Heliyon 8 (2022) e09180

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Structural indices of indigenous goats reared under traditional management systems in East Gojjam Zone, Amhara Region, Ethiopia

Mezgebu Getaneh [a,b,*], Mengistie Taye [a,c], Damitie Kebede [a], Dereje Andualem [b]

[a] College of Agriculture and Environmental Sciences, Bahir Dar University, P.O. Box 5501, Bahir Dar, Ethiopia
[b] College of Agriculture and Natural Resource, Dilla University, P.O. Box 419, Dilla, Ethiopia
[c] Institute of Biotechnology, Bahir Dar University, P.O. Box 79, Bahir Dar, Ethiopia

ARTICLE INFO

Keywords:
East Gojjam zone
Goat types
Indigenous goats
Structural indices

ABSTRACT

In phenotypic characterization of animal genetic resources, structural indices are essential components to understand the breed structure and body proportions. They are the ethnological characteristics as well as functional traits of animals providing information about the type, aptitude, and production purpose of animals. This study intends to provide information on the structural indices of indigenous goats reared under the smallholder management systems in selected districts of East Gojjam Zone, Amhara region, Ethiopia. Data on body weight and nine morphometric measurements were collected from 706 goats (589 does and 117 bucks) selected using their dentition (≥ One Pair of Permanent Incisor), physiological status (lactating females and intact males), and health condition (healthy). Nineteen structural indices were calculated from morphometric measurements and analyzed using the general linear model (GLM) procedure of the statistical analysis system (SAS, 9.0). Data were analyzed for does and bucks separately. Location had a significant ($p < 0.05$) influence on pelvic index, transversal and longitudinal pelvic indices, dactyl thoracic index, and relative cannon thickness index of bucks. Except for height slope, pelvic index, baron and crevat, body ratio, areal index, over increase index, weight-1, and weight-2, all other structural indices calculated for does were significantly ($p < 0.05$) influenced by location. Strong correlations were observed between the structural indices calculated from the linear body measurements. The study revealed that goats in the study area are longilinear and light animals that have dairy biotype. However, further studies are needed to classify the goat types for their production purposes.

1. Introduction

Structural indices, expressed as percentage, are the combined results of two or more morphometric measurements and indicate the type and function of the animal (Chiemela et al., 2016). Form meat production viewpoint, desirable body conformation is a complex character that little progress has been made to reduce it to a single corporal measurement taken on the live animal (Salako, 2006; Putra and Ilham, 2019). Structural indices calculated from different body measurements are objective assessments of body conformation from a type standpoint and may be relatively easier (Mwacharo et al., 2006). Structural indices are helpful to estimate the animal's conformation accurately and assess the animal's type, weight, and function better than do individual morphological measurements alone (Salako, 2006; Putra and Ilham, 2019). Therefore, this in turn enhances the ability of breeders to select potential breeding stock (Salako, 2006). Besides, knowledge of structural indices is useful to evaluate animal performances due to their relation with production characteristics (Mohammed and Amin, 1997). Thus, though conformation is related to performance, selection should be directed to maintain breed characteristics attained through natural selection. This is because, like performance traits, conformation traits are heritable and influenced by both genetic and environmental factors (Chacón et al., 2011).

Using structural indices to evaluate body conformation and assess animals' weight, type, and function is superior to individual morphometric measurements. Classfying animal breeds based on a single morphometric measurement is misleading. This is because large skeletal structure alone does not ensure a higher body weight (Salako, 2006). Structural indices incorporate the measure of desirable conformation, length, and balance, and hence, provide tested empirical alternative to the limited use of single measurements for the assessment of type, weight, and function (Chacón et al., 2011). Moreover, it assists in the selection of young animals as the values do not correlate with age

* Corresponding author.
E-mail address: getanehmezgebu11@gmail.com (M. Getaneh).

https://doi.org/10.1016/j.heliyon.2022.e09180
Received 8 October 2021; Received in revised form 25 November 2021; Accepted 17 March 2022

(Banerjee, 2016). Despite all these benefits, studies on structural indices of goats in Ethiopia are very scanty except some by Chiemela et al. (2016) for Boer, Central highland, and their F1 crossbred goats in South Wollo Zone, Dea et al. (2019) for local goats in Gamo Gofa Zone, and Hankamo et al. (2020) for local goats in Sidama Zone. Thus, this study was aimed to assess the structural indices and identify the type of indigenous goats reared under the extensive management systems of East Gojjam Zone, Amhara Region, Ethiopia.

2. Materials and methods

2.1. Description of the study areas

The study was conducted in three adjacent districts (Bibugn, Goncha Siso Enesie (GSE), and Hulet Eju Enesie (HEE) districts) of East Gojjam Zone, Amhara region, Ethiopia (Figure 1). The districts were selected purposively based on accessibility, the potential for indigenous goats, inclusiveness of all agro-ecologies, farmers' participation in goat production, and the economic contribution of goats in the household income. The geographical location and climate condition of the study districts are presented in Table 1.

2.2. Description of study animals and management

This study was based on morphological measurements of local goats reared under the traditional management systems in East Gojjam Zone of Amhara Region, Ethiopia. In the area, goats were herded and allowed to freely browse/graze on hillside browsing, and natural pasture in the daytime, had access to water twice a day, and had a nighttime shelter built using iron sheet and wood. Goats were supplemented with homemade grains, local brewery by-products, and salt during times of feed shortage. Annual vaccines were given as per the schedule of office of Agriculture, while treatments were given as the animal gets sick. Goat keepers use visual appraisal to select breeding flock, and breeding is through natural uncontrolled mating. Figure 2 shows a picture of a typical breeding doe and buck in the area.

Table 1. The geographical location, elevation, and climate condition of the study districts.

Descriptors	Districts		
	Bibugn	GSE	HEE
Geographical location			
Latitude	11°00′N to 12°24′N	10°27′36″ to 11°53′52″N	10°45′00″ to 11°10′00″N
Longitude	34°70′E to 37°35′E	37°12′56″ to 38°43′45″E	37°45′69″ to 38°10′00″E
Altitude (m.a.s.l)	1480–4160	1000–3400	1290–4036
Mean annual T° (°C)	16	15	18.5
Mean annual rainfall (mm)	1500	1000	1100

Sources: Districts' Agriculture Development Offices (2019).
GSE = Goncha Siso Enesie, HEE = Hulet Eju Enesie.

2.3. Sampling technique and sample size determination

A purposive multi-stage sampling technique was used to identify the sample sites. Based on information collected through preliminary field survey and discussions conducted with district's agricultural development bureau experts, peasant associations (PAs) development agents, and farmers living in the respective PAs hierarchically, three districts and nine PAs (three from each district) were selected. Selection criteria like agro-ecology, accessibility, the potential of the goat population, and the relative economic contribution of goats for the household's income in the areas were considered.

