformation trait measurements of does are presented in Table 3. Location had a significant effect on rear udder height (RUH), rear udder width (RUW), udder circumference (UC) and udder width (UW). However, teat length (TL), and udder depth (UD) of does were not significantly (P>0.05) affected by location. In other words their variation was not explained by locational differences. Does in Kurmuk recorded significantly the highest values of RUH and RUW (P<0.001) than does in Bambasi and Homosha. However, there were no statistically significant (P>0.05) difference between location in teat length (TL) measurements, the highest figurative values of these traits were observed for does in Homosha district. This showed that does in Homosha district recorded the highest values of external udder measurements suited for high milk production. The significant difference in RUH, RUW, UC and UW across location might be related to temperature, humidity, and rainfall differences across location which affects growth and body development, feed availability and quality, management practices, milking practices, health and disease prevalence and genotype by environment interaction.

The overall mean (29.00±4.27) of udder circumference in this study was higher that with Sahel does (28.00±2.35 cm), and Kano brown does (28.40±2.57 cm) reported by Sam et al. (2017). However, it was lower than Black does (37.98±1.96 cm) and Meriz does (34.36± 0.94 cm) (Merkhan et al., 2011). Josip et al. (2020) and Mezgebu et al. (2022) stated that the udder circumference, rear udder height (RUH), rear udder width (RUW), and depth of udder are strongly correlated with milk production of goats. This result indicated that udder circumference, width, height, RUH, RUW, and depth of udder have been identified as conformation traits that could replace the udder volume which in turn is directly related with milk yield. This variation might be due to genotype, lactation, parity, lactation stage of the examined does, management differences, and farmers' selection criteria. This result is in line with the report of Mingoas et al. (2017) who reported that udder characteristics were varied with breed, udder portion, lactation stage, and parity. Similarly, Minister et al. (2019) reported that udder circumference, rear udder diameter, and teat length of local does reared in the Central Zone of Tigray were significantly different among the studied districts. In contrast, Kefyalew et al. (2015) mentioned that district or location had no significant effect on rear udder diameter, rear udder length, teat length, and udder circumference of local does' reared in West Amhara.

Age of the does' had a significant (P<0.001) influence on udder measurements (RUH, RUW, udder circumferences, and udder width) and teat length (P<0.05), but not udder depth (P>0.05). This showed that like other conformation trait measurements, as does age increases, external udder size and teat measurements were also increased. This may be due to an increase in the hormonal status of the animal's body, nutrient intake, and metabolic activity of the animal.

Table 3: Mean (±SD) udder and teat measurements (cm) of does by age and location.

Sources	N	RUH Mean±SD	RUW Mean±SD	UW Mean±SD	UC Mean±SD	UD Mean±SD	TL Mean±SD
Overall	480	6.48±1.31	5.99±1.10	9.04±1.55	29.00±4.27	17.20±1.98	3.37±0.80
CV		4.16	7.1	7.49	3.86	11.52	22.07
R^2		0.61	0.1	0.17	0.29	0.41	0.14
Location		***	***	***	**	Ns	Ns
Bambasi	137	6.56±1.02^{c}	5.86±0.76^{c}	9.05±1.19^{c}	28.19±3.63^{bc}	17.09±1.78	3.38±0.62
Kurmuk	179	7.08±1.38^{a}	6.64±0.99^{a}	9.55±1.81^{a}	28.66±4.33^{a}	17.24±1.98	3.26±0.87
Homosha	164	6.84±1.25^{b}	6.00±1.21^{ab}	9.02±1.79^{ab}	28.33±4.02^{b}	17.06±2.06	3.47±0.79
Dentation		***	***	***	***	Ns	***
1PPI	47	5.74±1.39^{b}	5.26±1.19^{c}	8.19±1.19^{c}	25.36±2.67^{c}	16.72±1.87	2.71±0.73^{c}
2PPI	76	6.33±1.35^{a}	5.72±1.17^{b}	8.96±1.52^{b}	26.63±3.19^{b}	17.16±1.69	3.05±0.77^{b}
3PPI	100	6.35±1.31^{a}	5.82±0.87^{b}	9.51±1.68^{a}	28.15±4.09^{a}	17.22±1.89	3.18±0.78^{b}
4PPI	257	6.64±1.29^{a}	6.19±1.11^{a}	9.66±1.74^{a}	28.68±4.06^{a}	17.25±2.12	3.55±0.72^{a}

RUH= rear udder height; RUW = rear udder width; UW = udder width; UC = udder circumferences; UD = udder depth; TL = teat length; a, b, c, d = means on the same column with different superscripts are significantly different (P<0.05); SD = Standard deviation; CV =Coefficient of variation; R2 = coefficient of determination; Ns = Non-significant (P>0.05); *** = P<0.001; ** = P<0.01.

3.2. Structural Indices of Indigenous Goats

Morphology of an animal express strong relationship with productive potential since it contains the structure which supports the biological functionality of the animal. Calculated structural and morphometric functional indices for goat types reared in the studied districts are presented in Table 4 and Table 5, respectively. Location had a significant influence on proportionality index (PrI), thoracic pelvic index (TPI), longitudinal pelvic index (LPI), dactyl thoracic index (DTI), thoracic development (TD), cannon thickness index (CTI), and width slope (WS) of does. However, height slope (HS), body ratio (BR), Baron and Crevat (BC), weight2, and areal index (AI) of does were not significantly (P>0.05) affected by location. Similarly, thoracic development (TD), longitudinal pelvic index and transverse pelvic index (LPI and TPI), dactyl thoracic index (DTI), relative cannon thickness index (RCTI), and width slope (WS) of bucks were significantly (P<0.05) influenced by location. In line with this study, Dea et al. (2019) and Amsale et al. (2020) reported that location had a significant (P<0.05) influence on structural and functional indices of local goats reared in Gamo Gofa and Sidama Zones.

