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Structural Traits, Structural Indices and Body Weight Prediction of Arsi Cows

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ABSTRACT

Structural measurements are indictors of animal performance, productivity and carcass characteristics. This study was conducted with the objectives of assessing structural measurements, developing body weight predictions, and developing structural indices for cows of the Arsi breed. The cows were purchased from the highland and lowland agro-ecologies of the Arsi and East Shoa zones of Oromia and kept in the Adami Tulu Agricultural Research Center (ATARC) for breeding purposes. A total of 222 cows were included in the structural traits measurement. Thirty-four young heifers were also considered in the study. Twenty-two structural traits were considered during the observational survey. The structural index was calculated from the phenotypically correlated linear measurements. The observed average values of height at wither, chest depth, heart girth, body length, pelvic width, cannon bone circumferences of the cows were 107, 55.62, 141.06, 117.82, 31.41 and 13.58cm, respectively. Heart girth (0.82), flank girth (0.73), hook circumferences (0.67), chest depth (0.65) and height at rump (0.64) were highly correlated ($P< 0.01$) to the body weight of the cows. Regression analysis indicated that hearth girth had the highest coefficient of determination for the body weight of the cows and heifers. Accordingly, the simple linear equations were developed to predict the body weight of cows and heifers. The body weight of an Arsi cow (y)=-221.005 + 3.1 (heart girth) and the body weight of an Arsi heifer (y) =*-188.452 + 2.75 (heart girth)*. Based on

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this, the measuring chart tape can be developed to estimate the body weight of Arsi cows and heifers at field condition where there is no access to weighing scales.
Keywords: Cattle structural traits, Arsi cows, Structural indices, Body weight prediction

INTRODUCTION

Background and justification

Structural traits have been used for breed characterization and to describe changes in size and shape (Pundir *et al.,* 2011). It provides a scientific basis to describe biological variations between breeds as well as within a breed and thus can serve as a basis for measuring the performance, productivity and carcass characteristics that vary due to genotypes, environment and nutrients (Kugonza *et al.,* 2011).

Structural measurements serve as an alternative option for the assessment of body weight (Alsiddig *et al*., 2010). It is the best option where there is no access to weighing scales to predict animal body weight. Knowing the body weight of animals is important for management decisions such as breeding, culling, feeding, and determination of selling prices (Ozkaya and Bozkurt, 2008). However, many farmers in developing countries grade their livestock using informal methods of quality estimation such as feeling the loin area or by visual estimation alone (Banerjee *et al*., 2014; Lukuyu *et al.,* 2016) because of a lack of weighing scales, even if available, the weighing scales are mostly inaccurate due to lack of maintenance and calibration. Under such conditions, the livestock keepers are usually unable to receive a fair price for their livestock.

The structural indices are the combinations of several linear measurements which collate with the type and function of a particular breed. As indicated by Alderson (1999), linear body measurements are used to calculate indices which show the structure and proportions of each animal. Structural indices are considered most useful because they have a neutral correlation with age. Consequently, assessment of structural indices is useful as a measure as it allows selection of young animals for breeding purposes and predicts their mature rating. They provide a more realistic indicator for which a particular livestock breed was created and therefore provide a directional approach for further improvement of the same (Banerjee *et al.,* 2014).

Arsi cattle are distributed in Arsi, West Arsi, Bale, and some parts of the East Shoa and East Hararghe Zones of Oromia Regional State, Ethiopia (DAGRIS, 2019). Adami Tulu Agriculture Research Center (ATARC) also handles Arsi cows at its farm for composite breed development. At ATARC, some morphometric measurements are being taken as baseline information for the breed improvement work being undertaken on this breed. Such information is necessary to see the differences attained after the breed improvement program. However, this breed has to be characterized phenotypically in detail using structural indices. Therefore, this study was designed to assess structural traits, develop body weight prediction and structural indices for Arsi cows.