Animal care and all trait measurement procedures were complied with Federation of Animal Science Societies (2010) and were approved by Dilla University Agricultural Productivity, Food Security, and Livelihood Research team. Data on morphological characteristics of goats were collected from 706 goats (589 does and 117 bucks) randomly selected from the flock. The goats considered were with dentition ≥1PPI, healthy, lactating females, and intact males (Table 2). Sample goats were taken proportionally from each sampling PAs based on the goat population size

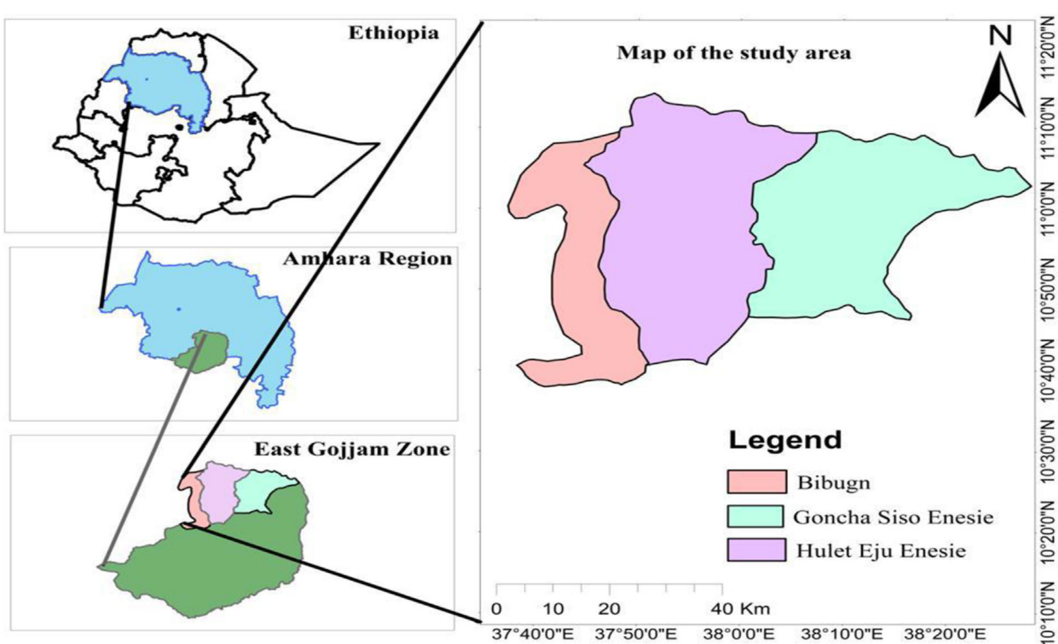

Figure 1. Map of the study areas.

Figure 2. A picture of a doe with her twin kids (left), and buck (right) in East Gojjam Zone. (Photo courtesy: Mezgebu Getaneh).

Table 2. Summary of the total number of sample PAs, and goats by districts.

District	No of PAs	Number of goats sampled		
		Does	Bucks	Total
Bibugn	3	110	39	149
HEE	3	242	39	281
GSE	3	237	39	276
Total	9	589	117	706

PAs = Peasant Associations, No = Number, HEE = Hulet Eju Enesie, GSE = Goncha Siso Enesie.

after the total sample size is determined using Cochran (1977) formula suggested by FAO (2012).

The formula used to determine the sample goat population to study the structural indices was:

$$n = \left(\frac{z}{m}\right)^2 p(1-p); \text{ then corrected } n' \text{ was calculated as } n' = \frac{n}{1+\frac{n}{N}};$$

Where;

n = required sample size
z = z value at a given percent confidence level
m = error margin (for this study 0.06 was considered)
P = estimated % of the sample that will respond a given way to a survey question
n' = corrected sample size
N = total population size

2.4. Data collection and analysis

Morphological measurements on hip height, wither height, body length, paunch girth, heart girth, rump width, rump length, cannon bone perimeter, chest width, and body weight were taken following the anatomical points and procedures specified by ICAR (2017) and FAO (2012) (Figure 3). Textile measuring tape was used to measure morphological traits, and live body weight was measured using weight

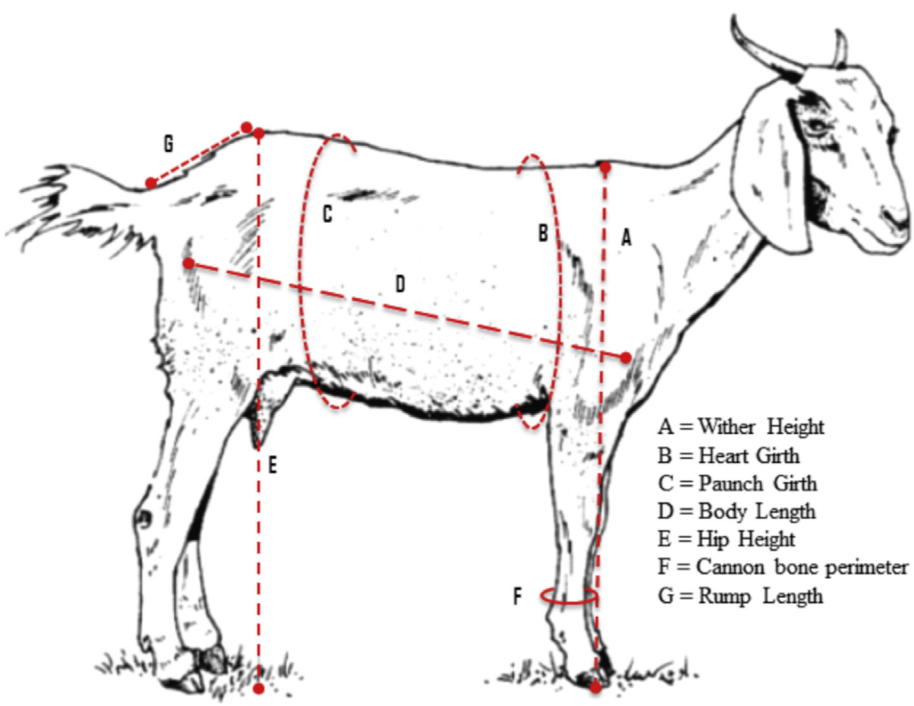

Figure 3. Presentations of the anatomical points to measure morphological traits. A = Wither Height; B = Heart Girth; C = Paunch Girth; D = Body Length; E = Hip height; F = Cannon circumference; G = Rump Length.

Table 3. List of the structural/functional indices and calculation formulas used to generate them.

