ACCURACY OF ESTIMATES FOR LIVE BODY WEIGHT USING SCHAEFFER'S FORMULA IN NON-DESCRIPT CATTLE (*BOS INDICUS*), NILI RAVI BUFFALOES (*BUBALUS BUBALIS*) AND THEIR CALVES USING LINEAR BODY MEASUREMENTS

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ABSTRACT: The overall objective of the present study was to devise a method to improve the accuracy of live body weight (BW) estimation using the available information. For this purpose, in the first place 15 non-descript cows, four buffaloes and six calves were weighed on digital weighing platform (observed BW) or their weight was estimated using their morphometric measurements determined by the tape (estimated BW) in two seasons i.e. summer and winter. The data on morphometric measurements were used to predict the BW and subject to simple and multiple linear regression analyses. The relationships between the individual independent variable such as heart girth (HG) with BW were significant (P<0.001) and higher (R^2 = 0.65, 0.97 and 0.90 and r = 0.80, 0.98 and 0.95) in all cases for cattle, buffalo and calves, respectively than for diagonal body length (DBL). The multiple linear regression involving more than one independent predictor (e.g. HG and BL) improved this relationship (R^2 = 0.67, 0.98 and 0.94, P<0.001) for each of the cattle, buffalo and calves, respectively. In the second place, the association between estimated and observed BW were determined using simple linear regression in order to improve the estimation. The data of this experiment and those of published studies for buffaloes and calves were aggregated. Regression co-efficient of estimated vs. observed BW were 0.88, 0.78 and 0.82 and were highly significant (P<0.001, R^2 = 0.68, 0.94, 0.97 and r = 0.83, 0.97 and 0.98) for cattle, buffalo and calves, respectively. The Schaeffer's formula consistently overestimated live BW for smaller animals while the opposite was true for the heavier animals. HG may be the single best linear measurement for BW prediction for adult cows and buffaloes. Further, the results suggest that the farmers may use the Schaeffer's formula and equation developed in the present study to estimate live BW with high accuracy for routine farm practices, in the absence of weighing platform.

Key words: Accuracy of estimation, Body weight, Cattle and Buffalo, Regression analysis

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INTRODUCTION

Livestock owners and animal production professionals need to know the weight of the animals for several purposes including feeding, growth estimation, medication, breeding, as well as marketing age and provision of housing, keeping the welfare in mind. The most reliable information of body weight can be obtained by weighing equipment (e.g. weighing platforms, etc.). Large size commercial farms may harbor the facilities for live animal weighing, however, farmers with limited financial resources are unable to install modern weighing facilities. Live animal traders and farmers mainly use their visual appraisal for live weight estimation which can be biased due to human error (Machila *et al*., 2008; Abdelhadi *et al*., 2009).

The measuring tape method (Schaeffer's formula) is a cheap, easily accessible and more reliable than visual estimation, and it has been widely validated (Otte *et al*., 1992; Heinrichs *et al*., 1992; Dingwell *et al*., 2006; Yan *et al*., 2009). The measuring tape method uses body measurements such as heart girth (HG), diagonal body length (DBL) and/or body height which are regressed against the formula to estimate live body weight (BW) in most species of livestock (Otte *et al*., 1992; Tariq *et al*., 2013; Siddiqui *et al*., 2015). Msangi *et al*. 1999) reported that a single linear body measurement such as HG can be used for estimating the BW of all age groups of dairy cattle with great accuracy. For various buffalo breeds a high correlation between HG and BW was reported by Tariq *et al*. (2013) and Francis *et al*. (2002).

Live BW is affected by the season of the year, species, age, sex, breed and the status of the animal (lactation, pregnancy, etc.) (Fitzhugh *et al*., 1967) resulting in variation between the estimated and observed BW. In the field, those small biases in the prediction of BW may increase or decrease the commercial value of the animals (price). Schaeffer's formula for live BW estimations has been widely validated across many breeds of dairy cattle and produced highly reliable results in exotic cattle breeds (Otte *et al*., 1992; Dingwell *et al*., 2006). However, this formula may present large errors in estimating live BW in local breeds of cattle and buffaloes in Pakistan. These breed to breed differences may question the reliability of Schaeffer's formula for the said purpose. Hence, it is important to validate the existing Schaeffer's formula for weight estimation to include more data pertaining to local breeds.