Body Index (BI): of goats show the proportionality of the breed and allows classifying goats according to baronian systematics into brevilinear (⩽ 85), mesolinear (86-88) or longlinear (⩾90) (Silva et al., 2019). In the present study, the overall body index (BI) values of does and bucks were (86.59±4.42 and 89.34±4.34) in Bambasi, (90.98±6.71 and 92.23±4.07) in Kurmuk, (88.22±5.39 and 91.75±5.26) in Homosha districts, respectively showing significant (p < 0.05) difference across the study area. This result indicated that the indigenous goat population in Bambasi had a mesolinear profile, whereas the goat populations in Kurmuk and Homosha had a longilinear profile, with longitudinal (length) measurements exceeding transverse measurements. The overall mean body index of does in the current study were comparable with Boar does (89.44±1.81) reported by Chiemela et al. (2016). However, Bambasi goat population was slightly compared with local does (87.7±0.28) in Gamo Gofa Zone (Dea et al., 2019), Central Highland (86.83±0.65) and Boar crossed with Central Highland (85.61±0.97) does in South Wollo Zone (Chiemela et al., 2016), Cuba Creole does (85.29±4.75) and Cuban Creole crossed does (81.96 ±4.49) (Chacon et al., 2011), and Katjang does (86.95±5.4) in Indonesia reported by Putra and Ilham (2019). It is noted that the Areba Minch Zuria goats demonstrated closer similarities in many structural and functional indices with that of Boer goats reared in Central Highlands of Ethiopia.

In the contrary, The BI of does in the current study was slightly lower than local does' aged 1-2 years (93.86±0.35 and 92.05±0.00) and aged 3-4 years (94.7±0.34 and 94.13±0.30) in Aroresa and Loka baya districts, respectively (Amsale et al., 2020). Similarly, the overall mean body index of bucks was slightly lower as compared with local bucks aged 1-2 years and 3-4 years in Aroresa (93.37±0.55; 92.10±0.73) and 1-2 years in Lokabaya (93.32±0.33) districts (Amsale et al., 2020).

3.2.1. Structural indices of Does and Bucks

Proportionality Index (PrI): relates the body height to the body length and denotes the shape of a given animal population (Barragán, 2017; Silva et al., 2019 and Dea et al., 2019). A PrI value less than (<100) (predominance of body length over body height) indicates that the breed's body tends to be rectangular which is a characteristic of meat type, while a value greater than (>100) denotes that the shape of the animal tends to be square, which is a characteristic of dairy type goats (Bravo and Sepúlveda, 2010; Barragán, 2017 and Silva et al., 2019). In the present study, the overall Proportionality index (PrI) values of does and bucks were (102.82±6.49 and 108.51±5.70) in Bambasi, (107.02±5.69 and 107.36±6.45) in Kurmuk, (104.58±6.28 and 107.95±4.7) in Homosha showing significant (p<0.05) difference across the study area (Table 4).

In the current study, the does in all the three districts showed higher Proportionality index (PrI) value with almost a square shape that tends to be related to dairy type. A similar result was recorded for local goats (PrI = 103) in Mirab-Abaya district however contrasting result was recorded for local goats (PrI= 97) in Arbaminch Zuria that possess dairy and meat characteristics, respectively (Dea et al., 2019).

Pelvic Index (PI) is the ratio of pelvic width to pelvic length that determines the proportionality of a racial diagnostic index which is used to determine the proportionality of the hindquarters and thus, could be related to the reproductive fitness of female goats (Cerqueira etal., 2011). PI determines the proportionality of the hindquarter correlated with reproductive fitness (Silva et al., 2019) and meat production ability of goats (Dauda, 2018). According to the current result of PI, the rump of the goats had a convex curve (p>100), with a predominance of the rump length over the width (Dea et al., 2019). The overall mean pelvic indices of does (77.54±6.25) and bucks (70.48±7.92) in the present study indicated that goats in the study areas have convex curve with a predominance of rump length over the width or disproportionality of the hindquarter. The pelvic indices value of both does and bucks in the present study were lower than Boar (92.93±0.05), Boar crossed Central Highland (82.01±0.02) and Central Highland (79.84±0.01) does in South Wollo (Chiemela et al., 2016). Similarly the values are consistent with, Cuban Creole does (76.00 ±3.50) and Cuban Creole Crossed does (78.62±7.54) reported by Chacon et al., 2011 and local does (93.0±11.3) in Gamo Gofa Zone (Dea et al., 2019). These differences may be due to age, breed and/or management differences as well as measurement imprecision between researchers.

Transverse Pelvic Index (TPI) and Longitudinal Pelvic Index (LPI) are functional indices used to estimate the meat aptitude (phenotype) of the animal by relating the width and length of the rump to the wither height, respectively (Barragan 2017; Dea et al., 2019). Silva et al. (2019) also reported that transverse pelvic and longitudinal pelvic indices are an estimator for the meat phenotype of the breed i.e. TPI >33 and LPI <37 are indicators of meat-phenotype of the goat breeds.

The overall transverse pelvic index (TPI) and longitudinal pelvic index (LPI) values for does (20.56±1.62 and 26.34±2.21) and bucks (22.97±1.34 and 27.12±2.54) in the present study were below the ranges for TPI and within the ranges for LPI noted by Silva et al. (2019). This result indicated that indigenous goat population in the study areas does not meet the standard for meat type goats. According to Chiemela et al. (2016), the LPI of Central Highland goat in South Wollo was 17.0, which was much lower than the value observed in the current study. Lower LPI values reflect relatively smaller pelvic and hindquarter development, potentially reducing pelvic capacity and increasing the risk of dystocia due to impaired fetal passage during parturition (Chacón et al., 2011 and Chiemela et al., 2016).