Structural Indices	Calculation Formulas	The implication of the indices	References
Height slope (HS)	Hip height - Wither height		(Khargharia et al., 2015)
Length index/Relative body index (LI)	(Body length x 100)/Wither height		(Chiemela et al., 2016)
Girth index (GI)	Paunch girth/Heart girth		(Khargharia et al., 2015)
Body index (BI)	(Body length/Heart girth) x 100	>0.90, the animal is longiline; between 0.86 to 0.88 is medigline; and <0.85, it is brevigline	(Dauda, 2018)
Proportionality (IPr)	(Wither height/Body length) x 100		
Pelvic index (PI)	(Rump width/Rump length) x 100		
Transverse pelvic (IPT)	(Rump width/Hip height) x 100		
Longitudinal pelvic (IPL)	(Rump length/Hip height) x 100		(Khargharia et al., 2015)
Dactyl thorax index (DTI)	(Cannon circumference/Heart girth) x 100	The DTI may not be more than 10.5 in light animals, up to 10.8 in an intermediary, up to 11.0 in light meat animals, and up to 11.5 in heavy meat type.	
Thoracic development (TD	Heart girth/Wither height	This indicates thoracic development of animals, with values above 1.2 indicating animals with good TD.	(Dauda, 2018)
Body ratio (BR)	Wither height/Hip height	If the withers are lower than the rump, the animal is low in front and vice versa	(Chiemela et al., 2016)
Baron & crevat/Conformation index (BC)	$(\text{Heart girth})^2$/Wither height	Should be close to 2.1 the bigger the index, the closer the animal is to the traction type; the smaller this index, the weaker the animal will be	(Dauda, 2018)
Compact index 1 (CI1)	(Weight/Wither height)/100	The compact index indicates how compact the animal is. Meat-type animals have values above 3.15. A value close to 2.75 indicates the dual purpose, and close to 2.60 indicates that the animals are more suitable for milk purpose	(Dauda, 2018)
Area index (AI)	Wither height x Body length		
Relative cannon thickness index (RCTI)	(Cannon circumference/Wither height)100		(Khargharia et al., 2015)
Weight-1(W1)	(0.5 × Heart girth) – 14.87		(Chiemela et al., 2016)
Weight-2 (W2)	(0.63 × Heart girth) – 19.5		
Over increase index (OII)	Hip height/Wither height x 100		(Hankamo et al., 2020)
Width slope (WS)	Rump width/Chest width		(Chiemela et al., 2016)

balance having 120 kg capacity and 0.2 kg precision. Then, the structural indices were calculated from morphometric measurements based on indices calculation formulas previously used (Table 3) to assess the type and function of indigenous goats (Khargharia et al., 2015; Chiemela et al., 2016; Dauda, 2018; Hankamo et al., 2020).

The data generated through the calculation of structural indices followed a normal distribution. The structural indices were analyzed using the General Linear Model (GLM) procedures of the Statistical Analysis System (SAS, 9.0) (SAS, 2003) for does and bucks separately. Location of goats was considered as a fixed factor, whereas structural indices were considered as dependent variables. Correlation among the indices was computed for each sex. The significance of the effect of the independent variable on the dependent variables was checked by Analysis of Variance (ANOVA), and if significance is declared, means were separated using Duncan multiple range mean separation method. The statistical model used to analyze the structural indices was:

$$Y_i = \mu + L_i + e_i;$$

Where;

Y_i = the recorded structural indices, μ = overall mean, L_i = effect of the i^{th} location (i = Bibugn, GSE, and HEE), e_i = random error term associated with each observation

3. Results and discussion

3.1. Structural indices of does and bucks

The results about structural and functional indices for does, and bucks in the study areas are presented in Table 4 and Table 5, respectively. Location had a significant ($P < 0.05$) influence on length index, girth index, body index, proportionality index, thoracic pelvic index, longitudinal pelvic index, dactyl thoracic index, thoracic development, cannon thickness index, compact index 1, and width slope of does. However, height slope, pelvic index, body ratio, baron and crevat, weight-1, weight-2, areal index, and over increase index of does were not significantly ($P > 0.05$) affected by location. Does in Bibugn district recorded the highest proportionality index, longitudinal pelvic index, dactyl thoracic index, and width slope than does in GSE and HEE districts. Conversely, the highest value of compact index 1 was recorded for does in HEE district than does in Bibugn and GSE. For bucks, proportionality index, transverse and longitudinal pelvic indices, dactyl thoracic index, relative cannon thickness index, and width slope were significantly ($P < 0.05$) influenced by location. The highest width slope was recorded for bucks in Bibugn, while the smallest dactyl thoracic index was recorded for bucks in GSE. In line with this, Dea et al. (2019) and Hankamo et al. (2020) reported the significant influence of location on structural and functional indices of local goats reared in Gamo Gofa and Sidama Zones.

The length indices (LI) in the current study were 96.60 ± 5.72 and 92.90 ± 4.86 for does and bucks, respectively. The length index of does was almost similar with Boer*Central Highland crossbred does (0.97 ± 0.01) and bucks (0.96 ± 0.01) (Chiemela et al., 2016), local does in Mirab-Abaya district (0.97) (Dea et al., 2019), and local does in Aroresa (0.99 ± 0.00) district (Hankamo et al., 2020). However, it was slightly lower than Cuban Creole goats (1.07 ± 0.45) and their cross (1.05 ± 0.50) (Chacón et al., 2011), local does in Arbaminch Zuria (1.03) (Dea et al., 2019), and Katjang does in Indonesia (1.07 ± 0.09) (Putra and Ilham, 2019). This indicated that goats understudy are shorter bodied than the aforementioned goat types. Chiemela et al. (2016) also reported a higher length index for Boer does (1.01 ± 0.02), but a lower length index for Central Highland does (0.93 ± 0.01), which was almost similar to the length index of bucks in the current study.

Table 4. Structural indices for indigenous does (≥1PPI) reared under the traditional management systems in East Gojjam Zone, Amhara Region, Ethiopia.

