Structural traits, structural indices and body weight prediction of Arsi cows

ABSTRACT

Structural measurements are indicators of animal performance, productivity and carcass characteristics. This study was conducted with the objectives of assessing structural measurements, developing body weight prediction and structural indices for cows of Arsi breed. The cows were purchased from highland and lowland agro-ecologies of Arsi and East Shoa zones of Oromia regional state, Ethiopia and kept in Adami Tulu Agricultural Research Center (ATARC) for the breed development purpose. 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 observational survey. The structural indices were calculated from the phenotypically correlated linear measurements. Structural traits were analyzed by T-test of SPSS version twenty four. 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 13.58 cm, 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 body weight of the cows. Regression analysis indicated that hearth girth had highest coefficient of determination for body weight of the cows and heifers. Accordingly, the simple linear equations were developed to predict the body weight of cows and heifers. Body weight of Arsi cow \( y = -221.005 + 3.1 \text{ (heart girth)} \) and Body weight of Arsi heifer \( y = -188.452 + 2.75 \text{ (heart girth)} \). Based on 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.

Key words: Structural traits, cows, structural indices, body weight.

INTRODUCTION

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 a best option where there is no access to weighing scales to predict animal body weight. Knowing body weight of linear measurements which collate with type and function of particular breed. As indicated by + (1999), linear body 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 lack of weighing scales and, 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 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 to select young animals for breeding purpose and predict 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 widely reared in Arsi, West Arsi, Bale, some parts of 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.

**METHODOLOGY**

**Study area**

Structural assessment was conducted at Adami Tulu Agriculture Research Center, which is located in mid rift valley at 167 km south from Addis Ababa, at an altitude of 1650 m above sea level. The agro-ecological zone of the area is semi-arid and sub humid with 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℃, respectively.

**Sampled population**

ATARC keeps Arsi cows with the aim of developing composite breed from Holstein Frisian-sire and Arsi-dam breeds. The Arsi cows were purchased from highlands of Arsi zone and lowland agro-ecologies of 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 from lowland agro ecology and Highland agro-ecologies respectively. Moreover, thirty four one to three years old female calves which were born from this herd were included in study.

**Measurement of structural traits**

Twenty two structural traits were considered during 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.

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) measurement were assessed using a calibrated wooden caliper. Body weight (BW) of cows was taken by 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 withers/body length,
- **Rump length** = rump length/body length
- **Body index** = body length/heart girth
- **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
- **Over increase index** = height at rump/height at withers.

**Statically analysis**

Structural traits were analyzed by T-test of SPSS version twenty four. The Pearson's correlations among various structural traits were estimated. The model used for the analysis of structural measurement was: \( y_{ijk} = \mu + a_i + e_{ij} \)

Where, \( Y \) =*is the phenotypic observation for one of the twenty two structural traits*,
\( \mu \) =is over all mean,
\( a_i \) = fixed effect of \( i^{th} \) agro-ecology, while
\( e_{ij} \) = is random residual error associated with each observation.

**RESULTS AND DISCUSSION**

Structural traits

Structural traits of cows and heifers are listed in Table 1.
The height at wither, height at rump, chest depth, rump width, heart girth, flank girth, body length, rump length, neck length, mouth circumference, pelvic width, body weight, cannon bone circumference and hock circumference had significant different across agro ecologies when chest width, neck circumference, ear length, horn length, face length and cannon bone length had not showed significant different at $P<0.05$.

The structural traits of cows are presented in Table 1. The observed average value of height at wither of Arsi cows was shorter than Begait cows reported by Teweldemedhn and Selam (2020) while, it was similar with the report of Dessalegn et al. (2012) for Arado cows. However, the average height at wither obtained was taller than Malle cows (Demerew et al., 2019). The average height at rump of Arsi cows was shorter than those reported by Worku (2017) for Sheka cows. Cattle with low chest girth usually have immense economic importance.

The results of the present study indicated that Arsi cows have lower heart girth than those reported by Teweldemedhn and Selam (2020) for Begait cows; Fasil and Workneh (2014) 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 Gofà 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 (Teweldel, 2017).

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

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

The average chest depth of Arsi cows was higher than those reported by Worku (2017) for Sheka cows. The animals chest depth and chest width are correlated with the pleural capacity. Both traits are correlated with chest girth of animals and therefore have immense economic importance.

The average chest depth of Arsi cows was higher than Malle cows reported from South Omo of Ethiopia (Demerew et al., 2019).

Height at wither and height at rump are important as they determine how tall the animals are (Worku, 2017). The height at wither and hip height are important skeletal measurements, which are associated with the skeletal dimension of the cattle. Some study indicated that animals adapted to the hot and humid climate have shorter height at wither while those adapted to the arid climate with sparse vegetation cover have higher height at withers 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 the Worku (2017) for Sheka cows. Further study indicated that Arsi cows have lower chest depth than Fogera cows (Zewdu et al., 2008).

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

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The height at wither, height at rump, chest depth, rump width, heart girth, flank girth, body length, rump length, neck length, mouth circumference, pelvic width, body weight, cannon bone circumference and hock circumference had significant different across agro ecologies when chest width, neck circumference, ear length, horn length, face length and cannon bone length had not showed significant different at $P<0.05$.