The longitudinal pelvic index of both sexes in the current study was slightly similar with local goats (27.9±2.05) in Gamo Gofa (Dea et al., 2019). Chiemela et al. (2016) reported slightly similar transverse pelvic and longitudinal pelvic indices for Boer (22.87±0.52; 19.48±1.88), Boer Crossed Central Highland (20.62±0.34; 18.38±0.25) and Central Highland (20.55±0.10; 17.03±0.19) does, respectively than the current findings. Higher transverse pelvic indices were also reported for local goats (26.1±1.20) in Gamo Gofa (Dea et al., 2019) and Black Creole goats (22.30±1.89) (Silva et al., 2019). This variation may be described by age of the examined goats, environmental factors and differences in breed type and function of the goats reared under different production systems.

Dactyl Thoracic Index (DTI) indicates a relationship between chest depths and withers height and serves as an indirect measure of leg length, whereby higher indices for this trait corresponds to animals with strong thick cannon bones, compact muscular body and higher meat production potential (Chacón et al., 2011). A low DTI (<10) indicates dairy-type goats (slender, fine bones), medium DTI (10-12) indicates dual-purpose goats while high DTI (>12) indicates meat type goats (compact, strong bones) (Chacón et al., 2011).

In the present study, the overall DTI values of does and bucks were (10.59±0.61 and 11.65±0.87) in Bambasi, (10.37±0.74 and 11.60±0.71) in Kurmuk, and (10.52±0.76 and 11.83±0.96) in Homosha districts, respectively. This result indicated that the goat types in all the three districts can be characterized as dual purpose. Moreover, it delivers information about the degree of fineness of the skeleton, classifying the animals as hypermetric (large format), eumetric (medium format), elipometric (small format), being <10.5 and >11.5 in dairy and meat animals through creating relationships between the pectoral mass and limbs, respectively (Barragan, 2017).

According to Chacon et al. (2011), dactyl thoracic index is greater in meat type than milk type animals' i.e. an increment in cannon bone perimeter assumes an increase in body size. The variation in DTI between the two sexes may be due to sexual dimorphism, which results in differences in body size, skeletal growth, and muscular development between the two sexes due to hormonal and genetic influences. The value observed for does in the current study was comparable with Katjang does (10.24±0.73) (Putra and Ilham, 2019) and Central Highland does (10.64±0.05) in South Wollo reported by Chiemela et al. (2016). However, it was higher as compared with Cuban Creole (9.58±0.50) and Cuban Creole Crossed does (9.15±0.69) (Chacon et al., 2011).

Thoracic Development (TD) is an important indicator of good fitness and respiratory system especially for animal breeds that are adapted to the higher altitudes (Khargharia et al., 2015 and Dea et al., 2019). The average mean (±SD) thoracic development values of does and bucks (1.13±0.09 and 1.11±0.14) in Bambasi district was slightly higher than Kurmuk and Homosha districts which indicated a better thoracic capacity enabling them to survive in relatively high-altitude terrains in the study area. This result is in line with local goat population (1.14±0.05) in Gamo Gofa (Dea et al., 2019) and Boer (1.13±0.03) and Boer Crossed Central Highland (1.13±0.01) two years old does in South Wollo (Chiemela et al., 2016).

However, the Mean (±SD) thoracic development values of does and bucks in all the three districts in the current study were below the recommended level (1.2) (Dauda, 2018). According to the author, values above 1.2 indicate good thoracic development and are associated with better physiological capacity, growth, and productivity in goats. This indicates that goats in the study area have poor thoracic capacity, an indication of thin and tall animals that may not be effectively survive in the highland areas. The observed value for does was consistent with those reported for the East Gojjam goat population (1.08 ± 0.06) by Mezgebu et al. (2022) and the Central Highland goat population in South Wollo (1.08 ± 0.01) by Chiemela et al. (2016).

Baron and Crevat (BC) index is an indicator of the overall body conformation of an animal. The higher the Baron and Crevat index, the greater the vigor and robustness of the breed (Dea et al., 2019). Accordingly, goats in Kurmuk district are expected to have a more robust body structure and a stronger physical appearance than goats in Homosha and Bambasi districts, respectively.

BC index value of does (70.38±7.03) calculated in the present study was higher than Boer (68.28±4.43), Boer Crossed Central Highland (72.22±1.41) and Central Highland (69.86±0.62) does in South Wollo (Chiemela et al., 2016) and local goats (77.9±7.57) in Gamo Gofa (Dea et al., 2019). Whereas the value observed for bucks (79.38±7.03) is in line with the report of Chiemela et al. (2016) for Boer does in South Wollo. However, the current findings for both sexes were lower than Assam Hill goat (93.18±2.86) in India (Khargharia et al., 2015) and Cuban Creole (97.01±3.96) and Cuban Creole Crossed (105.37±10.15) does reported by Chacon et al. (2011).

Body Ratio (BR): Body ratio (also called body index) is a numerical relationship between two body measurements of an animal. A body ratio is calculated by dividing one body measurement by another and multiplying by 100. The result pertaining to body ratio (BR) indicated that both does and bucks had similar value (0.96±0.02), and both sexes are slightly lower at the wither than the rump, which is supported by the height slope (HS). The present value was consistent with local does (0.96±0.00) in Sidama (Amsale Hankamo et al., 2020) and Boer (0.96±0.01) but, higher than Boer Crossed Central Highland (0.93±0.01) and Central Highland (0.94±0.00) does in South Wollo (Chiemela et al., 2016). Similarly, Khargharia et al. (2015) reported a lower body ratio for Assam Hill Goats (0.93 ±0.0) in India. Conversely, Chacon et al. (2011) reported a higher body ratio for Cuban Creole (0.97±0.01) and Cuban Creole Crossed (0.97±0.04) does than the current findings.

Body Weight of both sexes was estimated from conformation traits using different predictive formulas; however, the estimated values were not significantly different across the study districts. From the estimated weight values, the overall weight 2 (W2) values of does (28.36±3.33) and bucks (29.94±2.97) were somewhat similar to the actual overall mean weight values of does and bucks. This shows the possibility of weight estimation from conformation measurements by using different formulas. Among the estimation formulas, weight 2 was most accurate. Indices are often considered a superior option for assessment of weight since they incorporate measures of desirable conformation (mainly length and balance) (Chacon et al., 2011; Dauda, 2018).