Indices	Bibugn (N = 110)	GSE (N = 237)	HEE (N = 242)	Overall (N = 589)	CV	P-value
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD		
HS	2.88 ± 1.51	2.70 ± 1.50	2.77 ± 1.47	2.76 ± 1.49	53.92	Ns
RBI/LI	94.85 ± 5.74^{b}	96.42 ± 5.26^{a}	97.58 ± 5.95^{a}	96.60 ± 5.72	5.84	***
GI	1.10 ± 0.05^{a}	1.08 ± 0.05^{b}	1.10 ± 0.06^{a}	1.09 ± 0.05	4.75	***
BI	88.48 ± 5.12^{b}	90.38 ± 4.71^{a}	90.22 ± 5.39^{a}	89.96 ± 5.12	5.64	**
IPr	105.8 ± 6.49^{a}	104.0 ± 5.69^{b}	102.8 ± 6.28^{b}	103.8 ± 6.17	5.86	***
PI	74.91 ± 8.64	76.43 ± 7.99	76.00 ± 8.30	75.97 ± 8.25	10.85	Ns
IPT	19.99 ± 1.59^{a}	19.76 ± 1.42^{ab}	19.42 ± 1.79^{b}	19.66 ± 1.62	8.20	**
IPL	26.87 ± 2.37^{a}	26.01 ± 2.07^{b}	25.69 ± 2.08^{b}	26.04 ± 2.17	8.19	***
DTI	10.54 ± 0.61^{a}	10.25 ± 0.74^{b}	10.31 ± 0.76^{b}	10.33 ± 0.73	7.02	**
TD	1.07 ± 0.06^{ab}	1.07 ± 0.05^{b}	1.08 ± 0.06^{a}	1.08 ± 0.06	5.33	*
BR	0.96 ± 0.02	0.96 ± 0.02	0.96 ± 0.02	0.96 ± 0.02	2.14	Ns
BC	81.04 ± 10.05	79.05 ± 8.54	80.90 ± 9.43	80.18 ± 9.24	11.48	Ns
RCTI	11.29 ± 0.52^{a}	10.93 ± 0.75^{b}	11.16 ± 0.84^{a}	11.09 ± 0.76	6.79	***
W1	22.77 ± 2.82	22.05 ± 2.45	22.38 ± 2.73	22.32 ± 2.65	11.82	Ns
W2	27.92 ± 3.55	27.02 ± 3.08	27.43 ± 3.44	27.36 ± 3.33	12.15	Ns
CI1	0.005 ± 0.00^{b}	0.004 ± 0.00^{b}	0.005 ± 0.00^{a}	0.005 ± 0.00	15.27	***
AI	4674 ± 538	4620 ± 493	4626 ± 522	4633 ± 513	11.10	Ns
WS	1.11 ± 0.12^{a}	1.05 ± 0.11^{b}	1.01 ± 0.12^{c}	1.05 ± 0.12	11.21	***
OII	104.1 ± 2.23	103.9 ± 2.25	104.0 ± 2.24	104.0 ± 2.24	2.16	Ns

a, b, c = means on the same row with different superscripts are significantly different (P < 0.05); GSE = Goncha Siso Enesie; HEE = Hulet Eju Enesie; HS = Height Slope; LI = Length Index; GI = Girth Index; BI = Body Index; IPr = Proportionality Index; PI = Pelvic Index; IPT = Transverse Pelvic Index; IPL = Longitudinal Pelvic Index; DTI = Dactyl Thoracic Index; TD = Thoracic Development; BR = Body Ratio; BC = Baron and Crevat; RCTI = Relative Cannon Thickness Index; W1 = Weight-1; 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; * = P ≤ 0.05.

Table 5. Structural indices for indigenous bucks (≥1PPI) reared under the traditional management systems in East Gojjam Zone, Amhara Region, Ethiopia.

Indices	Bibugn (N = 39)	GSE (N = 39)	HEE (N = 39)	Overall (N = 117)	CV	P-value
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD		
HS	2.69 ± 1.20	2.95 ± 1.34	2.72 ± 1.12	2.79 ± 1.22	43.84	Ns
RBI	92.41 ± 4.86	93.47 ± 5.67	92.81 ± 3.97	92.90 ± 4.86	5.25	Ns
GI	1.07 ± 0.03	1.07 ± 0.05	1.07 ± 0.03	1.07 ± 0.04	3.58	Ns
BI	90.16 ± 4.47	90.41 ± 5.07	90.75 ± 5.26	90.44 ± 4.91	5.47	Ns
IPr	108.5 ± 5.70	107.3 ± 6.45	107.9 ± 4.76	107.9 ± 5.65	5.26	Ns
PI	68.53 ± 8.56^{b}	72.40 ± 7.23^{a}	68.02 ± 7.28^{b}	69.65 ± 7.90	11.08	*
IPT	19.10 ± 1.32^{a}	18.93 ± 1.11^{a}	18.20 ± 1.68^{b}	18.74 ± 1.43	7.42	*
IPL	28.12 ± 2.48^{a}	26.34 ± 2.37^{b}	26.90 ± 2.50^{b}	27.12 ± 2.54	9.03	*
DTI	12.10 ± 0.87^{a}	11.42 ± 0.71^{b}	12.13 ± 1.06^{a}	11.89 ± 0.94	7.50	***
TD	1.03 ± 0.04	1.03 ± 0.05	1.02 ± 0.06	1.03 ± 0.05	4.94	Ns
BR	0.96 ± 0.02	0.96 ± 0.02	0.96 ± 0.02	0.96 ± 0.02	1.85	Ns
BC	69.26 ± 6.59	69.66 ± 5.26	69.23 ± 8.93	69.38 ± 7.03	10.22	Ns
RCTI	12.40 ± 0.91^{a}	11.81 ± 0.75^{b}	12.40 ± 0.87^{a}	12.20 ± 0.88	6.93	**
W1	18.86 ± 2.45	18.78 ± 1.82	18.78 ± 2.76	18.81 ± 2.36	12.64	Ns
W2	23.00 ± 3.09	22.90 ± 2.29	22.90 ± 3.48	22.94 ± 2.97	13.06	Ns
CI1	0.004 ± 0.00	0.004 ± 0.00	0.004 ± 0.001	0.004 ± 0.001	13.20	Ns
AI	4009 ± 504	3983 ± 554	4007 ± 421	4000 ± 492	12.40	Ns
WS	1.04 ± 0.12^{a}	0.98 ± 0.09^{b}	0.94 ± 0.12^{b}	0.99 ± 0.11	10.80	***
OII	104.1 ± 1.94	104.5 ± 2.14	104.1 ± 1.70	104.2 ± 1.93	1.86	Ns

a, b, c = means on the same row with different superscripts are significantly different (P < 0.05); GSE = Goncha Siso Enesie; HEE = Hulet Eju Enesie; HS = Height Slope; LI = Length Index; GI = Girth Index; BI = Body Index; IPr = Proportionality Index; PI = Pelvic Index; IPT = Transverse Pelvic Index; IPL = Longitudinal Pelvic Index; DTI = Dactyl Thoracic Index; TD = Thoracic Development; BR = Body Ratio; BC = Baron and crevat; RCTI = Relative cannon thickness Index; W1 = Weight-1; 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; * = P ≤ 0.05.