MATERIALS AND METHODS

Research area

The structural assessment was carried out at the Adami Tulu Agricultural Research Center, which is located in the mid-rift valley 167 kilometers south of Addis Ababa, at an elevation of 1650 meters above sea level. The agro-ecological zone of the area is semi-arid and sub-humid with an acacia woodland vegetation type. The mean annual rain fall of the area is 760 mm and its mean minimum and maximum temperatures are 12.6 and 27^0c, respectably.

Population sampled

ATARC keeps Arsi cows with the aim of developing a composite breed from Holstein Frisian-sire and Arsi-dam breeds. The Arsi cows were purchased from the highlands of the Arsi zone and the lowland agro-ecologies of the Arsi and East Shoa zones. All cows were kept under similar management conditions. The cows having permanent teeth were taken for linear measurements. Accordingly, 222 and 78 cows were represented by lowland agroecology and Highland agro-ecology, respectively. Moreover, thirty-four one-to-three-year-old female calves that were born from this herd were included in the study.

Structural traits

Twenty-two structural traits were considered during the observational survey. Namely: height at wither, hip height, chest depth, chest width, rump width, heart girth, flank girth, body length, rump length, neck length, neck circumference, ear length, horn length, face length, muzzle circumference, forehead width, pelvic width, tail length, cannon bone length, cannon bone circumference, hock circumference and body weight.

Measurements tools

The physical measurements such as height at wither (HW), rump height (HR), chest depth (CD), chest width (CW), rump width (RW) and rump length (RL) were measured using graduate measuring sticks, whereas heart girth (HG), flank girth (FG), body length (BL), neck length (NL), neck circumference (NC), ear length (EL), horn length (HL), face length (FL), muzzle circumference (MC), tail length (TL), cannon bone length (CBL), cannon bone circumference (CBC), hock circumference (HC) were measured using plastic measuring tape. The pelvic width (PW) and forehead width (FW) measurements were assessed using a calibrated wooden caliper. The body weight (BW) of cows was taken on a standard weighing scale.

Structural Indices

The structural indices were calculated from structural traits as follows (Alderson, 1999; Salako, 2006; Chacon *et al.,* 2011; Pares-casanova *et al*., 2013):

Depth index =chest depth/height at wither,

Height index = height at the withers divided by body length

Rump length = rump length divided by body length

Body mass index = body length divided by heart circumference

Weight index = ((body length x chest depth) x ((rump width + chest width)/ 2)/ 1050))

Relative cannon length = cannon bone circumference/withers height

Body ratio index = height at withers/height at rump

Height at rump/height at withers = over increase index

Statically analysis

Structural traits were analyzed by the T-test of SPPS version twenty-four. The Pearson's correlation among various structural traits was estimated. The model used for the analysis of correlations among various structural traits was estimated. The model used for the analysis of structural measurements was: $y_{ijk} = \mu + ai + e_{ij}$

Where, Y =*is the phenotypic observation for one of the twenty-two structural traits*,

μ=is over all mean,

ai = fixed effect of i^{th} agro-ecology, while

e_{ij} = *is random residual error associated with each observation.*

RESULTS AND DISCUSSIONS

Structural traits

Structural traits of cows and heifers are listed in Table 1. Height at wither, height at rump, chest depth, rump width, heart girth, flack girth, body length, rump length, neck length, mouth circumference, pelvic width, body weight, cannon bone circumference, and hock circumference all differed significantly across agroecologies, but chest width, neck circumference, ear length, horn length, face length, and cannon bone circumference did not.

The structural traits of cows are presented in Table 1. The observed average value of height at the wither of Arsi cows was shorter than that of Begait cows that were reported by Teweldemedhn and Selam Teweldemedhn and Selam (2020), while it was similar to that of Dessalegn *et al.*, (2012) for Arado cows. However, the average wither height obtained was taller than Malle cows (Demerew *et al.,* 2019). The average height at the rump of Arsi cows was shorter than that of Dereje (Dereje, 2015) for Horro cows. The observed value of height at the rump was taller than the Malle cows that were reported from the South Omo, Ethiopia (Demerew *et al.,* 2019).