The objectives of the present study were to evaluate the effects of species and season on body weight estimates, investigate the relationship between observed BW and individual or combined linear body measurements, and assess the association between estimated BW (tape method) and observed BW (scale method) and develop an equation to improve the accuracy of live BW estimation for the use of farmers and other stakeholders based on body measurements for cattle, buffalo and calves.

MATERIALS AND METHODS

Description of animals and diets: The animals used were maintained at University Livestock Farm of University College of Veterinary and Animal Sciences, The Islamia University of Bahawalpur, Pakistan and cared according to the instructions of Animal Care and Management Committee (Bio-Ethics and Experimental Use Committee, 2015). Fifteen adult cows (>3 years), six female young cattle calves (1-3 years) belonging to local breeds (*Bos indicus*, non-descript) and four Nili-Ravi buffaloes (>3 years) were included at random. All animals included in this study were non-lactating and non-pregnant. All animals had free access to water and feed during the whole trial period. Animals were stall fed in groups consuming 20 and 30 kg fresh green fodder for cows and buffaloes, respectively, 2 kg wheat straw and 0.5 kg wheat bran per animal per day to fulfill the maintenance and growing requirements.

Weight estimation procedure and prediction of BW from linear body measurements: Measurements were taken when the animals were standing squarely with all four legs equally distanced under the body and head at its normal upright position. Heart girth was taken through a measuring tape, drawn from a point slightly behind the shoulder blade, down to the 6^{th} rib position and under the body behind the elbow, as suggested by Pater *et al*. (2007) or as shown in Figure 1a. The average DBL was taken from the point of shoulder to the point of pin bone on each side as illustrated in Figure 1b to reduce bias in the measurements. The body weights were determined two times in a season e.g. winter (February-March) and summer (July-August) during consecutive days in morning and evening times, using cattle measuring tape (tape method) and digital weighing platform (scale method with measuring range 0-1000 kg, accuracy 0.1 kg). The same person took measurements with both methods to exclude human factor related errors, and all measurements were taken before feeding. Body condition scoring was simultaneously performed on each animal by visual appearance on 1-5 scale with 0.5 score interval. The time required for weight estimation/measurement using both methods was about 20 minutes.

The data on morphometric measurements were used to predict the BW and subject to simple and multiple linear regression analyses. Akaike Information Criterion (AIC; Snipes and Taylor, 2014) was used to find the suitable number of predictors of BW from linear body measurements.

Association between estimated and observed body weight: To determine the association between the observed and estimated BW, data on buffaloes of this experiment and those of Tariq *et al*. (2013) from group 2 (>3-8 years, n=94) and 3 (>8 years, n=33) and Khan *et al*. (1978) for all age groups (n=350) were combined. For calves, the data of this experiment and those of Tariq *et al*. (2013) for age group 1 (1-3 years, n=84) were utilized.

Data treatment and statistical analysis: The measured parameters values for HG and DBL were used to estimate the BW using the following formula:

$$(Estimated\ BW) = \frac{(HG)2\ \times DBL}{300} \quad \text{(Johnson } et\ al., 1939\text{)}$$

Whereas, HG = Heart girth, DBL = Diagonal body length

The collected data were checked for any outliers and were subject to General Linear Model. The relationships between all parameters were determined using simple and multiple linear regression analysis using MINITAB® statistical software version 13.1.1. The results were declared significant when P was ≤0.05. The following regression models were employed:

Observed BW = α + β (HG) + Ɛ   Equation 1
Observed BW = α + β (DBL) + Ɛ   Equation 2
Observed BW = α + β1 (HG) + β2 (DBL) + Ɛ   Equation 3
Observed BW = α + β (estimated BW) + Ɛ   Equation 4

Whereas, α = intercept, β = regression co efficient, BW = body weight, HG = Heart girth, DBL = Diagonal body length

RESULTS AND DISCUSSION

The observed and estimated body weight ranged from 261.0 to 422.5 kg and 232 to 415 kg for cattle, from 502.5 to 600.5 kg and 530 to 614.5 kg for buffaloes, from 116.0 to 149.0 kg and 125 to 136 kg for calves (table-1). The values of HG and DBL ranged from 154.9 to 179.9 cm and 127.0 to 145.1 cm for cows, from 195.6 to 210.8

cm and 40.9 to 152.4 cm for buffaloes, and from 117.8 to 122.1 cm and 97.3 to 98.8 cm for calves.

