



Comparative Analysis of Measuring Bodyweight in Indigenous Bargur Hill Cattle by Direct and Indirect Methods using Morphometric Measurements

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ABSTRACT

Background: Bargur cattle, native to the Bargur hills of Tamil Nadu, India, are well-adapted to the region's hilly terrain and tropical climate. However, due to their semi-wild nature, they can be challenging to handle. Accurate body weight estimation is crucial for managing these animals, especially for decisions related to treatment, marketing and feeding. In the absence of weighing equipment in the field, body weight is often estimated using easily measurable body dimensions like Body Length (BL), Chest Girth (CG) and Height at Withers (HW). Several methods, including Weighbridge, Schaeffer's, Agarwal's and Lambourne formulas, are used to estimate body weight in such conditions.

Methods: Various methods have been employed to estimate the body weight of Bargur cattle in the absence of weighing equipment. The techniques used in this study include: Weighbridge: A standard calibrated weighing scale, considered the most accurate method for determining true body weight. Schaeffer's Formula: An equation based on body measurements to estimate body weight. Agarwal's Formula: Another formula using body measurements for estimating body weight. Lambourne Formula: A method that estimates weight using certain body measurements.

Result: The results of the study indicate that the body weight of Bargur cattle can be reliably estimated using Schaeffer's method. This method demonstrated higher accuracy compared to the other techniques (Agarwal's formula and Lambourne formula), making it a valuable tool for effective decision-making in marketing, drug dosing and feeding. Schaeffer's formula proved to be the most efficient and accurate for assessing the weight of Bargur cattle, thereby assisting in the management and monitoring of the breed in field conditions.

Key words: Bargur cattle, Body measurements, Body weight, Schaeffer's method.

INTRODUCTION

Bargur cattle are a native cattle breed of Bargur hills of Tamil Nadu, India. It is well adapted to hilly terrain and tropical climate, but due to its semi-wild nature, animals can be tough to handle (Ganapathi *et al.*, 2009). These animals are medium sized animals and specially adopted to forest grazing in hilly areas. Bargur hilly cattle has been maintained as transhumance method of management system. Most of the time in the year animals spent their life in the forest. None of the farmer asses to direct weightment system due to non-availability of weightment equipment in the field. Animal weights are fundamentally important to the management and routine monitoring of an animal and taking decision regarding treatment and marketing. Management decisions, nutrient requirements and health components of a dairy heifer program often are based on body weight (BW), animal age, body condition score and the desired management protocol of the farm manager (Heinrichs *et al.*, 2007). Livestock body weight is the basis for determining ration amounts and sale prices of animals. Body weight plays an important role in reproductive performance of a dairy animal and therefore, influences milk production (Kanuya *et al.*, 2006 and Roche *et al.*, 2007). Body weight calculation in the field is a difficult process due to lack of availability of weighing equipment's. Livestock pathogens, remain an important constraint to

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agricultural production in East Africa and the main control method available to smallholder farmers is the use of

drugs. Appropriate use of these drugs depends on knowledge of the animal's live body weight (LBW) as their posology is based on milligram of drug per kilogram of bodyweight (Perry *et al.*, 2002). It is very easy to under dose or overdose cattle if the weight is unknown. Inaccurate dosing can lead to poor control of livestock diseases, inefficient use of drugs, drug resistance and potential harm to individual animals or the quality of their by-products (Machila *et al.*, 2008).

Many methods can be used to determine an animal's weight. Use of a weighing scale is considered the gold-standard if the scales used are well calibrated. Estimation of LBW of cattle is not difficult but requires training and practice, which in turn requires a reference method (e.g. weighing scale or validated weigh-band) or an experienced trainer to provide feedback of accuracy of estimates; smallholder rural farmers rarely have either. The prediction of body weight enables breeders to define suitable medicinal doses for remedy of an animal, its feed amount per day and expressly for marketing (Tadesse *et al.*, 2012).