The body index of goats shows the proportionality of the breed and allows to classify goats according to baronian systematics into brevilinear (≤85), mesolinear (>86 and <88), or longilinear (≥90) (Silva-Jarquin et al., 2019). The overall mean value obtained in the present study (89.96 ± 5.12 for does and 90.44 ± 4.91 for bucks) indicated that indigenous goats in the study areas have a longilinear profile that the transversal measures surpass over length measures. The overall mean body index of does in the current study was similar with Boer does (89.44 ± 1.81) reported by Chiemela et al. (2016). However, it was slightly higher as compared with local does (87.7 ± 0.28) in Gamo Gofa Zone (Dea et al., 2019), Central Highland (86.83 ± 0.65), and Boer 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 crossbred does (81.96 ± 4.49) (Chacón et al., 2011), and Katjang does (86.95 ± 5.4) in Indonesia (Putra and Ilham, 2019). On the contrary, it was slightly lower than the local does of age 1–2 years (93.86 ± 0.35; 92.05 ± 0.00) and age 3–4 years (94.7 ± 0.34; 94.13 ± 0.30) in Aroresa and Lokabaya districts, respectively (Hankamo et al., 2020). Similarly, the overall mean body index of bucks was almost similar to local bucks of age 3–4 years in Lokabaya (87.04 ± 2.16), but it was slightly lower as compared with local bucks of age 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 (Hankamo et al., 2020). However, it was higher than the value for Boer, and Central Highland crossed bucks (83.96 ± 1.40) at the age of 2 years in South Wollo Zone (Chiemela et al., 2016). These variations may be due to age composition, breed type, and differences in the management conditions of goats in different areas.

The proportionality index tells about the shape of the animal (Silva-Jarquin et al., 2019) by relating the body height to the body length (Barragán, 2017). Proportionality value of <100 (predominance of the body length on body height) indicates that the body tends to be rectangular, which is a characteristic of meat-type breeds, but the value > 100 suggests that the form of the animal tends to be square, characteristics of dairy breeds (Barragán, 2017; Silva-Jarquin et al., 2019). The overall mean proportionality indices observed for both does (103.88 ± 6.17) and bucks (107.94 ± 5.65) in the current study were greater than 100, which indicates that indigenous goats in the study areas have dairy characteristics. A similar result was recorded for local goats in Mirab-Abaya district (IPr = 103); however, it is larger than the values reported for local goats in Arbaminch Zuria (IPr = 97) that possess dairy and meat characteristics, respectively (Dea et al., 2019).

The pelvic index determines the proportionality of the hindquarters hence related to reproductive fitness (Silva-Jarquin et al., 2019) and meat production ability of goats (Dauda, 2018). The overall mean pelvic indices of does (75.97 ± 8.25) and bucks (69.65 ± 7.90) in the present study indicated that goats in the study areas have a convex curve with a predominance of rump length over the width or disproportionality of the hindquarter (Silva-Jarquin et al., 2019). This, in turn, results in reproduction difficulties of does. The pelvic indices value of both does and bucks in the present study were lower than the value reported for Boer (1.93 ± 0.05), Boer crossed Central Highland (2.01 ± 0.02), and Central Highland (1.84 ± 0.01) does in South Wollo (Chiemela et al., 2016), Cuban Creole does (76.00 ± 3.50) and Cuban Creole Crossbred does (78.62 ± 7.54) (Chacón et al., 2011), and local does (93.0 ± 11.3) in Gamo Gofa Zone (Dea et al., 2019).

The transverse pelvic and longitudinal pelvic indices are functional indices used to estimate the meat aptitude of the animal by relating the width and length of the rump to the wither height, respectively (Barragán, 2017). Silva-Jarquin et al. (2019) also stated that transverse pelvic and longitudinal pelvic indices are an estimator for the meat suitability of the breed, i.e. a transverse pelvic index greater than 33 and longitudinal pelvic index less than 37 are indicators for meat-type breeds. The transverse pelvic and longitudinal pelvic indices values for does (19.66 ± 1.62 and 26.04 ± 2.17) and bucks (18.74 ± 1.43 and 27.12 ± 2.54) in the present study were below the ranges noted by (Silva-Jarquin et al., 2019). The longitudinal pelvic index of both sexes in the current study were slightly similar with local goats (27.9 ± 2.05) in Gamo Gofa (Dea et al., 2019), Black Creole goats (26.87 ± 2.80) (Silva-Jarquin et al., 2019), and Cuban Creole Crossed does (27.97 ± 2.71) reported by (Chacón et al., 2011). Chiemela et al. (2016) reported slightly higher transverse pelvic index and lower longitudinal pelvic index 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 and bucks, respectively, than the current findings. Higher transverse pelvic index were also recorded for local goats (26.1 ± 1.20) in Gamo Gofa (Dea et al., 2019) and Black Creole goats (22.30 ± 1.89) (Silva-Jarquin et al., 2019). This variation may be ascribed by the age of the examined goats, environmental factors, and differences in breed type and function of the examined goats reared under different production systems.

The dactyl thoracic index indicates the format or shape of the animal by creating relationships between the pectoral mass and limbs. It is highly associated with dairy characteristics. 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), in dairy (<10) and meat (>11) animals (Barragán, 2017). In the present study, the overall dactyl thoracic index values of does and bucks were 10.33 ± 0.73 and 11.89 ± 0.94, respectively. These values indicated that does can be grouped udder light animals (<10.5) with dairy biotype, whereas bucks can be grouped under heavy meat-type animals (>11.5). Chacón et al. (2011) noted that dactyl thoracic index is greater in meat-than milk-type animals that an increment in cannon bone perimeter assumes an increase in body size. The variation between the two sexes may be due to sexual dimorphism. 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 Crossbred does (9.15 ± 0.69) (Chacón et al., 2011) and lower than Boer (11.94 ± 0.33), and Boer and Central Highland Crossed does (11.19 ± 0.19) reared in South Wollo (Chiemela et al., 2016). Similarly, the recorded value for bucks was slightly lower than Boer bucks (12.84 ± 0.42), but somewhat higher than Boer Crossed Central Highland bucks (11.24 ± 0.21) in South Wollo reported by Chiemela et al. (2016).

Thoracic development is an essential indicator of good fitness and the respiratory system, especially for breeds that adapt higher altitudes (Khargharia et al., 2015). The value above 1.2 is an indicator of good thoracic development. The overall thoracic development values for does (1.08 ± 0.06) and bucks (1.03 ± 0.05) obtained in the current study was lower than the recommended level (1.2) (Dauda, 2018). This indicates that goats in the study area have poor thoracic capacity, an indication of thin and tall animals that may not be effectively survived in the highland areas. The observed value for does was consistent with Central Highland does (1.08 ± 0.01) in South Wollo reported by Chiemela et al. (2016). But, values from both sexes were lower than Assam Hill Goat (1.32 ± 0.02) in India (Khargharia et al., 2015), local goats (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) does of age 2 years in South Wollo (Chiemela et al., 2016).