The animal species and season of the year significantly influenced ($P<0.001$) animal BW and body measurements. In general, for all species, the animals having an observed BW of 390 kg or more showed a weight change in the range of 2 to 24 kg in winter while those having an observed BW below 390 kg showed a difference of 1 to 16 kg (table-2). The average BW differences between species (adult animals) and seasons were 160 and 13 kg, respectively.

Average values of HG and DBL for buffalo are higher than reported by Tariq *et al*. (2013). The values of both variables from the present study are also higher than those of Milla and Mahjoub (2012) for Nilore cattle and calves but lower than those of Khan *et al.* (1978) for Nili Ravi buffaloes. These differences might be due to age and nutritional factors (Tariq *et al*., 2013). For individual animal noticeable differences can be seen for estimated and observed values using both methods.

It was observed that animals lost an average 13 kg weight during summer. Further, it was noticed that the animals having a live BW of 390 kg or above lost more than those animals with less than 390 kg BW. Contrary to these results, Spencer *et al*. (1988) reported that BW was higher during summer than in winter. They also described that when the sex of the animal was included as a factor with respect to BW estimation, the predictions were even poorer for females compared to males probably, because the females experience changes in body condition scoring as a result of many stress conditions like calving, lactation, different managment practices, etc.

Prediction of live body weight using linear body measurements: The single and multiple linear regressions between the observed BW, HG and DBL alone and in combination (HG plus DBL) were calculated (table-3). The results showed that the correlation coefficient between BW and HG varied from 0.80 to 0.98 and was the highest for buffaloes. All the values were statistically significant ($P<0.001$). The correlation coefficient between BW and DBL varied from -0.63 to 0.47 and all the values were non-significant except for cattle; the BW and DBL showed a negative correlation for buffalo. The co-efficients of determination for HG were higher (R^2 = 0.65, 0.97 and 0.90, $P<0.001$) than that for DBL when HG was alone used to predict observed BW. These higher values explained that BW can be predicted with high accuracy using a single body measurement like HG.

Many published studies (Nesamvuni *et al*., 2000; Bagui and Valdez, 2007; Siddique *et al*., 2015) supported the observation of using HG as single linear measurement in adult cattle. The results of present study for adult buffalo also coincide with the results of Tariq *et al*. (2013) and Khan *et al*. (1978) who reported that highest accuracy of BW estimation was achieved from HG measurements. However, literature about the prediction of BW using HG in calves is quite equivocal. It was observed that HG measurements can equally accurately predict BW in calves as those in adult animals. Contrary to present study findings, results of many studies revealed that the highest accuracy in prediction of BW using single linear measurement can be achieved with DBL instead of HG. This is because there is highly positive correlation in DBL-estimated BW in growing animals (Naz *et al*., 2006). The same was observed by Davis *et al*. (1993). They reported that R^2 for DBL relative to BW decreases but that of HG relative to BW increases as animal matures because small animals have both a low BW and a small thoracic girth while the opposite is true for large animals as HG tends to increase significantly as the animal matures (Otte *et al*., 1992). The regression equation was highly significant ($P<0.001$) for all heart girth-estimated BW correlations for all species.

In order to improve the accuracy of prediction of observed BW from linear body measurement, multiple linear regression equations were developed. Interestingly, a combination of HG and DBL as predictors significantly improved R^2, reduced SE of estimate and AIC in general for all species of animals. It is also apparent that the response in the above said parameters was more prominent in calves than in adult animals. Contrary to current findings, Milla and Mahjoub (2012) reported that HG and DBL show no predictable differences in growing calves.