Many commercial dairy farms do not have complete restraint and handling systems and few have animal scales to determine body weights. Especially the Bargur hill cattle are maintaining under the semi wild system of management. Therefore, equations to estimate body weight from other body measurements are needed, including those using other body measurements that are easy to measure in the field condition. Hence, the objective of this study was to formulate and analysis the indirect weighment techniques to be fitted hilly Bargur cattle in the field.

MATERIALS AND METHODS

The Bargur cattle maintained in the Bargur Cattle Research Station, Bargur in the latitude 11.816909 and Longitude 77.537855 and adjacent farmers herd animals also utilised for this study. The research station is located at an altitude of 1002 mean sea level. The primary objective of these research station is conservation of Bargur hilly cattle from extinction. The number of animals included in the study was 109 pure breed Bargur hill cattle in the different age group and sex. The study took place between June 2024 to November 2024. All the measurements were performed by same operator on a flat surface with all limbs on the ground (Cerqueira *et al.*, 2013). Body measurements are better predictors of bodyweight (Bhakat *et al.*, 2008). Body length (BL), chest girth (CG) and height at withers (HW) were measured using standard measuring tape. A strong correlation between biometric parameters and carcass weight enabling accurate estimation of carcass weight from live animal measurements (Djeghar *et al.*, 2024). BL was measured as a straight line from the tip of the scapula (the most prominent point of the scapulohumeral joint) to the ischial tuberosity. CG was measured with a tape around the chest just behind the scapula and HW was measured highest point of the withers to the ground (Fig 1). The body weight measurement techniques employed were Weighbridge,

Schaeffer's formula, Agarwal's formula and Lambourne formula method. Weighbridge is the standard calibrated weighing scale, which provides true body weight. Therefore, this was used as a reference point for other three techniques. Each Bargur animal was estimated separately by four measurement techniques. The body weight estimates of three techniques were compared with the weights obtained by Weighbridge. The experimental animals were kept off feed and water for 12 hours before measurement.

Weigh bridge

It is a standard calibrated scale, therefore, in this study, it was used as the main reference point for other techniques. Animals were allowed to approach the Weigh-bridge and proceed directly onto the platform. Animals were made to stand for about 20-30 seconds and weight measurement on the scale was recorded in kilograms.

Schaeffer's formula

The equation used for calculating live weight was:

$$W = \frac{L \times G^2}{300}$$

Where,

W = Body weight in lbs.

L = Length of the animal from point of shoulder to pin bone in inches.

G = Chest girth of the animal in inches.

The final weight was converted from lbs to kilograms.

Agarwal's formula

It is the modified Schaffer's formula developed for the Indian cattle. The equation used for calculating live weight was:

$$W = \frac{\text{Girth} \times \text{Length}}{Y}$$

Where,

W = Body weight in kg.

Y = Equal to 9.0 if girth is less than 65 inches.

Y = Equal to 8.5 if girth is between 65 and 80 inches.

Y = Equal to 8.0 if girth is over 80 inches.

The Bargur hill cattle is a medium size animal, its girth measurement is always 65 inches. Hence, the 9.0 used as constant Y value in this study.

Lambourne formula

Calculating using the Lambourne formula:

$$BW = \frac{CC^2 \times BL}{10.840}$$

Where,

BW = Body weight in kgs.

CC = Chest circumference in centimetre

BL = Body length in centimetre.

10.840 = Provision of the lambourne formula.

Data analysis

The data set was tested for normalcy and homogeneity of variances using ShapiroWilk and Levene's tests,

respectively. Wherever required, data were logarithmically transformed to meet the assumptions of ANOVA. A Tukey test was performed when significant differences between means of more than two groups were detected. All statistical tests were conducted IBM @SPSS® Statistics, v26 (SPSS). To assess initial association between variables, Spearman's rank correlation coefficient was calculated.

RESULTS AND DISCUSSION

The mean live body weights of Bargur hill cattle included in this study and their BWs and MSs are shown in Table 1 and the data distribution is shown in Fig 2. Both sexes of the animals had a slightly different in BWs and MSs measured. From the data distribution shown in Fig 3, BW had the greatest variability between all measurements. All MSs were correlated with BW and with each other ($p < 0.001$) (Table 1). It was observed that height at withers of Gir cows had a positive significant correlation (0.131) with weekly milk yield (Mashalji *et al.*, 2016). CG had the best correlation with BW, followed by BL and HW. Plotting BW against measurements showed in Box and Whisker plot (Fig 2).