The baron and crevat or conformation index is an indicator of the overall body shape of the animal. The greater the baron and crevat index is the more vigorous the breed (Dea et al., 2019). The conformation index value of does (80.18 ± 9.24) in the present study was higher than reported values for 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 (69.38 ± 7.03) was consistent with the report of Chiemela et al. (2016) for Boer goats 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 Crossbred (105.37 ±

10.15) does reported by Chacón et al. (2011). The result pertaining to body ratio indicated that both does and bucks had similar values (0.96 ± 0.02), and both sexes are slightly lower at the whither than the rump, which is supported by the height slope. The present value was consistent with local does (0.96 ± 0.00) in Sidama (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, Chacón et al. (2011) reported a higher body ratio for Cuban Creole (0.97 ± 0.01) and Cuban Creole Crossbred (0.97 ± 0.04) does than the present findings.

The relative cannon thickness index shows the relationship between the cannon bone perimeter and the height of the animal and is considered as a good indicator of breed type (higher in meat than dairy biotypes) (Barragán, 2017) and animal balance (Dauda, 2018). The present result showed that the relative cannon thickness index of does (11.09 ± 0.76) was slightly lower than bucks (12.20 ± 0.88). This indicated that bucks have good muscling ability than does and can be confirmed by the higher dactyl thoracic index value of bucks in this study. Moreover, bucks are better balanced than does, enabling them to resist long hard walks and reduce susceptibility to joint problems in the anterior and posterior limbs (Dauda, 2018). Khargharia et al. (2015) and Putra and Ilham (2019) reported a slightly higher relative cannon thickness index for Assam Hill Goat (12.95 ± 0.14) in India, and Katjang does (12.64 ± 1.08) in Indonesia, respectively, than the present findings for both sexes. This implies that compared to the aforementioned goat types, goats under-study have lower muscling aptitudes.

The body weight of both sexes were estimated from conformation traits using two different formulas and two different weights (weight-1 and weight-2) were obtained. From the estimated weight values, the overall weight-2 (W2) values of does (27.36 ± 3.33) and bucks (22.94 ± 2.97) were slightly similar to the actual overall mean weight of does (32.07 ± 5.79) and bucks (25.84 ± 4.01) (Getaneh, 2020). This shows the possibility of weight estimation from conformation measurements using different formulas. Accordingly, for the current observation, weight-2 was a better estimate of live weight.

Indices are often considered a superior option for the assessment of weight since they incorporate measures of desirable conformation (mainly length and balance) (Chacón et al., 2011; Dauda, 2018). The compact index 1 values for both does (0.005 ± 0.00) and bucks (0.004 ± 0.001) were very far below 2.60; compact index value indicates dairy aptitude (Dauda, 2018). Similarly, Dauda (2018) reported a very low compact index value for Uda sheep (0.01). Conversely, 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 these goats are labelled as meat-type.

The width slope is an essential parameter for estimating balance and assessing the breed's function (Dauda, 2018). The overall mean width slope values for does and bucks were 1.05 ± 0.12 and 0.99 ± 0.11, 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). Khargharia et al. (2015) also reported a lower width slope for Assam Hill goat (0.84 ± 0.02) from India. The areal index of both does, and bucks were higher than the areal index of 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 a larger body surface area relative to their body mass, enabling them to withstand heat stress to effectively dissipate excess heat from their body surface (Dea et al., 2019). These variations between goat types are explained by the type and function of goats, environmental factors, and management conditions employed for goats in different production environments.

The over increased index values of does (104.03 ± 2.24) and bucks (104.28 ± 1.93) showed that both sexes are slightly lower at the whither than the rump. 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 lower at the front than the hind part are prone to dust infestations (Hankamo et al., 2020). The over increased index values observed in the current study were almost similar to the report for local

Table 6. Pearson correlations coefficients between structural indices of indigeneous does and bucks reared under the traditional management systems in East Gojjam Zone, Amhara Region, Ethiopia.