While comparing accuracy of prediction of BW for same value of HG, we observed that the cows exhibited less accuracy compared to buffaloes. Many plausible reasons can be quoted here; the compact, wide and deep body of the buffalo as compared to that of cattle. Hump variation due to cross bred animals and age, brisket fat and dewlap may vary the results. Therefore, species to species effect on prediction of BW should be included in future research. But for the simplicity to the prediction of BW in mature animals, single linear body measurement i.e. HG should be considered because it explained more than 64% of the variation among all predictors and species.

The results of the present study indicated that the value of regression co-efficient significantly improved with multiple linear regression models for cattle and calves, but had no effect on buffalo. By close interpretation it was estimated that for every 1 cm increase in HG of cattle results in a corresponding increase of 4.24 kg whereas every 1 cm increase in each HG and DBL results in a corresponding increase of 3.89 Kg BW with constants shown in table-3. Similarly, a unit increase in HG of calves corresponds to a 5.88 Kg increase in animal BW while including both HG and DBL improves the regression co-efficient to a value of

5.68 Kg. However, the value of regression co-efficient reduced for buffalo when both body measurements were included in the model (4.37 Vs 4.79).

Association between estimated and observed body weight: Association between both methods varied as the data was interpreted (table-4). In the present experiment, estimated and observed BW were highly correlated (r = 0.83, 0.96 and 0.72: P<0.001) for cattle, buffalo and calves, respectively. The regression co-efficient valued 0.88, 0.78 and 0.93 for cattle, buffalo and calves, respectively when simple linear regression was used (R^2 = 0.68, 0.92, 0.75: P<0.001).

Average weight differences (estimated-observed) for cattle were 24.7 Kg (range from -24.3 to 80.1), for buffaloes were 8.37 Kg (range from -77.1 to 96.5) and for calves were 17.8 Kg (range from 24.5 to 104.9) and the overall co-efficient of variation for observed vs. estimated BW were 8.0, 1.0, and 4.0% for cattle, buffalo and calves, respectively and these were slightly improved after the corrective regression equation was employed. However, Otte *et al*. (1992) showed that the variability between-method differences tended to increase as the animals became heavier. It was interesting to know that the co-efficient of variation was reduced to zero when the data were regressed against a live BW of 153 Kg for cattle, 453 Kg for buffalo and 109 Kg for calves. The Schaeffer's formula consistently overestimated live BW for smaller animals while the opposite was true for the heavier animals.

Although weight estimates by both methods were highly correlated, still a 100% accurate estimation of BW in live animals is not possible owing to limitation of current methods of data acquisition as well as factors already described responsible for weight changes. Luckily, a rough approximation to the nearest possible values can be achieved with the linear body measurements for various species of the animals. It should be noted that the considerable differences for individual animals can occur between weight estimates by the both methods. This between animal variations can be reduced by including more number of experimental animals. It is further advised that in trials where BW is an independent variable the large differences in estimated and observed BW may be misleading and reduce the usefulness of tape method. For example, the classification of heifers on the basis of BW into groups with larger vs. small intervals from service to conception as suggested by Otte *et al.* (1992). While in the trials where the BW is dependent variable such as weaning weight of animals maintained at various dietary treatments, the larger differences between estimated and observed BW do not produce noticeable errors in interpreting data.

Table-1. Mean values and standard deviation (SD) of body measurements, estimated and observed body weight (BW) of cattle, buffalo and calves.

Variables	Cattle	SD	Buffalo	SD	Calves	SD
N	15		04		06	
n	64		08		12	
HG	165.5	8.64	200.5	7.57	121.3	2.59
DBL	136.6	4.35	147.3	3.90	91.6	10.57
Predicted BW[1]	347.3	41.75	547.6	33.00	131.9	17.08
Observed BW[2]	333.7	43.22	542.6	33.70	136.5	14.79

N = no. of animals, n = no. of observations (most of the animals had weight recording for more than three time during the whole experiment), HG = heart girth (cm), DBL = diagonal body length (cm), BW = body weight (kg)

[1] Estimated BW by the formula developed by Schaeffer (Johnson, 1939)

[2] Observed BW by scale method in this study

Table-2. Least squares means and standard error of the mean (SEM) for estimated and observed body weight (BW) of cattle, buffalo and calves as affected by species of the animal and season of the year.