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In the present study, the values for 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 body 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 (Alsidig et al., 2010). But cattle with short skeletal dimensions require low space and maintenance cost (Cerqueira et al., 2013). The rump length of cows in the current study is lower than those reported by Abdulmojeed et al. (2010) for Bunaji and Red Angus cattle. The rump length has a 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 narrower pelvic girth are prone to birth defects and that the trait shows sexual dimorphisms with the values being higher in females than in males (Teweldemedhn and Selam, 2020). Average values for pelvic width of Arsi cows are in accordance with the finding 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 are wider than that of the dairy breeds, there exists sexual dimorphism for this trait too (Tewelde et al., 2017). The values pertaining to forehead width for the Arsi cows is higher than those for Sheka cows (Worku, 2017) but lower than those for Begait cows (Tewelde et al., 2017).

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The observed average body 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 that reported for Begait cows (Tewelde et al., 2017). The animals with narrow cannon bone circumference usually have lower body weight as the space for muscle attachment is less in such types of animals. The cannon bone circumference observed for cows in this study are narrower than those reported by Dereje (2015) for Horro cows but similar to those reported by Endashaw et al. (2015) for Mursi cows. The values regarding the neck circumference indicate that the neck is narrower when compared with 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 masculinuty of cattle. The observed neck length of Arsi cow was shorter than that of the Begait cattle (Tewelde et al. 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 neck are usually preferred over those with short and thick necks (Takele, 2005).

**Correlations of structural traits for cows**

The correlation of biometric traits cows are listed in Table 2. Height at wither, height at rump, chest depth, chest width, rump width, heart girth, flank girth, body length, mouth circumference, pelvic width, cannon bone circumference and hook circumference of the cows are positively correlated to each other 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 the live body weight.

The observed highest correlation between heart girth and body weight is in close accordance with the finding of Rashid et al. (2015) for Brahman crossed bred and Musa et al. (2011) for Kenana cattle. Bivariate correlation indicated that flank girth was the second highest correlated trait with live body weight than other structural traits. 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

**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 Correlation between body weight and structural traits are significant at 0.01 level (2-tailed).
correlated ($P< 0.01$) to body weight which might be due to their less association with skeletal traits.

**Body weight prediction**

**Simple 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 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. However, taking multiple measurements in bovines are problematic especially under field conditions where the infrastructure is wanting and there are lack of crushes and appropriate livestock handling tools (Banerjee et al., 2016). Under such condition, single trait is preferable to predict body weights. The study showed that among the structural measurements, the best treat was 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 weight of these organs are highly correlated with the live weight of the animals (Mwacharo et al., 2006).

**Multiple linear equations for cows**

Stepwise multiple linear regression models of cows are shown in Table 4. The coefficient of determination of multiple linear regressions increases as number of traits is added to models. The study indicated that single trait linear equation for Arsi cows has low coefficient compared to the multiple traits. The equation developed from heart girth alone has low 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 finding of Rashid et al. (2016). However, as livestock handling is difficult in rural areas due to lack of restraining equipments and due the behavior of 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.

**Curve fit regression equations**

Linear and non linear regression models of few structural are listed in Table 5. 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 coefficient of determination with simple linear regression. Particularly, the quadratic regression equation has almost equal coefficient of determination to 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. Further this study indicated that the linear and non-linear equations have lower accuracy when compared to multiple linear regression equations.

**Structural indices**

The structural indices of Arsi cows are listed in Table 6. Weight index was significantly different ($P<0.05$) for cows in the two agro-ecologies. 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 that 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.

The values observed for height and over increase 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

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**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.
Table 4: Stepwise multiple linear regression models.

| R²   | Multiple linear equations                                                                 |
|------|------------------------------------------------------------------------------------------|
| 0.818| -221.00 + 3.1HG                                                                         |
| 0.848| -256.1 + 2.6HG + 2.87RW                                                                  |
| 0.869| -310.6 + 2.2HG + 2.6RW + 8.85CBC                                                        |
| 0.881| -318.1 + 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                         |

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

| Regression   | Heart girth R² | Equation                          | Flank girth R² | Equation                          | Hock circumference R² | 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          | -706.561 + 1.486 + 0.006x²        | 0.734          | 91.42 - 0.27(x) + -9.69x²        | 0.677                 | 20.4 + 0.003(x) + 5.1x²         |
| Exponential  | 0.813          | 29.476 + e0.14(x)                 | 0.718          | 103.45 + e0.002(x)               | 0.674                 | 18.52 + e0.001(x)               |

Table 6: Structural indices of the cows.

| Location | DI | HI | RLI | BI | WI | RCT | BRI | OII |
|----------|----|----|-----|----|----|-----|-----|-----|
| Highland | 0.52 | 0.91 | 0.31 | 0.84 | 214.24 | 0.13 | 0.95 | 1.05 |
| Lowland  | 0.52 | 0.91 | 0.31 | 0.84 | 201.43 | 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.

Conclusions and recommendation

The highland Arsi cows have wider chest and pelvic bone, longer rump and body length, bigger heart and flank girth, thicker cannon and hock bone, taller hip and heavier body than lowland Arsi cows. This might be correlated to the ecological adaption of the cattle. These variations in structural traits indicate the possibilities to undertake within breed selections.

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

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

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