Width Slope (WS) is an important parameter for estimating balance and assessing the function of the breed (Dauda, 2018). The overall mean width slope values for does and bucks were 1.04±0.22 and 0.98±0.13, respectively. This indicates that does are slightly wider at the hip than at the shoulder, while bucks are slightly wider at the shoulder than at the hip. However, both sexes possess a relatively desirable balance. The present findings were higher than Boer (0.77±0.04), Boer Crossed Central Highland (0.71±0.01) and Central Highland (0.91±0.01) does from South Wollo (Chiemela et al., 2016) suggesting better balance of indigenous goats in the current study. Khargharia et al. (2015) also reported lower width slope for Assam Hill goat (0.84±0.02) in India.

Areal Index (AI): The AI expresses the relationship between chest girth and body height, indicating the body area or body massiveness of the animal. The overall AI of both does (3633.05±513.86) and bucks (4149.82±491.95) were similar with Mezgebu et al. (2022) and higher than local goats in Gamo Gofa (3618±196) (Dea et al., 2019), Assam Hill Goats (3355.13±48.84) (Khargharia et al., 2015) and Katjang does (3394.46±379.2) (Putra and Ilham, 2019). This indicates that goats in the study areas have larger body surface area relative to their body mass, enabling them to withstand heat stress effectively by dissipating excess heat from their body surface (Dea et al., 2019). These variations between goat types are explained by type and function of goats, environmental factors and management condition employed for goats in different production environments.

Compact Index 1 (CI1): measures the degree of compactness of the animal's body by comparing body weight or chest girth with body length. It is calculated as body weight divided by withers height and divided by 100, and it indicates the degree of body compactness. Values above 3.15 are associated with meat-type animals; values around 2.75 indicate dual-purpose animals, while values close to 2.60 suggest animals more suitable for milk production (Dauda, 2018; Chacón et al., 2011).

The CI1 values for does in Bambasi, Kurmuk and Homosha districts are 2.62±0.10, 2.58±0.90 and 2.61±0.50, respectively which are close to 2.6 suggesting that the goat populations in the study areas are characterized by relatively less compact body conformation and may be more suitable for milk production rather than meat production. Dea et al. (2019) and Chiemela et al. (2016) have observed higher values for local goats (4.90±0.16) in Gamo Gofa and Central Highland does (3.91±0.05) in South Wollo, respectively, and labelled them as meat-type. The relatively lower compact index values in the present study could be due to differences in age, breed, feed, and feeding practices of the studied goat populations.

Over Increase Index (OII) values of does and bucks (103.13±0.18 and 105.14±1.74) in Bambasi, (104.24±2.34 and 105.19±2.44) in Kurmuk and (104.07±2.24 and 105.23±1.67) in Homosha districts, respectively, showed that both sexes are slightly lower at the whither than the rump.

The OII values observed in the current study were almost similar with the report of Amsale et al. (2020) who reported index values of does (101.23±0.23) and bucks (104.20±0.18). These findings suggested that the OII indicates that the height at rump is more or less similar to those of the withers; however, there are incidences where the rump height is higher than the withers height. This result was also confirmed by the results from height slope and body ratio in the present study. Such conformation of goats is not desirable since goats that are lower at the front than the hind part are prone to dust infestations (Amsale et al., 2020). Height slope values of does (104.03±2.24) and bucks (105.19±1.95) observed in the current study were higher than Assam Hill Goats (103.43±0.29) in India reported by Khargharia et al. (2015).

Table 4: Structural indices for does aged above one year across location.

	Bambasi N=137	**Kurmuk N=179**	**Homosha N=164**	**Overall N=480**		
Indices	Mean±SD	Mean±SD	Mean±SD	Mean±SD	CV	P-value
HS	2.88±1.51	2.70±1.50	2.77±1.47	2.76±1.49	5.92	Ns
BI	86.59±4.42[b]	90.98±6.71[a]	88.22±5.39[a]	88.59±6.12	4.94	**
PrI	102.82±6.49[a]	107.02±5.69[b]	104.58±6.28[b]	104.81±6.17	5.76	***
PI	76.99±8.64[b]	78.03±7.09[a]	77.60±5.30[c]	77.54±6.25	9.95	***
TPI	20.99±1.59[b]	21.76±1.42[a]	21.02±1.79[ab]	20.56±1.62	8.20	**
LPI	25.82±2.47[a]	27.14±2.07[b]	26.05±2.08[b]	26.34±2.21	9.10	***
DTI	10.59±0.61[a]	10.37±0.74[b]	10.52±0.76[a]	10.53±0.73	5.02	**
BR	0.96±0.02	0.96±0.02	0.96±0.02	0.96±0.02	1.85	Ns
BC	70.26±6.59	70.66±5.26	70.23±8.93	70.38±7.03	8.12	Ns
W2	28.92±3.55	29.02±3.08	28.43±3.44	28.36±3.33	10.15	Ns
CI1	2.62±0.10[b]	2.58±0.90[b]	2.61±0.50[a]	2.59±0.78	5.27	***
AI	3620.60±493.78	3674.99±538.38	3626.18±522.86	3633.05±513.86	10.11	Ns
WS	1.11±0.12[a]	1.05±0.11[b]	1.01±0.12[c]	1.04±0.22	11.21	***
OII	103.13±0.18[c]	104.07±2.24 [a]	104.24±2.34[b]	104.03±2.24	9.16	***

a, b, c = means on the same row with different superscripts are significantly different (P<0.05); HS = Height Slope; BI=Body index; PrI = Proportionality Index; PI = Pelvic Index; TPI = Transvers Pelvic Index; PLI = Longitudinal Pelvic Index; DTI = Dactyl Thoracic Index; TD = Thoracic Development; BC =Baron and Crevat; W2 = Weight 2; CI1= Compact index 1; AI = Areal Index; WS = Width slope; OII = Over increase Index; SD = Standard deviation; CV =Coefficient of variation; Ns = Non-significant (P>0.05); *** = P<0.001; ** = P<0.01.