Variables	Cattle	SEM	Buffalo	SEM	Calves	SEM	Significance	
							Species	Season
HG	168.2	2.09	200.5	2.71	122.0	2.40	<0.001	<0.001
DBL	137.3	1.26	147.3	1.62	94.7	1.45	<0.001	0.014
Estimated BW[1]	347.3	10.21	547.6	14.09	131.8	11.73	<0.001	<0.001
Observed BW[2]	333.7	510.91	542.6	14.14	137.46	12.52	<0.001	<0.001

For abbreviations and other terms, see Table 1

SEM = Standard error of the mean

Table-3. Prediction of body weight from single linear body measurements for cattle, buffalo and calves using single and multiple linear regression equations (Equations 1 through 3).

Regression parameters	HG vs. observed BW			DBL vs. observed BW			HG and DBL vs. observed BW		
	Cattle	Buffalo	Calves	Cattle	Buffalo	Calves	Cattle	Buffalo	Calves
Intercept (α)	-377	-334	-580	-345	1348	-64	-530	-587	-598
Regression coefficient (β)									
HG	4.24	4.37	5.88	---	---	---	3.89	4.79	5.68
DBL	----	---	---	4.95	-5.46	0.766	1.54	1.14	0.45
P-value	<0.001	<0.001	<0.001	<0.001	0.092	0.266	<0.001	<0.001	<0.001
R^2	0.65	0.97	0.89	0.23	0.40	0.12	0.67	0.98	0.94
r	0.80	0.98	0.95	0.48	0.63	0.35	---	---	---
SE	25.88	6.64	4.95	38.25	28.19	14.53	25.43	6.25	4.06
AIC	418.4	31.9	40.2	468.4	55.1	66.0	417.1	31.6	36.2

For abbreviations and other terms, see Table 1

R^2 = co-efficient of determination, r = Pearson correlation, SE = standard error of estimate, AIC = Akiake Information Criterion

Table-4. Association between estimated and observed body weight using simple linear regression model.

Parameters	**Simple Linear Regression (Equation 4)**		
	Cattle	Buffalo	Calves
Descriptive statistics			
N	15	477	90
n	64	485	96
HG	168.2	276.3	134.6
DBL	137.3	200.7	109.4
Estimated BW	347.3	491.0	192.4
Observed BW	333.7	482.6	179.0
Regression parameters			
Intercept (α)	18.29	98.25	19.94
Regression coefficient (β)	0.88	0.78	0.82
P-value	<0.001	<0.001	<0.001
R^2	0.68	0.94	0.97
R	0.83	0.96	0.98
SE	24.62	23.2	11.43
COV	0.08	0.01	0.04
COV after	0.07	0.01	0.04

N = no. of animals, n = no. of observations, R^2 = co-efficient of determination, r = Pearson correlation, SE = standard error of estimate, COV = Co-efficient of variation before the regression modeling, COV after = Co-efficient of variation after the regression modeling

Figure-1a. Image showing linear body measurements represented as diagonal body length