Method selection of body weight assessment

The methods having lower coefficient of determination (R^2) value having less than 0.60 excluded from this study. Three final methods were selected and best method were compared using goodness of fit tests. In all the methods except BW directly measured was statistically different from zero ($p < 0.1$; paired t-test), meaning that they were not perfect agreement with the measured BW and that there is a statistically relevant difference (Table 2). However when the difference between actually measured body weight and

Schaeffer's method calculated body weight, was regressed on the mean of actual body weight and Schaeffer's method calculated body weight, in that the β coefficient was close to one ($\beta = 0.824$) and $p = 0.676$, indicating that there is a strong positive relationship between actually measured body weight and Schaeffer's method calculated body weight, as can be seen in the Bland-Altman plot in Fig 7. The vast majority (94%) of the difference between the two methods fall within the limits of agreement, indicating a good level agreement between the methods, despite the statistical difference. Furthermore, as shown in the graphical distribution of the data (Fig 3), there appears to be no trend in the difference between the actual calculated body weights at any particular range of body weight.

The methods separated by sex showed a difference in the indirectly calculated bodyweight compared than pooled sample analysis. The scatter plot was drawn for male, female and pooled measures of body weights calculated by direct and indirect methods. Fig 4, 5, 6 shows the comparison between actual bodyweight with body weights derived by Schaeffer's, Agarwal's and Lambourne formula methods. In Fig 4, 5, 6 letters a, b and c indicating male, female and pooled estimates respectively. The R^2 value of each method indicated in the figure itself, it represents the regression of mean value of each method over actual calculated body weight.

Descriptive statistics for sex, bodyweight and different morphometric measurements is tabulated (Table 3) and their distribution against body measurement shown in Fig 2. Irrespective of statistical differences between techniques, two techniques were deviate from the original weight on higher side in Bargur hill cattle live body weight. In Bargur



Fig 1: a- Body length (BL); b- Chest girth (CG); c- Height of withers (HW).

Table 1: Descriptive statistics (Mean $\pm$ SE) for sex, bodyweight and morphometric measurements.

N	Sex	BW, kg	BL, cm	CG, cm	HW, cm
11	Male	211.72 $\pm$ 7.80	119.0 $\pm$ 0.65	141.54 $\pm$ 1.66	119.90 $\pm$ 1.98
98	Female	203.80 $\pm$ 3.02	112.62 $\pm$ 0.07	136.60 $\pm$ 0.59	109.19 $\pm$ 0.50
109	Pooled	204.60 $\pm$ 2.82	113.27 $\pm$ 0.70	137.10 $\pm$ 0.57	110.27 $\pm$ 0.57

hill cattle breed, the pooled body weight estimates of Schaeffer's formula, Lambourne formula were significantly greater than the Weigh-bridge. In Schaeffer's formula males have comparatively higher weight than both female and actual weighbridge calculated body weight. The body weight estimated by Agarwal's technique was significantly lower than the actual body weight measured using standard Weigh-bridge.

Table 2: Spearman's correlation between body weight and morphometric measurements in bargur hill cattle.

	BW	BL	CG	HW
BL	0.690			
CG	0.800	0.571		
HW	0.276	0.265	0.401	

All correlations were significant at $p < 0.001$ BW-Body weight in kgs; BL- Body length in cms; CG- Chest girth in cms; HW- Height at withers in cms.