Table 5: Structural indices for bucks aged above one year across location.

	Bambasi N=40	Kurmuk N=40	Homosha N=40	Overall N=120		
Indices	Mean±SD	Mean±SD	Mean±SD	Mean±SD	CV	P-value
HS	2.69±1.20	2.95±1.34	2.72±1.12	2.79±1.22	43.84	Ns
BI	89.34±4.34[c]	92.23±4.07[a]	91.75±5.26[b]	91.11±4.91	5.07	***
PrI	108.51±5.70	107.36±6.45	107.95±4.76	107.94±5.65	5.26	Ns
PI	70.83±8.16[b]	71.40±8.03[a]	69.22±7.58[b]	70.48±7.92	9.12	***
TPI	22.19±1.32[a]	23.83±1.38[b]	22.90±1.33[a]	22.97±1.34	8.42	***
LPI	26.12±2.48[a]	28.34±2.37[b]	26.00±2.50[a]	27.12±2.54	9.13	***
DTI	11.65±0.871[a]	11.60±0.71[a]	11.83±0.96[a]	11.89±0.94	10.50	***
TD	1.11±0.14[a]	1.09±0.06[b]	1.08±0.06[b]	1.09±0.08	4.04	**
BR	0.96±0.02	0.96±0.02	0.96±0.02	0.96±0.02	1.85	Ns
BC	78.04±10.05	80.15±8.54	79.90±9.43	79.38±7.03	10.48	Ns
RCTI	12.40±0.91[a]	11.81±0.75[b]	12.40±0.87[a]	12.20±0.88	7.93	**
W2	29.00±3.09	29.90±2.29	29.90±3.48	29.94±2.97	10.06	Ns
CI1	2.73±1.76[a]	2.68±1.10[b]	2.70±1.22[b]	2.69±1.33	3.20	**
AI	4139.33±504.34	4183.18±553.67	4126.95±421.25	4149.82±491.95	11.40	Ns
WS	1.04±0.12[a]	0.98±0.09[a]	0.94±0.12[b]	0.98±0.13	2.80	***
OII	105.14±1.74	105.23±1.67	105.19±2.24	105.19±1.95	3.66	Ns

a, b, c = means on the same row with different superscripts are significantly different (P<0.05); HS = Height Slope; BI=Body index; PrI = Proportionality Index; PI = Pelvic Index; PTI = Transvers Pelvic Index; PLI = Longitudinal Pelvic Index; DTI = Dactyl Thoracic Index; TD = Thoracic Development; BR = Body Ratio; BC =Baron and Crevat; RCTI= Relative cannon thickness index; W2=Weight 2; CI1=Compact index 1; AI = Areal Index; WS = Width slope; OII = Over increase Index; SD = Standard deviation; CV =Coefficient of variation; Ns = Non-significant (P>0.05); *** = P<0.001; ** = P<0.01.

3.3. Correlation between structural indices of does and bucks

The Pearson correlation coefficients (r) between the structural indices of does and bucks in the sampled goat population from the study area are presented in Tables 6–9. The results of the study have shown that, in both sexes, strong and positive correlations (P<0.001) were observed between over increase index and height slope (r = 0.98, for both sexes), thoracic development and Baron and Crevat index (r =0.87 for does; r = 0.82 for bucks),weight 2 and Baron and Crevat (r = 0.80 for does; r = 0.70 for bucks), relative cannon thickness index and dactyl thoracic index (r = 0.71 for does; r = 0.83 for bucks), areal index and weight 2 (r=0.77 for does and r = 0.79 for bucks), Baron Crevat and weight 2 (r = 0.80 for does; r = 0.70 for bucks).

The strong correlation between over increase index and height slope suggests both indices measure almost the same body shape characteristic (the slope of the goat's body) (Kassahun and Solomon, 2008) or can be used to predictor or estimate body weight. Similarly, weight 2 and compact index1 were strongly and positively correlated (P<0.001) with thoracic development of does (r=0.67 and r=0.66), respectively (Table 7). The result further indicated strong and positive correlations (P<0.001) between compact index1 and Baron and Crevat index (r = 0.76), transverse pelvic index and pelvic index (r = 0.64), width slope and transverse pelvic index (r = 0.71), compact index1 and weight 2 (r = 0.73) of does (Table 7). Body index and length index (r = 0.59), areal index and Baron and Crevat index (r = 0.54) and compact index1 and Baron and Crevat index (0.76) have shown medium and positive correlation in does (Tables 6 and 7). Moreover, body index and length index (r = 0.58) and pelvic index and transverse pelvic index (r = 0.52) have shown medium and positive correlation (P<0.001) in bucks (Table 6).

Conversely, proportionality index with length index (r=-1.00 in does and r=-0.99 in bucks) showed perfect negative correlations (P<0.001) in both sexes (Table 6). Besides, in both sexes strong and negative correlations (P<0.001) were observed between body ratio and height slope (r= -0.99 for does; -0.90 for bucks) (Tables 8 and 9) and longitudinal pelvic index and pelvic index (r = -0.66 for does; -0.73 for bucks) (Table 6). On the other hand, moderate negative correlations (P<0.001) were observed between body index with proportionality index (-0.59 in does; -0.58 in bucks) (Table 6), and body index with thoracic development (r = -0.42 in does and -0.55 in bucks) (Tables 8 and 9). In bucks, Baron and Crevat with dactyl thoracic index (r=-0.58) and weight 2 with dactyl thoracic index (r=-0.52) have also shown moderate and negative correlations (Table 8).

Generally, strong correlation coefficients were observed between structural indices which were calculated from the same linear body measurements. Similar correlations between structural indices were observed for Boer, Boer crossed Central Highland and Central highland goats (Chiemela et al., 2016), Cuban Creole goats and their crossbreds (Chacon et al., 2011) and for Katjang does (Putra and Ilham, 2019)

Table 6: Pearson correlation coefficients between structural indices of does and bucks.