Table 1: Structural traits of cows and heifers (Mean ± SE)

	Structural traits (cm)										
	HW	***HR***	***CD***	***HG***	***FG***	***BL***	***RL***	***NL***	***MC***	***PW***	***BW(kg)***
Highland cows	108.3±0.5	113.6±0.4	56.3±0.3	143.3±0.8	147.5±0.9	119.6±0.7	36.5±0.2	34.9±0.3	38.7±0.3	32.1±0.3	223.4±2.99
Lowland cows	106.3±0.3	111.7±0.3	55.3±0.2	139.8±0.6	143.7±0.7	116.8±0.4	35.8±0.1	33.8±0.2	37.8±0.2	31.0±0.2	211.8±2.24
P values	*0.001*	*0.001*	*0.002*	*0.001*	*0.001*	*0.001*	*0.009*	*0.006*	*0.003*	*0.001*	*0.002*
Overall mean	107±0.3	112.4±0.3	55.6±0.2	141.1±0.5	145.1±0.6	117.8±0.4	36.1±0.1	34.2±0.2	38.2±0.1	31.41	215.98±1.8
Heifer	102.6±3.4	109.4±2.4	48.7±2.5	125.9±4.7	128.6±5.7	107.6±6.1	32.5±1.4	30.9±2.8	33.9±1.5	10.1±1.1	156.8±14.8

Table 1 continued…

	Structural traits (cm)										
	CW	***RW***	***NC***	***EL***	***HL***	***FL***	***FW***	***TL***	***CBL***	***CBC***	***HC***
Highland cows	30.1±0.3	38.5± 0.3	71.7±0.8	18.9±0.2	27.5±0.6	40.6±0.2	17.5±0.1	73.5±0.7	18.6±0.1	13.7±0.1	23.7±0.1
Lowland cows	29.5±0.2	35.8±0.2	70.5±0.5	19.1±0.1	27.5±0.3	40.5±0.2	17.4±0.1	73.3±0.5	18.5±0.1	13.5±0.1	23.3±0.1
P values	*0.12*	*0.04*	*0.12*	*0.73*	*0.99*	*0.74*	*0.41*	*0.81*	*0.51*	*0.03*	*0.004*
Overall mean	29.7±0.2	36.1±0.2	70.9±0.4	19±0.1	27.5±0.4	40.5±0.1	17.4±0.1	73.3±0.4	18.6±0.1	13.58	23.4±0.1
Heifer	24.7±1.7	30.9±1.7	62.4±4.7	19±1.5	37.7±1.7	37.7±1.7	15.8±1	69.3±7.2	18.6±0.7	12.8±0.6	22.7±0.7

Some structural values of cows within the same column not vary significantly at P<0.05

Height at wither and height at the rump are important as they determine how tall the animal are (Worku, 2017). Wither height and hip height are important skeletal measurements that are associated with the skeletal dimensions of cattle. According to some studies, animals adapted to hot and humid climates have shorter wither height, whereas those adapted to arid climates with sparse vegetation cover have higher wither height and longer limbs (Mwacharo *et al.,* 2006).

The average value of chest width obtained in this study is lower than those reported by Demerew *et al.,* (2019) for Malle cows but higher than those reported by Worku (2017) for Sheka cows. Further studies indicated that Arsi cows have a lower chest depth than Fogera cows (Zewdu *et al.,* 2008). The average chest depth of Arsi cows was higher than those reported by Worku (2017) Sheka cows. The animals' chest depth and chest width are correlated with the pleural capacity. Both traits are correlated with the chest girth of animals and therefore have immense economic importance.

Study results indicated that Arsi cows have lower heart girth than those reported by Teweldemedhn and Selam (2020) for Begait cows; Fasil and Workneh (2017) for Fogera cows. However, it was observed that Arsi cows had higher heart girth than Arado cows (Dessalegn *et al.,* 2012). The observed value for heart girth was similar to the finding of Chencha *et al.* (2013) for Goffa cows. Cattle with low chest girth usually have lower body weight as the pleural cavity houses many of the vital organs and the development of these organs influences their body weight (Tewelde *et al*., 2017) .