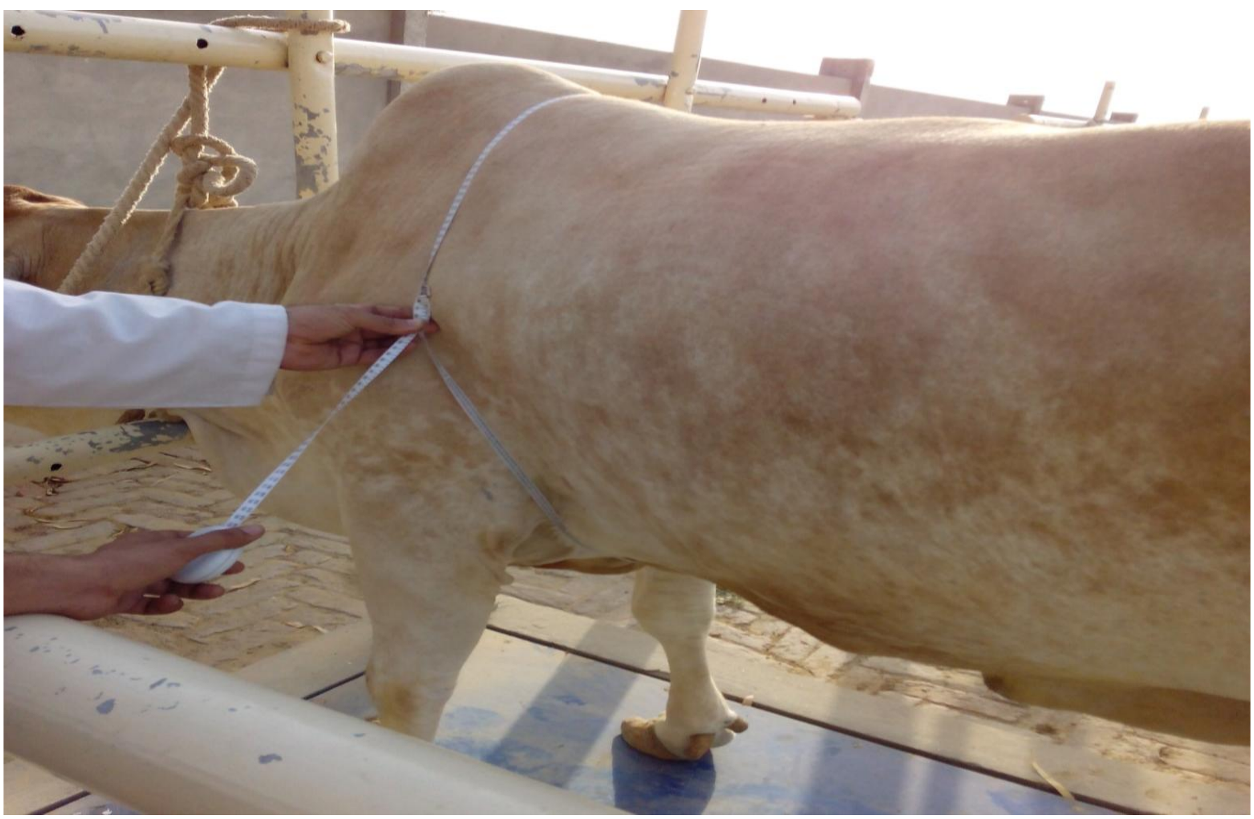

Figure-1b. Image showing linear body measurements represented as heart girth

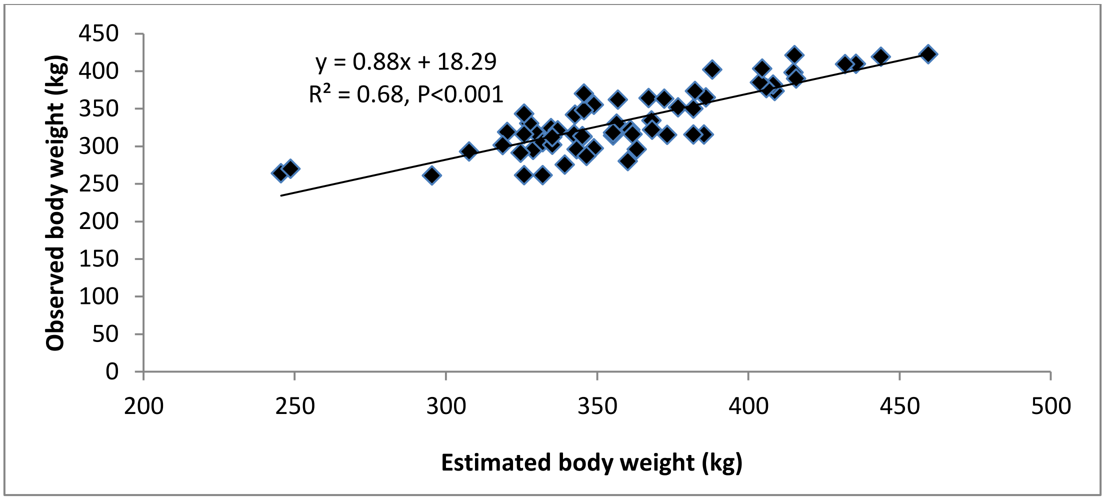

Figure-2a. Data showing an association between estimated and observed body weights for cattle.