Indices	HS	LI	GI	BI	PrI	PI	TPI	LPI	DTI
HS	—	0.28**	0.09Ns	0.07Ns	-0.25*	0.06Ns	-0.15Ns	-0.13Ns	0.02Ns
LI	0.16**	—	0.04Ns	0.58***	-0.99***	-0.05Ns	0.15Ns	0.17Ns	-0.12Ns
GI	0.06Ns	0.12**	—	-0.03Ns	-0.05Ns	0.09Ns	0.03Ns	-0.08Ns	0.02Ns
BI	-0.04Ns	0.59***	0.06Ns	—	-0.58***	-0.05Ns	-0.08Ns	-0.02Ns	0.28**
PrI	-0.11*	-1.00***	-0.12**	-0.59***	—	0.02Ns	-0.16Ns	-0.15Ns	0.10Ns
PI	-0.07Ns	0.12**	-0.01Ns	0.04Ns	-0.13**	—	0.52***	-0.73***	-0.12Ns
TPI	-0.10*	0.22***	0.05Ns	0.00Ns	-0.22***	0.64***	—	0.20*	-0.12Ns
LPI	-0.02Ns	0.07Ns	0.05Ns	-0.04Ns	-0.06Ns	-0.66***	0.18***	—	0.04Ns
DTI	0.07Ns	-0.11*	0.12**	0.28***	0.11**	-0.05Ns	0.01Ns	0.06Ns	—

Note: Values in the lower diagonal represent does, whereas values in the upper diagonal represent bucks.
HS = Height Slope; LI = Length Index; GI = Girth Index; BI = Body Index; PrI = Proportionality Index;
PI = Pelvic Index; TPI = Transvers Pelvic Index; LPI = Longitudinal Pelvic Index; DTI = Dactyl Thoracic Index;
Ns = non-significant (P>0.05); *** = P<0.001; ** = P<0.01; * = P<0.05.

Table 7: Pearson correlation coefficients between structural indices of does and bucks.

Indices	TD	BR	BC	RCTI	W2	CI1	AI	WS	OII
TD	—	-0.29**	0.82***	0.22*	0.44***	0.31***	-0.11Ns	-0.02Ns	0.29**
BR	-0.18***	—	-0.12Ns	-0.27*	0.01Ns	0.01Ns	0.10Ns	-0.02Ns	-0.98***
BC	0.87***	-0.004Ns	—	-0.03Ns	0.70***	0.40***	0.49***	0.13Ns	0.14Ns
RCTI	0.35***	-0.23***	0.21***	—	-0.28**	0.13Ns	-0.44***	-0.09Ns	0.27**
W2	0.67***	0.12**	0.80***	0.07Ns	—	0.30***	0.79***	0.19*	-0.02Ns
CI1	0.66***	0.02Ns	0.76***	0.19***	0.73***	—	0.20*	-0.09Ns	-0.06Ns
AI	0.18**	0.26***	0.54***	-0.09*	0.77***	0.73***	—	0.23*	-0.14Ns
WS	-0.08Ns	-0.01Ns	0.01Ns	-0.02Ns	0.07Ns	-0.07Ns	0.16***	—	0.09Ns
OII	0.18***	-0.93***	0.03Ns	0.33***	-0.13**	0.02Ns	-0.26***	-0.01Ns	—

Note: Values in the lower diagonal represent does, whereas values in the upper diagonal represent bucks.
TD = Thoracic Development; BR = Body Ratio; BC =Baron and Crevat; RCTI = Relative Cannon Thickness Index;
W2 = Weight 2; CI1 compact index 1; AI = Areal Index; WS = Width slope; OII = Over increase Index;
Ns = non-significant (P>0.05); *** = P<0.001; ** = P<0.01; * = P<0.05.

Table 8: Pearson correlation coefficients between structural indices of bucks.

Indices	TD	BR	BC	RCTI	W2	CI1	AI	WS	OII
HS	0.25^{*}	-0.90^{***}	0.18*	0.19^{*}	0.07^{Ns}	0.01^{Ns}	0.02^{Ns}	0.04^{Ns}	0.98^{***}
LI	0.44^{***}	-0.30^{***}	0.22^{*}	0.17^{Ns}	0.01^{Ns}	0.23^{*}	0.10^{Ns}	0.01^{Ns}	0.30^{***}
GI	0.08^{Ns}	-0.08^{Ns}	-0.02^{Ns}	0.07^{Ns}	-0.09^{Ns}	0.00^{Ns}	-0.15^{Ns}	0.07^{Ns}	0.07^{Ns}
BI	-0.55^{***}	-0.02^{Ns}	-0.52^{***}	-0.04^{Ns}	-0.39^{***}	-0.05^{Ns}	0.19^{*}	0.03^{Ns}	0.02^{Ns}
PrI	-0.42^{***}	0.29^{**}	-0.21^{*}	-0.17^{Ns}	-0.01^{Ns}	-0.24^{**}	-0.11^{Ns}	-0.02^{Ns}	-0.30^{***}
PI	0.02^{Ns}	0.02^{Ns}	0.14^{Ns}	-0.12^{Ns}	0.19^{*}	-0.04^{Ns}	0.19^{*}	0.37^{***}	-0.02^{Ns}
TPI	0.25^{**}	0.15^{Ns}	0.30^{***}	0.04^{Ns}	0.27^{**}	0.09^{Ns}	0.17^{Ns}	0.67^{***}	-0.15^{Ns}
LPI	0.19^{*}	0.10^{Ns}	0.10^{Ns}	0.17^{Ns}	0.01^{Ns}	0.12^{Ns}	-0.07^{Ns}	0.09^{Ns}	-0.10^{Ns}
DTI	-0.43^{***}	-0.05^{Ns}	-0.58^{***}	0.83^{***}	-0.52^{***}	-0.08^{Ns}	-0.31^{***}	-0.04^{Ns}	0.08^{Ns}

TD = Thoracic Development; BR = Body Ratio; BC =Baron and Crevat; RCTI = Relative Cannon Thickness Index;
W2 = Weight 2; CI1 compact index 1; AI = Areal Index; WS = Width slope; OII = Over increase Index; HS = Height Slope;
LI = Length Index; GI = Girth Index; BI = Body Index; PrI = Proportionality Index;
PI = Pelvic Index; TPI = Transvers Pelvic Index; LPI = Longitudinal Pelvic Index; DTI = Dactyl Thoracic Index;
Ns = non-significant (P>0.05); *** = P<0.001; ** = P<0.01; * = P<0.05.