Indices	HS	LI	GI	BI	IPr	PI	IPT	IPL	DTI	TD	BR	BC	RCTI	W1	W2	CI1	AI	WS	OII
HS		0.26**	0.06^{Ns}	0.02^{Ns}	-0.25*	0.00^{Ns}	-0.15^{Ns}	-0.13^{Ns}	0.02^{Ns}	0.25*	-0.99***	0.18*	0.19*	0.09^{Ns}	0.09^{Ns}	0.01^{Ns}	0.02^{Ns}	0.04^{Ns}	0.99***
LI	0.12**		0.04^{Ns}	0.56***	-1.00***	-0.04^{Ns}	0.15^{Ns}	0.17^{Ns}	-0.12^{Ns}	0.44***	-0.30***	0.22*	0.17^{Ns}	0.01^{Ns}	0.01^{Ns}	0.23*	0.10^{Ns}	0.01^{Ns}	0.30***
GI	0.06^{Ns}	0.12**		-0.03^{Ns}	-0.05^{Ns}	0.09^{Ns}	0.03^{Ns}	-0.08^{Ns}	0.02^{Ns}	0.08^{Ns}	-0.08^{Ns}	-0.02^{Ns}	0.07^{Ns}	-0.09^{Ns}	-0.09^{Ns}	0.00^{Ns}	-0.15^{Ns}	0.07^{Ns}	0.07^{Ns}
BI	-0.04^{ns}	0.58***	0.07^{ns}		-0.58***	-0.05^{Ns}	-0.08^{Ns}	-0.02^{Ns}	0.28**	-0.50***	-0.02^{Ns}	-0.51***	-0.04^{Ns}	-0.39***	-0.39***	-0.05^{Ns}	0.19*	0.03^{Ns}	0.02^{Ns}
IPr	-0.11*	-1.00***	-0.12**	-0.58***		0.02^{Ns}	-0.16^{Ns}	-0.15^{Ns}	0.10^{Ns}	-0.42***	0.29**	-0.21*	-0.17^{Ns}	-0.01^{Ns}	-0.01^{Ns}	-0.24**	-0.11^{Ns}	-0.02^{Ns}	-0.30***
PI	-0.07^{Ns}	0.12**	-0.01^{Ns}	0.04^{Ns}	-0.13**		0.52***	-0.73***	-0.12^{Ns}	0.02^{Ns}	0.02^{Ns}	0.14^{Ns}	-0.12^{Ns}	0.19*	0.19*	-0.04^{Ns}	0.19*	0.37***	-0.02^{Ns}
IPT	-0.10*	0.22***	0.05^{Ns}	0.00^{Ns}	-0.22***	0.62***		0.20*	-0.12^{Ns}	0.25**	0.15^{Ns}	0.30***	0.04^{Ns}	0.27**	0.27**	0.09^{Ns}	0.17^{Ns}	0.67***	-0.15^{Ns}
IPL	-0.02^{Ns}	0.07^{Ns}	0.05^{Ns}	-0.04^{Ns}	-0.06^{Ns}	-0.65***	0.18***		0.04^{Ns}	0.19*	0.10^{Ns}	0.10^{Ns}	0.17^{Ns}	0.01^{Ns}	0.01^{Ns}	0.12^{Ns}	-0.07^{Ns}	0.09^{Ns}	-0.10^{Ns}
DTI	0.07^{Ns}	-0.10*	0.12**	0.28***	0.11**	-0.05^{Ns}	0.01^{Ns}	0.06^{Ns}		-0.43***	-0.05^{Ns}	-0.56***	0.79***	-0.53***	-0.53***	-0.06^{Ns}	-0.31***	-0.02^{Ns}	0.05^{Ns}
TD	0.17***	0.49***	0.06^{Ns}	-0.42***	-0.48***	0.10*	0.24***	0.12**	-0.41***		-0.29**	0.79***	0.22*	0.44***	0.44***	0.31***	-0.11^{Ns}	-0.02^{Ns}	0.29**
BR	-0.99***	-0.13***	-0.06^{Ns}	0.03^{Ns}	0.13**	0.07^{Ns}	0.08*	-0.01^{Ns}	-0.09*	-0.18***		-0.14^{Ns}	-0.25*	0.00^{Ns}	0.00^{Ns}	0.01^{Ns}	0.10^{Ns}	-0.02^{Ns}	-1.00***
BC	0.04^{Ns}	0.38***	0.05^{Ns}	-0.43***	-0.39***	0.15***	0.17***	-0.02^{Ns}	-0.47***	0.89***	-0.004^{Ns}		-0.08^{Ns}	0.90***	0.90***	0.37***	0.48***	0.11^{Ns}	0.14^{Ns}
RCTI	0.20***	0.27***	0.17***	-0.04^{Ns}	-0.26***	0.03^{Ns}	0.19***	0.15***	0.71***	0.35***	-0.23***	0.21***		-0.27**	-0.27**	0.14^{Ns}	-0.40***	-0.03^{Ns}	0.25**
W1	-0.06^{Ns}	0.26***	0.03^{Ns}	-0.37***	-0.26***	0.16***	0.09*	-0.12**	-0.44***	0.69***	0.13**	0.94***	0.07^{Ns}		1.00***	0.30***	0.78***	0.18*	-0.01^{Ns}
W2	-0.06^{Ns}	0.26***	0.03^{Ns}	-0.37***	-0.26***	0.16***	0.09*	-0.12**	-0.44***	0.69***	0.12**	0.94***	0.07^{ns}	1.00***		0.30***	0.78***	0.18*	-0.01^{Ns}
CI1	0.02^{Ns}	0.45***	0.23***	-0.12**	-0.45***	0.11**	0.07^{Ns}	-0.07^{Ns}	-0.29***	0.63***	0.02^{Ns}	0.75***	0.19***	0.73***	0.73***		0.19*	-0.07^{Ns}	-0.01^{Ns}
AI	-0.18***	0.40***	0.05^{Ns}	0.25***	-0.40***	0.19***	0.00^{Ns}	-0.23***	-0.22***	0.18**	0.26***	0.54***	-0.09*	0.75***	0.75***	0.57***		0.23*	-0.11^{ns}
WS	0.02^{Ns}	-0.01^{Ns}	-0.03^{Ns}	0.06^{Ns}	0.00^{ns}	0.41***	0.61***	0.07^{ns}	0.04^{Ns}	-0.08^{Ns}	-0.01^{Ns}	0.01^{Ns}	-0.02^{Ns}	0.07^{Ns}	0.07^{Ns}	-0.07^{Ns}	0.16***		0.01^{Ns}
OII	0.99***	0.13**	0.06^{Ns}	-0.03^{Ns}	-0.13**	-0.07^{Ns}	-0.08^{Ns}	-0.01^{Ns}	0.09*	0.18***	-1.00***	0.00^{Ns}	0.23***	-0.13**	-0.13**	0.02^{Ns}	-0.26***	-0.01^{Ns}	

Note: The values in the lower diagonal indicate the values for does while in the upper diagonal the values for bucks. HS = Height Slope; LI = Length Index; GI = Girth Index; BI = Body Index; IPr = Proportionality Index; PI = Pelvic Index; IPT = Transverse Pelvic Index; IPL = Longitudinal Pelvic Index; DTI = Dactyl Thoracic Index; TD = Thoracic Development; BR = Body Ratio; BC = Baron and Crevat; RCTI = Relative Cannon Thickness Index; W1 = Weight-1; W2 = Weight-2; CI1 Compact Index 1; AI = Areal Index; WS = Width slope; OII = Over Increase Index; Ns = Non-significant ($P > 0.05$); *** = $P \leq 0.001$; ** = $P \leq 0.01$; * = $P \leq 0.05$.

goats of age 1–2 years in the Aroresa and Lokabaya districts (Hankamo et al., 2020). But, height slope values of does (2.76 ± 1.49) and bucks (2.79 ± 1.22) observed in the current study were lower than Assam Hill Goats (3.43 ± 0.29) from India (Khargharia et al., 2015).

3.2. Correlation between structural indices of does and bucks

The correlation values are indicative of the traits which can be improved through selection and how different traits are influenced to each other (Banerjee, 2016). Moreover, the study of the correlation between traits indicates the genetic difference between populations within a breed (Birteeb et al., 2012). In the present study, strong and positive correlations ($P < 0.001$) were observed between thoracic development and baron crevat index ($r = 0.89$ for does; $r = 0.79$ for bucks), relative cannon thickness index and dactyl thoracic index ($r = 0.71$ for does; $r = 0.79$ for bucks), areal index and weight-1 and weight-2 ($r = 0.75$ for does; $r = 0.78$ for bucks), baron crevat and weight-1 and weight-2 ($r = 0.94$ for does; $r = 0.90$ for bucks), and over increase index and height slope ($r = 0.99$, for both sexes) in both sexes (Table 6). These strong and positive correlations between those traits may be due to their calculation from similar morphometric measurements. Similar with this, Chacón et al. (2011) and Chiemela et al. (2016), observed a strong and positive correlation between structural indices based on the same morphometric measurement for Cuban Creole and their crossbred goats, and Boer, Central highland and Boer*Central Highland goats. The present findings are also similar to the report of (Salako, 2006), who observed higher and positive correlation between structural indices of Yankasa and WAD sheep breeds.