Method of agreement

In all methods except actual measurement weight, the mean difference was statistically differed from zero ($P < 0.01$; paired 't' test) meaning that they are not perfect agreement with actually measured body weight in Bargur hill cattle and there is a statistically relevant difference (Table 1). However, the difference between actual measured body weight and Schaeffer's formula method was regressed on the mean of actual and estimated the β coefficient was close to one ($\beta = 0.824$) and $p = 0.058$, indicating that there is no deterministic bias forwards lower or higher actual body weight from estimated method as can be seen in Bland-Altman's plot (Fig 7). The vast majority of the difference between the two methods fall within the units of agreement, indicating a good level of agreement between methods despite the statistical difference. In Fig 8 (Violin plots) Part a shown the comparison between the actual measured body weight and body weight derived by Schaeffer's formula, Part b shown the comparison between

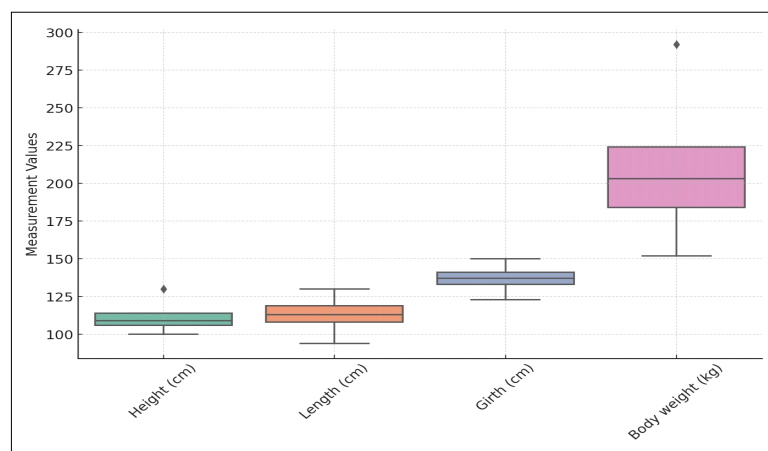


Fig 2: Data distribution of body weight and morphometric measurements of Bargur cattle.

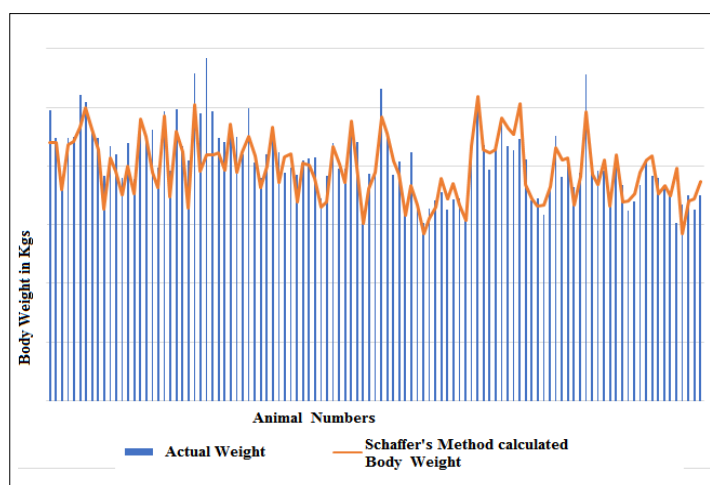


Fig 3: Comparison of actual and Schaeffer's techniques calculated bodyweights.

actual and estimated body weight by Agarwal's method and final part of the plot, Part c represents the comparison between actual and estimated body weight by Lambourne formula method.

The use of different measurements can be used indirectly predict the bodyweight of animals; several methods have been developed over the years. However, due genetic selection, this relationship can change (Heinrichs *et al.*, 2017). However, all body measures are correlated to some degree with body weight (Heinrichs *et al.*, 1992). Studies reported that, with different breeds of cattle (Lukuyu *et al.*, 2016) or after breed selection has occurred over a period of time (Heinrichs *et al.*, 1992), prediction equations do differ and appropriate equations must be used for a given population of animals. Breed of cattle significantly affected all linear body measurements and live weight, therefore selection method suited for of specific breed is essential.

The body weight of different sex of adult Bargur hill cattle estimated through indirect techniques were deviate from the true weight measured in Weigh-bridge. The deviation from the true weights were indicated in Table 2. Commonly available methods, the estimates are within ± 20 per cent, the body weight estimates of all techniques are within $\pm 20\%$ of true weight, which is acceptable for dosing with veterinary drugs (Williamson *et al.*, 1970 and Leach *et al.*, 1981).

