Relationship between body measurements and Body weight in Bali *(Bos javanicus)* and Bali cross *(Bos taurus x Bos javanicus)* bulls in Muaro Jambi Regency of Indonesia

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Abstract

Body measurements could be used for predicting body weight of beef cattle if the weighing scale was not available. Four measurements consisted of body weight at 2PPI (BW), body length (BL), heart girh (HG) and withers height (WH) were applied to Bali (36 bulls) and Bali cross (80 bulls) at one year age. Bali cross genetic structure consisted of Limousine x Bali (44 bulls) and Simmental x Bali (36 bulls). Simple and multiple linear regression models were done using SPSS 16.0 software. Linear regression models were fitted with BW as the dependent variable and body measurements (BL, HG and WH) as the independent variables to obtain the relationship between BW and body measurements. Lower of BW and body dimensions (BL, HG, WH) means were showed in Bali. Body weight and dimensions of Bali cross from Simmental and Limousine straws were similar (P < 0.01). Moderate coefficient of determination values (0.40 to 0.70) were found in simple linear regression using HG alone as independent variable in both breeds (Bali and Bali cross). Non-collinearity was found in each variable and mention that each variable could be included to the linear regression analysis. Commonly, prediction of BW based on HG were not significantly different (P > 0.05) when compared to actual BW in both breeds. It was concluded that HG was the best predictor of BW estimate for both breeds and HG alone contributed 49% (Bali) and 53% (Bali cross) of the variation in the BW.

Keywords: Bali bulls, Bali cross bulls, body measurements, body weight, linear regression

Introduction

Bali cattles *(Bos javanicus)* is one of Indonesian beef cattle that plays major role for beef production Improvement of growth traits such as weaning and yearling weight are an increasingly important breeding goal in beef cattle. This cattle breed is yet to be improved with regard to production performance parameters for higher meat yield under stressful tropical conditions such as low quality nutrient feed, tropical climate, diseases and parasites. As this is the native cattle in Indonesia, there should be intensive genetic improvement by the government (breeding centre) and the breeders to increase the mean performance of body weight parameters. Since 1990 *Bos taurus* straws (Limousine and Simmental) were introduced for genetic improvement in Bali cows by government. Most Bali cross *(Bos taurus x Bos javanicus)* cattles are located in the rural areas of Indonesia specifically in Muaro Jambi Regency, Jambi province and owned by rural households, including farmers and minor business owners with small herd size practising traditional feeding and management system.

Often, the marketing of animals is based on visual assessment, while drugs are administrated mostly by estimation, because the use of live weight criterion in feeding, marketing and drug administration requires a weighing scale, which is expensive and not readily affordable by many small rural households. Besides, most farmers do not have the training to use the weighing scales properly. Several studies have been carried out to develop methods of estimating the live body weight of cattle in Indonesia using formulae derived from body measurement (Gunawan and Jakaria, 2010; Wijono et al., 2007). Body measurements are simple and easily measured variables for estimating the live weight, although the derived prediction equation using body measurements to estimate body weight is unlikely to be more accurate than direct measurement of body weight (using a weighing scale) due to errors in the location of reference points and the anatomical distortions of muscle tone produced when the animal changes position or posture during the procedure of body measurements.

However, body measurements have been used to evaluate breed performance and characterize animals (Warwick et al., 1990), though general studies have considered only heart girth (HG) or may also include body length (BL) and withers height (WH) in developing predictive equations. The heart girth measurement has been reported to have high correlation with body weight in many breeds of cattle (Goe et al., 2001). High correlation between heart girth and body weight were also found in Bali cattle (Gunawan and Jakaria 2010), Ongole grade cows (Paputungan et al., 2013), male Kamphaengsaen beef cattle (Sawanon et al., 2011) and Tanzania Shorthorn Zebu cattle (Kashoma et al., 2011). The present study was therefore aimed at establishing relationship between body measurements and body weight of Bali and Bali cross cattles for managerial decisions in rural areas of Indonesia.

Materials and Methods

Research site and animals

The research was carried out in reputed private cattle ranch at Muaro Jambi Regency, Jambi Province, Indonesia. The area is situated at along latitude 10.511'20.011 S and longitude 1030.151'1040.301 E about 30-80 meters above the sea level. The climate is hot with temperature 31.55±0.56 ^{o}C with rainfall occuring 175.31±67.00 mm/day. This research administered of 44 bulls of Limousine x Bali (LB), 36 bulls of Simmental x Bali (SB) and 36 bulls of Bali, randomly selected from one visit survey to the local farmers.

General management

The bulls were managed under a traditional system, in which they freely grazed on the natural range land during the day and return to pens built from local materials in the evening where their feeding was supplemented with whole grained and dry grass forage. Fresh water was given ad libitum.

Parameters measured

Linear body measurements such as withers height (WH), body length (BL) and heart girth (HG) were measured in centimeters (cm) using caliper, whereas body weight (BW) was determined in kilograms (kg) using a digital weight scale. All bulls age in this study have two pairs of permanent incisors (2PPI). The measurements were followed to Pandir et al. (2011) and taken on each animal (Figure 1). Withers height measured with a stick-ruler as the distance from the surface of the platform to the dorsal point (*Os vertebrae thoracalis III*) of the withers. Body length measurements (using a tape) of the distance between the point of the shoulder (*Tuber humerus* on *Os humerus*) and the pinbone (*Tuber ischiadicum* on *Os coxa*). Heart girth measured with a tape measure as circumference of the chest just behind the foreleg (*Os costa V*).