Table 9. Pearson correlation coefficients between structural indices of does.

Indices	HS	LI	GI	BI	PrI	PI	TPI	LPI	DTI
TD	0.17^{***}	0.49^{***}	0.06^{Ns}	-0.42^{***}	-0.48^{***}	0.10^{*}	0.24^{***}	0.12^{**}	-0.41^{***}
BR	-0.99^{***}	-0.15^{***}	-0.06^{Ns}	0.03^{Ns}	0.13^{**}	0.07^{Ns}	0.08^{*}	-0.01^{Ns}	-0.09^{*}
BC	0.04^{Ns}	0.39^{***}	0.05^{Ns}	-0.43^{***}	-0.39^{***}	0.15^{***}	0.17^{***}	-0.02^{Ns}	-0.47^{***}
RCTI	0.20^{***}	0.27^{***}	0.17^{***}	-0.04^{Ns}	-0.26^{***}	0.03^{Ns}	0.19^{***}	0.15^{***}	0.71^{***}
W2	-0.06^{Ns}	0.29^{***}	0.03^{Ns}	-0.37^{***}	-0.26^{***}	0.16^{***}	0.09^{*}	-0.12^{**}	-0.44^{***}
CI1	0.02^{Ns}	0.46^{***}	0.25^{***}	-0.12^{**}	-0.45^{***}	0.11^{**}	0.07^{Ns}	-0.07^{Ns}	-0.29^{***}
AI	-0.18^{***}	0.44^{***}	0.05^{Ns}	0.25^{***}	-0.40^{***}	0.21^{***}	0.02^{Ns}	0.23^{***}	-0.22^{***}
WS	0.02^{Ns}	-0.01^{Ns}	-0.03^{Ns}	0.08^{Ns}	0.00^{ns}	0.41^{***}	0.71^{***}	0.07^{Ns}	0.04^{Ns}
OII	0.98^{***}	0.13^{**}	0.06^{Ns}	-0.03^{Ns}	-0.13^{**}	-0.07^{Ns}	-0.08^{Ns}	-0.01^{Ns}	0.09^{*}

TD = Thoracic Development; BR = Body Ratio; BC =Baron and Crevat; RCTI = Relative Cannon Thickness Index;
W2 = Weight 2; CI1 compact index 1; AI = Areal Index; WS = Width slope; OII = Over increase Index; HS = Height Slope;
LI = Length Index; GI = Girth Index; BI = Body Index; PrI = Proportionality Index;
PI = Pelvic Index; TPI = Transvers Pelvic Index; LPI = Longitudinal Pelvic Index; DTI = Dactyl Thoracic Index;
Ns = non-significant (P>0.05); *** = P<0.001; ** = P<0.01; * = P<0.05.

4. Conclusion and Recommendation

The observed variation in structural indices among indigenous goats across the study locations indicates the existence of exploitable phenotypic diversity that could serve as a basis for within-breed selection and genetic improvement programs. The structural indices further suggest that the goat population possesses characteristics of a dual-purpose production type, with a tendency toward dairy aptitude. The body conformation profile of these goats, particularly the lower wither height relative to rump height, provides valuable information for designing appropriate management and breeding strategies. The significant associations between most conformation traits, structural indices, and body weight demonstrate the practical utility of these measurements as selection criteria for improving productivity in situations where direct weight measurement is difficult. Therefore, conformation traits and structural indices can serve as useful tools for the characterization, selection, and sustainable improvement of indigenous goat populations in the study area. Finally, focused genetic evaluation supported by a community-level recording system would enable accurate assessment of goat genetic potential, thereby supporting sustainable breeding practices, improving the utilization of indigenous genetic resources, and contributing to long-term conservation of locally adapted goat populations.

Conflicts of interest

The authors declared that there is no conflict of interest.

References

Alderson, G.L.H. (1999). The development of a system of linear measurements to provide an assessment of type and function of beef cattle. Animal Genetic Resources Information, 25, 45–55.

American Dairy Goat Association (ADGA). (2014). Linear Appraisal System / Dairy Goat Scorecard and Breed Standards. Spindale, NC, USA: ADGA.

Amsale, H., Tariku, W., and Sandip, B. (2020). Morphometrical characterization and structural indices of indigenous goats reared in two production systems in Sidama Zone, Southern Ethiopia. International Journal of Animal Science and Technology, 4 (1): 6-16.

ASARC (Assosa Agriculture Research Center). 2011. Results of Farming System Survey Benshangul-Gumuz Regional State. Ethiopian Institute of Agricultural Research, Assosa.

Barragán, R.M. (2017). Zoometry: a useful tool for determining the productive aptitude of domestic ruminants. Journal of Dairy, Veterinary and Animal Research 5(3):86–87.

Bambasi District Administration Office. (2022). Annual report/administrative records of Bambasi District. Bambasi Woreda Administration, Benishangul-Gumuz Regional State, Ethiopia.

Bravo, S. and Sepúlveda, N. (2010). Zoometric indices in Araucanas Creole ewes. International Journal of Morphology 28(2): 489-95.

Cerqueira, J. O. L., Feás, X., Iglesias, A., Pacheco, L.F., Araújo, J.P.P., & Sánchez, L. (2011). Morphological traits and zoometric indices in Portuguese Serrana goats. Archivos de Zootecnia, 60(231), 635–638.