Among techniques, Schaeffer's formula provides estimates closer to the true body weight and indicates the greater reliability of this technique in estimating the body weight of Bhutanese cattle (Wangchuk *et al.*, 2017). In our study also Schaeffer's formula appears to be a good estimate of live body weight. Good estimates of live bodyweights using linear measurements have been demonstrated in different species and breeds of livestock's (Thiruvankadan *et al.*, 2005; Mohammad *et al.*, 2012; Eydurán *et al.*, 2013 and Ali *et al.*, 2015).

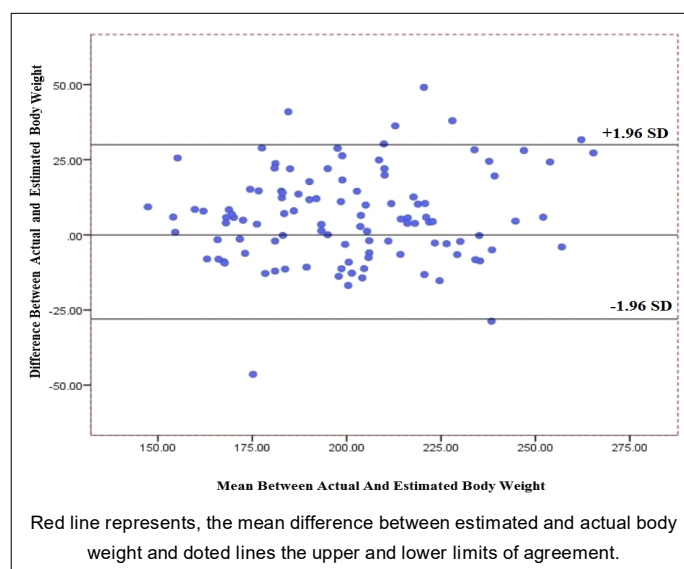


Fig 4: Bland-Altman's of estimated bodyweight (Schaeffers formula method) against actual bodyweight.

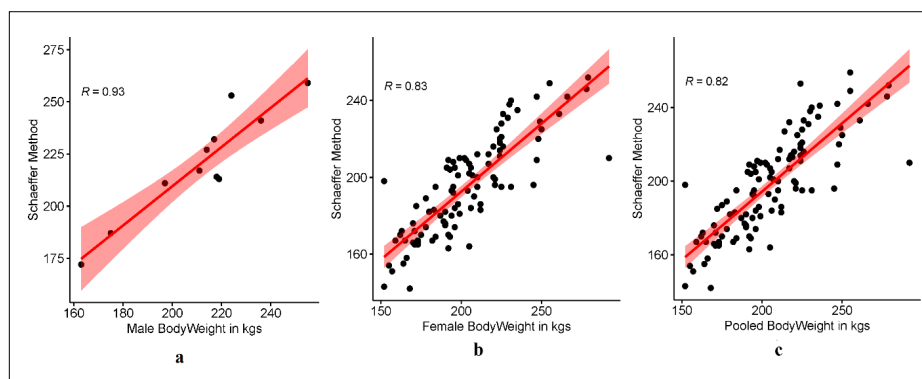


Fig 5: Scatter plot of direct method and Schaeffersformula derived bodyweights of Bargur hill cattle and its respective equation: $R^2=0.672$.

Among techniques, Schaeffer's formula provides estimates closer to the true body weight and indicates the greater reliability of this technique in estimating the body weight of Bargur cattle using correlation and regression method. It is having a deviation of only 3 percent from the actual true bodyweight in pooled samples. This results also follow the same experiment conducted in Bhutanese cattle (Wangchuk *et al.*, 2017). It has been shown that the weight estimation has greater variability in males (-8.82) and lesser variability in females (8.59) and it may due to different sample numbers of different genders. But in pooled samples it is 3.04 per cent only, it very closes to true value estimate. Hence Schaeffer's formula may be commonly used in Bargur cattle.