Values for the average body length of Arsi cows are lower than those results reported by Shiferaw (2006) and Getinet *et al.,* (2009) for Kereyu and Ogaden cows, respectively. The observed average body length was longer than Arado cows (Dessalegn *et al.,* 2012). Cows with longer bodies usually have better potential as meat animals, provided that they are properly managed. Body length is correlated with the body weight of cattle (Lukuyu *et al.,* 2016). Cattle with large skeletal dimensions fetch higher price/value when compared to those with shorter skeletal dimensions (Alsiddig *et al.,* 2010). But cattle with short skeletal dimensions require low space and maintenance costs. The rump length of cows in the current study is lower than those reported by Yakubu *et al.* (2010) for Bunaji and Red Angus cattle. Rump length has significant importance for livestock, as cows with optimal rump length usually have lower incidences of abortion and dystocia. This is so because of the fact that the fetus gets enough space to grow.

The average value of rump width observed for cows in this study was higher than what was reported for Mursi cows (Endashaw *et al.,* 2015) but lower than those reported for Sheka cows (Worku, 2017). It has been reported that cattle with a narrower pelvic girth are prone to birth defects and that the trait shows sexual dimorphism with the values being higher in females than in males (Teweldemedhn and Selam, 2020). Average values for pelvic width of Arsi cows are in close accordance with the findings of Dessalegn *et al.,* (2012) for Arado cows. However, the values are lower than those reported by Fasil and Workneh (2014) for Fogera cows.

Forehead width is one of the important features defining a breed. While the head width of beef breeds of cattle is wider than that of dairy breeds, there is sexual dimorphism for this trait too (Tewelde *et al.*, 2017). The values pertaining to forehead width for the Arsi cows are higher than those for Sheka cows (Worku, 2017) but lower than those for Begait cows (Tewelde *et al.*, 2017).

The average value of the cannon bone length of Arsi cows was shorter than that of Horro cows (Dereje, 2015). The cannon bone circumferences observed for cows in this study were also narrower when compared to those reported for Begait cows *(*Tewelde *et al.,* 2017*)*. Animals with narrow cannon bone circumference usually have lower body weights as the space for muscle attachment is less in such types of animals. The cannon bone circumference observed for cows in this study is narrower than those reported by Dereje (Dereje, 2015) for Horro cows but similar to those reported by Endashaw *et al.,* (2015) for Mursi cows.

The values pertaining to the neck circumference indicate that the neck is narrower when compared to that of the Begait breed (Mulgeta and Berhan, 2015), but wider than that of Malle cattle (Demerew *et al.*, 2019). This may be ascribed to the breed character. Neck length is a trait which is correlated with the femineity and masculinity of cattle. The observed neck length of the Arsi cow was shorter than that of the Begait cattle (Teweldemedhn and Selam, 2020). Neck length values are correlated with development of cervical vertebrae (Worku, 2017), which is helpful for draft purposes in cattle. Cows with long, thin necks are usually preferred over those with short and thick necks (Takele, 2005).

Correlations of structural traits for cows

The correlation of biometric traits of cows is listed in Table 2. Cows' wither height, rump height, chest depth, chest width, rump width, heart girth, flank girth, body length, mouth circumference, pelvic width, cannon bone circumference, and hook circumference are all positively correlated and highly correlated ($P< 0.01$) to body weight. The findings indicated that rump length, neck length, neck circumference, ear length, horn length, face length, forehead width, tail length, and cannon bone length have weak correlation coefficients to live body weight.

The observed highest correlation between heart girth and body weight is in close accordance with the findings of Rashid *et al.,* (2015) for Brahman crossed bred and Musa *et al.,* (2011) for Kenana cattle. Bivariate correlation revealed that flank girth was the second most correlated trait with live body weight. It was observed that hock circumference, chest depth, hip height, cannon circumference, chest width, weight at withers and rump width were highly correlated to body weight in a decreasing manner. It was also observed that ear length, horn length, and dewlap width were not significantly correlated (*P*< 0.01) to body weight, which might be due to their less association with skeletal traits.