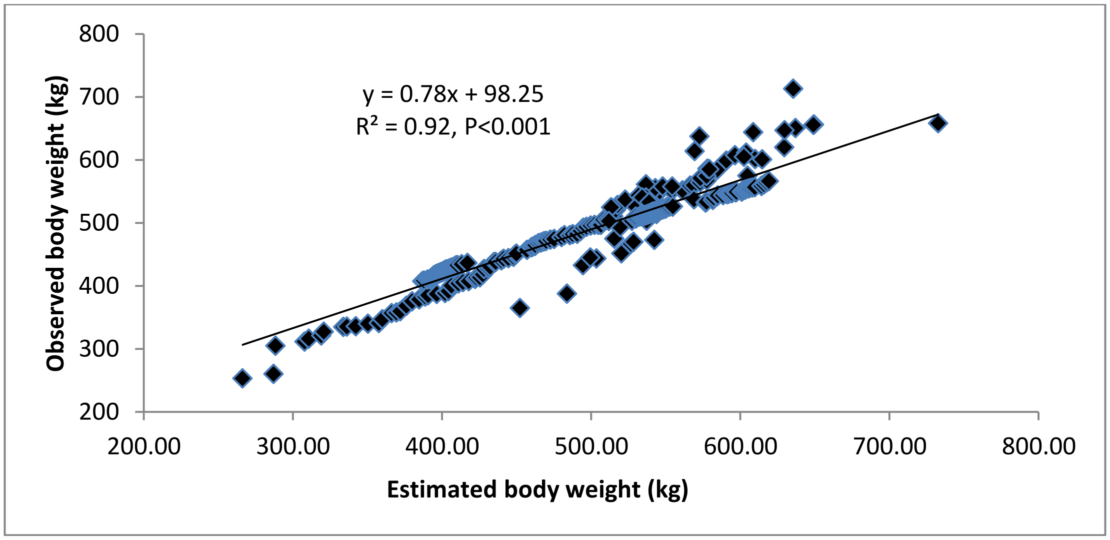

Figure-2b. Data showing an association between estimated and observed body weights for buffalo

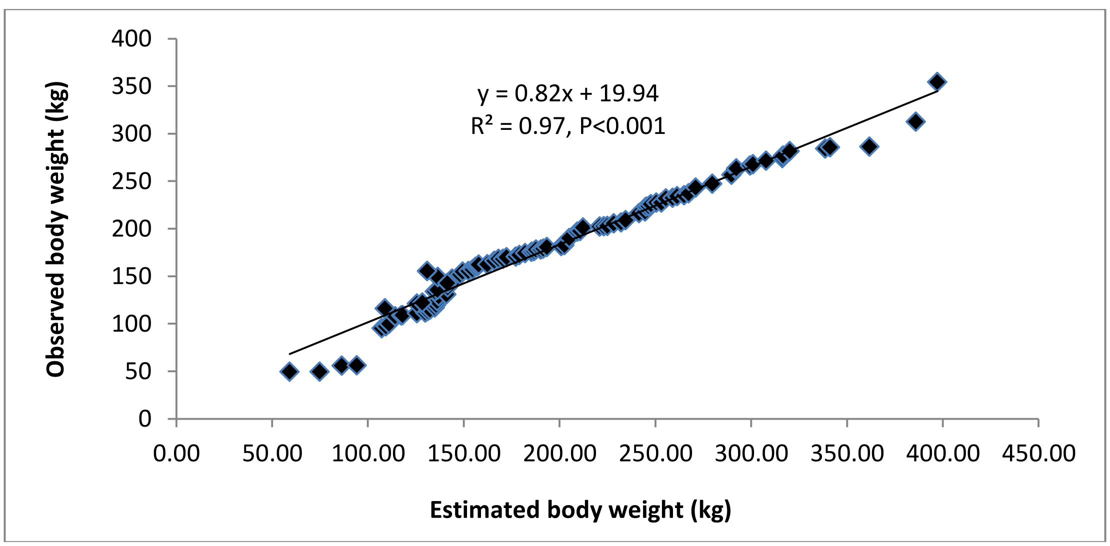

Figure-2c. Data showing an association between estimated and observed body weights for calves.

Conclusions: It was concluded that body weight in animals can be predicted with acceptable accuracy by linear body measurements such as heart girth as the sole predictor.

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