The Lambourne formula technique also gives the pooled sample estimates closer to the true body weight in Bargur hill cattle by variation of 3.26 per cent only. It suggests that Lambourne formula may provide reliable estimates in Bargur hill cattle, hence it may be used next to Schaeffer's formula for live weight estimation.

Even though Agarwal's formula is specifically meant for the Indian cattle that are reared in production and management systems which are different from that of the Bargur hill cattle. While Indian cattle production system is largely based on crop residues and concentrate feeding in majority of cattle breeds, but for the production system in Bargur cattle is largely based on forest grazing and transhumance system of management. Difference in

Table 3: Descriptive statistics (mean $\pm$ standard error) of bargur hill cattle body weights estimated by different techniques.

Method	Body weight (kg)			Deviation from true weight			Deviation per cent for Pooled
	Male (N=11)	Female (N=98)	Pooled (N=109)	Male	Female	Pooled	
Weighbridge (True weight)	211.72 $\pm$ 7.80 ^a	203.80 $\pm$ 3.02 ^b	204.00 $\pm$ 2.82 ^a	-	-	-	-
Schaeffer's formula	220.54 $\pm$ 7.88 ^a	195.21 $\pm$ 3.02 ^a	197.88 $\pm$ 2.53 ^a	-8.82	8.59	6.22	3.04
Agarwal's formula	289.90 $\pm$ 7.70 ^b	265.33 $\pm$ 2.57 ^c	267.81 $\pm$ 2.45 ^b	-78.18	-61.53	-63.81	- 31.28
Lambourne formula	220.27 $\pm$ 7.79 ^a	194.80 $\pm$ 2.56 ^a	197.33 $\pm$ 2.54 ^a	-8.55	9.0	6.67	3.26

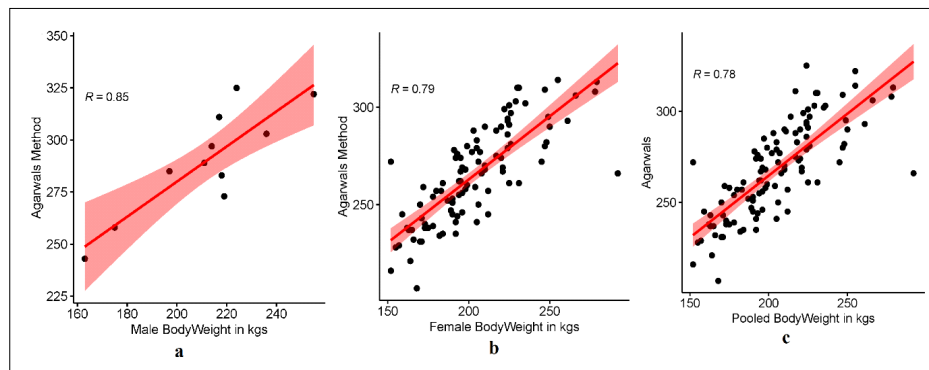


Fig 6: Scatter plot of direct method and Agarwal formula derived bodyweights of Bargur hill cattle and its respective equation: $R^2=0.608$.

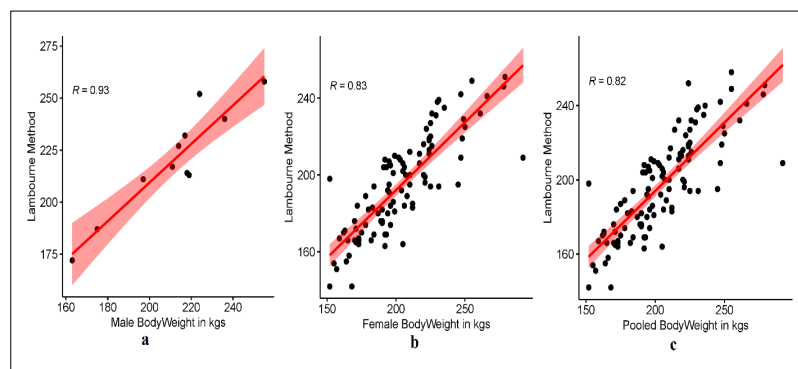


Fig 7: Scatter plot of direct method and Lambourne formula derived bodyweights of Bargur hill cattle and its respective equation: $R^2=0.672$.