Table 2: Correlation between body weight and structural traits for cows

Traits	BW	Traits	BW	Traits	BW	Traits	BW
HW	0.602	FG	0.736	RL	0.441	FL	0.416
HR	0.644	BL	0.510	NL	0.290	FW	0.339
CD	0.652	MC	0.528	NC	0.336	TL	0.184
CW	0.607	PW	0.581	CBL	0.207		
RW	0.599	CBC	0.608	EL	0.051		
HG	0.818	HC	0.675	HL	0.082		

All of the correlations between body weight and structural traits are statistically significant at the 0.01 (2-tailed) level

Body weight prediction

Straightforward linear equation

The simple regression models are presented in Table 3. Simple linear regression results pertaining to the structural measurements indicated that cows from highland agro-ecology had a lower coefficient of determination when compared to those from lowland agro-ecology. The multiple linear equations have more coefficient of determination in predicting the body weight of Arsi cows. Taking multiple measurements of bovines, on the other hand, is difficult, especially in field conditions where infrastructure is lacking and there is a lack of crushes and appropriate livestock handling tools (Banerjee *et al.*, 2016) under such conditions, a single trait is preferable to predicting body weights. The study showed that among the structural measurements, the best treated were the heart girth measurements, which are in close accordance with those of Lukuyu *et al.,* (2016) and Rashid *et al*. (2016). This may be ascribed to the fact that the thoracic cavity holds some of the most vital organs of the animals, and the weight of these organs is highly correlated with the live weight of the animals (Mwacharo *et al*., 2006).

Table 3: Simple linear regression of weight on heart girth for the cows and heifers

Cattle	R^2	Regression equation
Highland agro-ecology cows	0.777	-195.63 + 2.90(x)
Lowland agro-ecology cows	0.826	-232.65 + 3.18(x)
Combined equations	0.818	-221.005 + 3.10(x)
Heifers	0.723	-188.452 + 2.75(x)

x: heart girth

Multiple linear equations for cows

Stepwise multiple linear regression models of cows are presented in Table 4. The coefficient of determination of multiple linear regressions increases as the number of traits is added to models. The study indicated that the single trait linear equation for Arsi cows has a low coefficient compared to the multiple traits. The equation developed from heart girth alone has a lower coefficient of determination than the equation developed from rump width and heart girth. Furthermore, the study indicated that the accuracy of body weight prediction increases as the number of morphometric traits included in the linear equation increases. Both these scenarios are in close accordance with the findings of Rashid *et al*., (2016). However, as livestock handling is difficult in rural areas due to lack of restraining equipment and to the behavior of the zebu breed (Banerjee *et al*., 2016), it becomes difficult to assess multiple measurements for an animal. Hence, relying on any single trait measurement which is highly correlated with body weight (Gunawan and Jakaria, 2014) is inevitable.

Table 4: Stepwise multiple linear regression models

R^2	Multiple linear equations
0.818	-221 + 3.1HG
0.848	-256.1 + 2.6HG + 2.87RW
0.869	-310.6 + 2.2HG + 2.6RW + 8.85CBC
0.881	-318 + 1.68HG + 2.45RW + 7.74CBC + 0.74FG
0.887	-322.5 + 1.52HG + 2.4RW + 6.9CBC + 0.66FG + 1.5PW
0.892	-319.1 + 1.26HG + 1.87RW + 7CBC + 0.7FG + 1.5PW + 1.42CW
0.896	-357.7 + 1.1HG + 1.9RW + 6CBC + 0.68FG + 1.3PW + 1.5CW + 0.76HR

Regression equations with a curve fit

Table 5 lists linear and non-linear regression models for a few structural variables. The study indicated that heart girth was the best body weight predictor, followed by flank girth and hock circumference, in that order. Their respective non-linear regression equations have similar coefficients of determination to simple linear regression. In particular, the quadratic regression equation has almost an equal coefficient of determination as the linear equation. However, the result of this study disagrees with that reported by Banerjee *et al.,* (2016), who stated that the quadratic regression equations have a better accuracy when compared to the linear measurements for Borana bulls. Furthermore, this study indicated that single linear and non-linear equations have lower accuracy when compared to multiple linear regression equations.