Chacón, E., Macedo, F., Velázquez, F., Rezende Paiva, S., Pineda, E., & McManus, C. (2011). Morphological measurements and body indices for Cuban Creole goats and their crossbreds. Revista Brasileira de Zootecnia, 40(8).

Chiemela, P., Sandip, B., Mestawet, T., Egbu, C., Ugbo, E., Akpolu, E., and Umanah I. (2016). Structural indices of Boer, Central highland and their F1 crossbred goats reared at ataye farm, Ethiopia. Journal of Agricultural and Research, 2 (2):1-19.

Cochran, W. (1977). Sampling Techniques (3rd edition). John Wiley and Sons. New York, Chichester, Brisbane, Toronto, Singapore.

Dauda, A. (2018). Morphological indices and stepwise regression for assessment of function and type of Uda sheep. J Res Rep Genet, 2 (3):1-4.

Dea, D., Melesse, A., and Mekasha, Y. (2019). Application of morphometric traits and body indices in assessing the type and function of local goats reared in two districts of Gamo-Gofa Zone, South Ethiopia. Ethiopian Journal of Animal Production 19(1): 73–90.

Food and Agriculture Organization of the United Nations (FAO). (2011). *Report of the Commission on Genetic Resources for Food and Agriculture: Thirteenth Regular Session, Rome, 18–22 July 2011*. Rome: FAO.

FAO. (2012). Phenotypic characterization of animal genetic resources. FAO Animal Production and Health Guidelines no 11, Rome, Italy.

Halima, H., Baum, M., Rischkowsky, B. and Tibbo, M. (2012). Phenotypic characterization of Ethiopian indigenous goat populations. African Journal of Biotechnology, 11(73), pp. 13838–13846.

Hankamo, A., Woldeyohannes, T., & Banerjee, S. (2020). Morphometrical characterization and structural indices of indigenous goats reared in two production systems in Sidama Zone, Southern Ethiopia. International Journal of Animal Science and Technology, 4(1), 6–16. https://doi.org/10.11648/j.ijast.20200401.12.

ICAR (International Committee for Animal Recording). (2017). Guidelines for conformation recording of dairy cattle, beef cattle and dairy goats: Section 5.

Josip, V., Zvonimir, P., Dubravka, Samarzija, I., Miljenko, K., Nikolina, K. (2020). Udder morphology, milk production and udder health in small ruminants. Mljekarstvo, 70 (2): 75-84.

Kassahun, A. and Solomon, A. (2008). Breeds of sheep and goats. In: Yami A. and Merkel R.C. (eds.), Sheep and Goat Production Handbook for Ethiopia. Ethiopia Sheep and Goat Productivity Improvement Program (ESGPIP), USAID, pp. 5–26.

Kefyalew, A., Damitie, K., and Endalkachew, G. (2015). Survival and population viability of Fogera cattle (Bos indicus, Zenga type) in North West Amhara, Ethiopia. Global Journal of Animal Breeding and Genetics, 3(6), pp. 181–187.

Khargharia, G., Kadirvel, G., Kumar, S., Doley, S., Bharti, P. and Das, M. (2015). Principal component analysis of morphological traits of Assam Hill Goat in Eastern Himalayan India. The Journal of Animal and Plant Sciences, 25 (5): 1251-1258.

Merkhan, K., and Alkass, J. (2011). Influence of udder and teat size on milk yield in Black and Meriz goats. Research Opinions in Animal and Veterinary Sciences,1 (9): 601-605.

Mezgebu, G., Mengistie, T., Damitie, K., and Dereje, A. (2022). Structural indices of indigenous goats reared under traditional management systems in East Gojjam Zone, Amhara Region, Ethiopia. Heliyon 8 (2022) e09180.

Mingoas, K.J.P., Awah-Ndukum, J., Dakyang, H., and Zoli, P.A. (2017). Effects of body conformation and udder morphology on milk yield of Zebu cows in North region of Cameroon. Veterinary World, 10(8), pp. 901–905.

Minister, B., Kefyalew, A. and Getinet, M. (2019). Morphological characterization of goat populations in Central Zone of Tigray, Ethiopia. Tropical Animal Science Journal, 42 (2):81-89.

Mwambene, P. L., Katule, A. M., Chenyambuga, S. W., & Mwakilembe, P. A. A. (2012). Fipa cattle in the southwestern highlands of Tanzania: Morphometric and physical characteristics. Animal Genetic Resources, 51, 15–29.

Olaniyi, T., Popoola, M., Olaniyi, O., Faniyi, T., and Inioboneg, U. (2018). Relationship between morphological traits, body indices and body condition score as welfare indicators of Nigerian Sheep. Journal of Animal Science and Veterinary Medicine, 3 (1):1-5.

Putra, W. and Ilham, F. (2019). Principal component analysis of body measurements and body indices and their correlation with body weight in Katjang does of Indonesia. Journal of dairy, veterinary and animal research, 8 (3): 124-134.

Salako, A.E. (2006). Application of morphological indices in the assessment of type and function in sheep. International Journal of Morphology, 24(1), pp. 13–18.

Sam I.M., Akpa G.N. and Alphonsus C. (2017). Factors influencing udder and milk yield characteristics of indigenous goats in North-West Nigeria. Asian Research Journal of Agriculture, 3(2), pp. 1–9.

Silva, J., Román፣ P., Durán, A., Vera, Á., Cambrón, S. and Andrade, M. (2019). Morphostructural characterization of the Black Creole goat raised in Central Mexico, a currently threatened zoogenetic resource. Animals, 9(7), 459.

Valencia-Posadas, M., Barboza-Corona, J.E., Ángel-Sahagún, C.A., Gutiérrez-Chávez, A.J., Martínez-Jaime, O.A., and Montaldo, H.H. (2017). Phenotypic correlations between milk production and conformation traits in goats. Acta Universitaria, 27(3), 3–8.

Zewdie, B., and Welday K. (2015). Reproductive performance and breeding strategies for genetic improvement of goats in Ethiopia: A review. Greener Journal of Agricultural Sciences, 5(1), pp. 23–33.