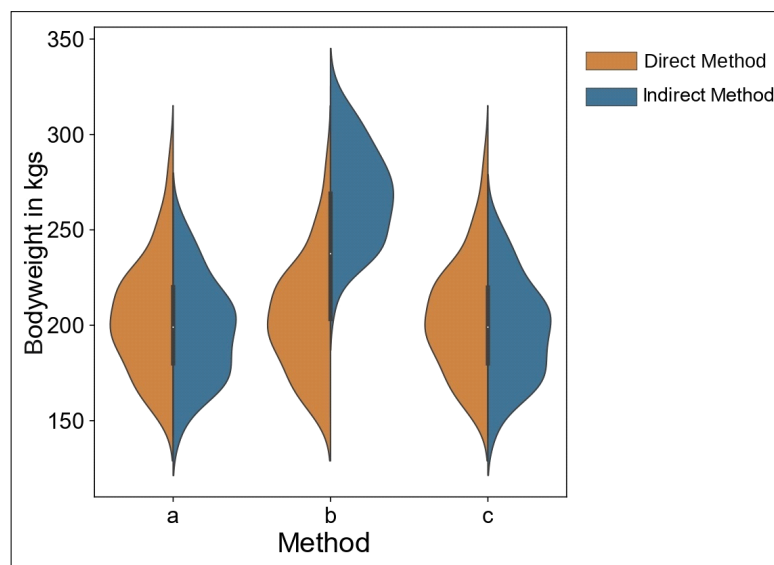


Fig 8: Violin plots of actual measured body weight against indirectly measured body weights by three different methods (a, b, c).

production systems has been reported to result in variations in cattle morphology including heart girth and body length (Kugonza *et al.*, 2011). On the contrary, the Agarwal's formula techniques provide overestimate of the bodyweight and suggests that these techniques are inaccurate with respect to Bargur hill cattle bodyweight measurement and also unreliable to field condition estimation. Because the production system in Bargur hill cattle is unique, largely based on forest grazing and these animals specially adopted for hilly conditions and also these animals are maintained in the migratory type of herding (Ganapathi *et al.*, 2012). Difference in production systems has been reported to result in variations in cattle morphology including heart girth and body length (Kugonza *et al.*, 2011).

The overestimates of these technique are explained by the fact that this technique may be used for other large size indigenous cattle and European cattle that are morphologically different from these hilly cattle. From the feeding standpoint, the heavier body weight has feed implications and would mean more feed demand and intake. Therefore, these techniques are likely to result in overestimation of feed and eventually increases the cost of production. The Bargur cattle breeding tract has been experienced with severe summer, for these time additional supplement of crop residues are necessary. For this estimation of the body weight is crucial for feed supplementation. Compared with the other larger livestock breeds in India, the body weight of Bargur hill cattle was definitely lower due to moderate body size and adaptation to hilly environment. Hence, it should be defined separately for live body weight estimation. Based on this only feeding and calculation of the drugs for treatment will be decided. Therefore, Schaeffer's formula method was considered as

the most accurate method of estimating accurate body weight in Bargur hill cattle.

CONCLUSION

In this study, bodyweight of Bargur cattle were estimated from the body measurements by three different indirect techniques. Apart from these three indirect body weight estimation techniques, Agarwal's formula provides high amount of body weight underestimate compared with the true weighbridge measured body weight, therefore, this techniques is not recommended and its use may be discontinued in Bargur hill cattle. The results indicated that Bargur hill cattle weight can be reliably estimated by Schaeffer's method to reliably assess the efficiency of marketing decision, drug dosing and feeding decisions. The relationship between morphometric measurements and body weights may depend on the genetic make-up of the population. Therefore, further studies to validate this method in different age group of animals would be beneficial to increase it robustness.

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Informed consent

All animal procedures for experiments were approved by the university.

Conflict of interest

The authors declare that there is no conflict of interest in this study.

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