Table 5: Linear and non-linear regression models for different traits

Regression	Heart girth		Flank girth		Hock circumference	
	R^2	Equation	R^2	equation	R^2	Equation
Linear	0.818	-221.005 + 3.098(x)	0.736	96.14 + 0.226(x)	0.675	17.95 + 0.025(x)
Logarithmic	0.817	-1961.031 + 439.99ln(x)	0.734	-120.268 + 49.42ln(x)	0.669	-6.25 + 5.53ln(x)
Inverse	0.815	658.186 - 62219.6(1/x)	0.728	194.5 – 10529.9(1/x)	0.659	28.91 – 1169.1(1/x)
Quadratic	0.818	$-106.375 + 1.486(x) + 0.006x^2$	0.736	$91.42 - 0.27(x) + -9.69x^2$	0.677	$20.4 + 0.003(x) + 5.1x^2$
Exponential	0.813	$29.476 + e^{0.14(x)}$	0.718	$103.45 + e^{0.002(x)}$	0.674	$18.52 + e^{0.001(x)}$

Notice x = heart girth

Structural indices

The structural indices of Arsi cows are listed in Table 6. The weight index was significantly different (*P<0.05*) for cows in the two agro-ecologies. The depth index, rump length index, body index, relative cannon thickness index, body ration index, and over increase index were not statically different between agro-ecologies.

The rump length index of the Arsi cows is quite smaller when compared to that of the other breeds. This is an indication of the compactness of the Arsi cows (Aldreson, 1999). The results pertaining to the weight index showed that the weights of the Arsi cows are lower than those of the Malle cattle (Demerew *et al.,* 2019). The difference in body weight index may be associated with the difference in agro-ecologies from where the cows came.

Table 6: Structural indices of the cows

	Index							
Location	**DI**	**HI**	**RLI**	**BI**	**WI**	**RCT**	**BRI**	**OII**
Highland	0.52	0.91	0.31	0.84	214.24[a]	0.13	0.95	1.05
Lowland	0.52	0.91	0.31	0.84	201.43[b]	0.13	0.95	1.05
Overall	0.52	0.91	0.31	0.84	205.93	0.13	0.95	1.05

DI: depth index, HI: height index, RLI: Rump length index, BI: body index, WI: body weight index, RCT: relative cannon thickness, BRI: body ratio index, OII: over increase index

The values observed for height and over-increased indexes in this study were lower than those reported by Tariku (2018). The values for the over increase and body ratio indexes showed that the hind quarters of the cows are raised. The relative cannon thickness index obtained for cows in this study indicated that their cannon are quite narrow. Animals with thin cannon bones are expected to be less masculine and to produce a lower carcass yield (Chacon *et al.,* 2011). The value of the depth index was higher than that of the Sheka cows (Worku, 2017). An observed value shows that chest depth was half height at wither.

CONCLUSION AND RECOMMENDATION

Highland Arsi cows have a wider chest and pelvic bone, a longer rump and body length, a larger heart and flank girth, a thicker cannon and hock bone, and are taller and heavier. This might be correlated to the ecological adaption of the cattle. These variations in structural traits indicate the possibility of undertaking within-breed selections.

The regression equations need to be validated at an on-farm level to predict the body weight of female Arsi cattle. Measuring chart tape should be developed to predict the body weight from the heart girth of Arsi cows and heifers for field conditions where there is no access to weighing scales.

The depth index revealed that chest depth is half of the wither height. This might show the body is balanced, which may help the animal walk a long distance. Thus, this might explain why Arsi cattle are distributed in different areas of the country. The Over-increase index indicates that the hip of Arsi cows is taller by 5% than its height at wither. Further, the rump length index indicated that rump length is 31% of the body length. Indices indicate that Arsi cows are compact and light, which implies that the breed is suitable for crossing by virtue of being small dairy-type breeds.

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