In addition, in does, significant ($P < 0.001$), strong and positive correlations were observed between weight-1 and weight-2 with thoracic development ($r = 0.69$), compact index 1 and thoracic development ($r = 0.63$), compact index 1 and baron and crevat index ($r = 0.75$), transverse pelvic index and pelvic index ($r = 0.62$), width slope and transverse pelvic index ($r = 0.61$), and compact index1 with weight-1 and weight-2 ($r = 0.73$) (Table 6). Body index and length index ($r = 0.58$), areal index and baron and crevat index ($r = 0.54$) and compact index1 ($r = 0.57$) in does and body index and length index ($r = 0.56$) and pelvic index and transverse pelvic index ($r = 0.52$) in bucks were showed medium and positive correlations ($P < 0.001$). In both sexes, weight-1 and weight-2 showed a perfect positive correlation (Table 6). The higher correlations between the structural indices of does may be due to higher correlations of morphometric traits used to calculate the indices beyond their calculation from similar morphometric measurements. These findings are similar to those of (Putra and Ilham, 2019), who observed higher correlation coefficient values between correlations of structural indices for Katjang does of Indonesia.

Conversely, proportionality index with length index, and over increase index with body ratio showed a perfect negative correlations ($P < 0.001$) in both sexes. Besides, strong and negative correlations ($P < 0.001$) were observed between longitudinal pelvic index and pelvic index ($r = -0.65$ for does;-0.73 for bucks) and body ratio and height slope ($r = -0.99$). Medium negative correlations ($P < 0.001$) were also observed between proportionality index and body index ($r = -0.58$) of both sexes and body index and thoracic development ($r = -0.50$), baron and crevat index ($r = -0.51$) of bucks. In bucks, baron and crevat, and weight-1 also showed a medium and negative correlation with dactyl thoracic index (Table 6). Similar to the present observations, negative correlations between structural indices of goats and sheep were reported in Ethiopia and elsewhere (Chacón et al., 2011; Banerjee, 2016; Chiemela et al., 2016; Putra and Ilham, 2019).

4. Conclusion

The structural indices indicated that indigenous goats in the study area are short-bodied, longilinear, curved, less compacted animals with poor thoracic development, and balanced light animals; and hence, have dairy biotype. However, the dactyl thoracic index and relative cannon thickness index showed that bucks have better muscling ability and possess meat aptitude. Thus, further studies are needed to classify the indigenous goat types into their production purpose and develop appropriate breeding programs.

Declarations

Author contribution statement

Mezgebu Getaneh: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Mengistie Taye; Damitie Kebede; Dereje Andualem: Performed the experiments.

Funding statement

This work was supported by the Ministry of Education, Ethiopia, Dilla University, and Bahir Dar University.

Data availability statement

The data that has been used is confidential.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

The authors would like to express their great appreciation to the Ministry of Education, Ethiopia, Dilla University, and Bahir Dar University. The authors also duly acknowledge all agriculture development experts and goat keepers for their help during data collection.

References

Banerjee, S., 2016. Body indices of Garole sheep reared in West Bengal (India). In: Proceedings of the Zoological Society. Springer India, pp. 61–73.

Barragán, R.M., 2017. Zoometry : a useful tool for determining the productive aptitude of domestic zoometry : a useful tool for determining the productive aptitude of domestic ruminants. J. Dairy, Vet. Animal Res. 5, 5–7.

Birteeb, P.T., Peters, S.O., Yakubu, A., Adeleke, M.A., Ozoje, M.O., 2012. Multivariate characterisation of the phenotypic traits of djallonke and sahel sheep in Northern Ghana. Trop. Anim. Health Prod. 45, 267–274.

Chacón, E., Macedo, F., Velázquez, F., Paiva, S.R., Pineda, E., McManus, C., 2011. Morphological measurements and body indices for Cuban Creole goats and their crossbreds. Rev. Bras. Zootec. 40, 1671–1679.

Chiemela, P.N., Sandip, B., Mestawet, T.A., Egbu, C.F., Ugbo, E.H., Akpolu, E.S., Umanah, I.J., 2016. Structural indices of Boer, Central highland and their F1 Crossbred goats reared at Ataye farm, Ethiopia. J. Agric. Res. 2, 1–19.

Cochran, W., 1977. Sampling Techniques, third ed. John Wiley & Sons, New York.

Dauda, A., 2018. Morphological indices and stepwise regression for assessment of function and type of Uda sheep. J. Res. Rep. Genet. 2, 1–14.

Dea, D., Melesse, A., 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. Ethiopian J. Anim. Product. 19, 73–90.

Districts' Agriculture Development Offices, 2019. Livestock Censes of Hulet Eju Enesie, Goncha Siso Enesie, and Bibugn Districts, East Gojjam Zone, Ethiopia (unpublished).

FAO, 2012. Phenotypic Characterization of Animal Genetic Resources. FAO Animal Production and Health Guidelines no 11, Rome, Italy.

Federation of Animal Science Societies, 2010. Guide for the Care and Use of Agricultural Animals in Research and Teaching.

Getaneh, M., 2020. Phenotypic Characterization of Conformation Traits and Production System of Indigenous Goat Types in Selected Districts of East Gojjam Zone, Amhara Region, Ethiopia. Bahir Dar University.

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. Int. J. Anim. Sci. Technol. 4, 6–16.

ICAR, (International Committee for Animal Recording), 2017. Guidelines for Conformation Recording of Dairy Cattle, Beef Cattle and Dairy Goats: Section 5.

Khargharia, G., Kadirvel, G., Kumar, S., Doley, S., Bharti, P.K., Das, M., 2015. Principal component analysis of morphological traits of Assam Hill goat in Eastern Himalayan India. J. Anim. Plant Sci. 25, 1251–1258.

Mohammed, I., Amin, J., 1997. Estimating body weight from morphometric measurements of Sahel (Borno White) goats. Small Rumin. Res. 24, 1–5.

Mwacharo, J.M., Okeyo, A.M., Kamande, G.K., Rege, J.E.O., 2006. The small East African shorthorn zebu cows in Kenya . I : linear body measurements. Trop. Anim. Health Prod. 38, 65–74.

Putra, W.P.B., Ilham, F., 2019. Principal component analysis of body measurements and body indices and their correlation with body weight in Katjang does of Indonesia. J. Dairy, Vet. Animal Res. 8, 124–134.

Salako, A.E., 2006. Application of morphological indices in the assessment of type and function in sheep. Int. J. Morphol 24, 13–18.

SAS, 2003. SAS User's Guide: Statistics. Ver. 9.1. Statistical Analysis System, Cary.

Silva-Jarquin, J.C., Román-Ponce, S.I., Durán-Aguilar, M., Vera-Ávila, H.R., Cambrón-Sandoval, V.H., Andrade-Montemayor, H.M., 2019. Morphostructural characterization of the Black Creole goat raised in Central Mexico, a currently threatened zoogenetic resource. Animals 9, 1–12.