Statistical analysis

Descriptive statistics including means, standard deviation (SD), coefficient of variance (CV), maximum and minimum values of the continous data were calculated. Pearsonís correlation coefficient (r) among body measurements were calculated in each breed. Steel and Torrie (1995) explained that the r value could be positive and negative. The r value consisted of some categories such as very low (0.00 to 0.20), low (0.20 to 0.40), moderate (0.40 to 0.70), high (0.70 to 0.90) and very high (>0.90).

Seven equation models were established in this study and consisted of simple and multiple linear regeression. Linear regression equation with highest coefficient of determination (R^2) and lowest mean of square error (MSE) values were the best equation for BW preciction. The category of R^2 are similar to r value and also positive or negative (Steel and Torrie, 1995). The comparison between actual and predicted BW from each linear regression models were estimated by T-test

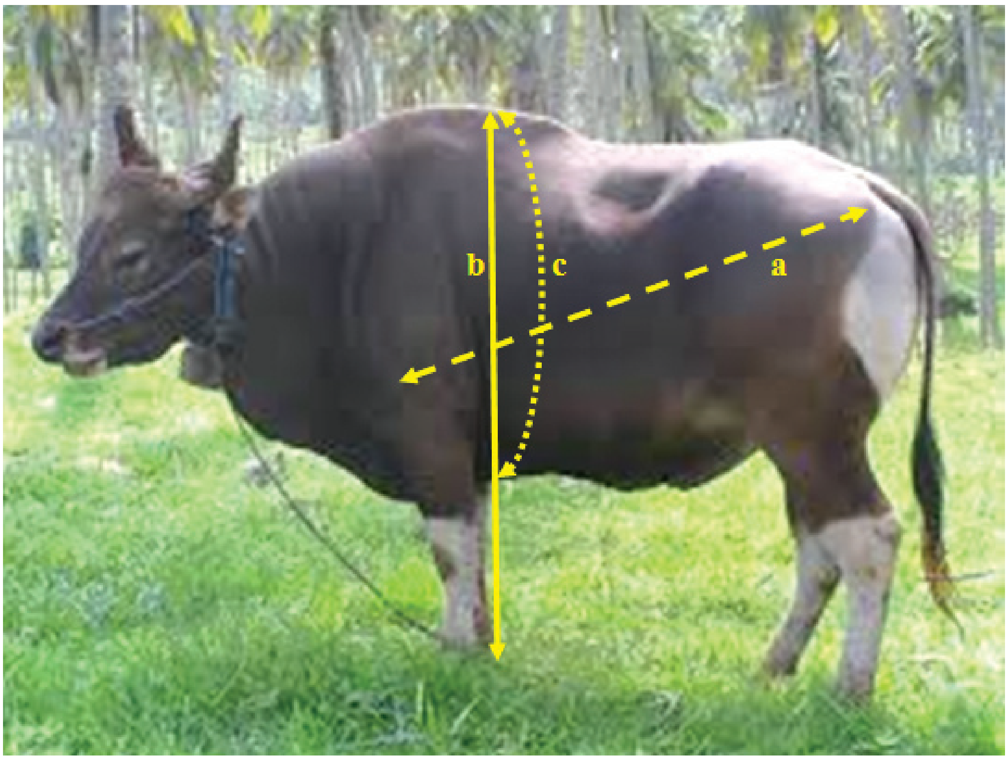

Figure 1. Linear body measurements scheme of Bali bull. a) body length; b) withers height; c) heart girth (circumferance)

analysis. The linear regression equation were included in the following model (Steel and Torrie 1995):

$$Y = a + bi\ Xi + E$$

Where: Y = body weight (BW), the dependent variable; a = constanta or intercept; bi = regression coefficient of the i th independent variable; Xi= the value of the ith independent variable. Such that: X^1 = body length (BL); X_2 = heart girth (HG); X_3 = withers height (WH); E = standard error of regression.

Collinearity analysis were used in this study for detecting the correlation among independent variables (when the data distribution is not normal in some independent variable (BL, HG and WH). Detecting collinearity of body measurement in this study based on variance inflation factor (VIF) and tolerance (T) values. A variable suggested to collinearity when VIF > 10.00 or T < 0.10. All statistical analysis above were calculated using Microsoft Office Excel 2007 and SPSS 16.0 software. A collinearity variable should be excluded from linear regression analysis for reduce the error (MSE) in the linear regression equation. The VIF and T equations were included as follow (Yakubu, 2009):

$$VIF = \frac{1}{1-R^2} \qquad T = 1-R^2$$

Where: VIF = variance inflation factor; T = tolerance; R^2 = coefficient of determination.

Results

Body measurements

Means of BW, BL, HG and WH in Bali bulls were lower than Bali crossbred (Table 1). The average of BW in SB breed was higher than LB breed, Meanwhile body dimensions in LB breed was higher than SB breed. Overall coefficient of variation (CV) for all traits were moderate (0.10 < CV < 0.20). Coefficient of variation value for BL were low (0.02) in SB breed and high (0.21) in LB breed. Highest maximum value of body dimensions were reached by LB breed and the lowest values reached by Bali breed. Research showed that maximum value in all traits for Bali breed were higher than SB breed. It was indicated that genetic improvement for Bali cattle could be done through selection program.

Table 1. Mean of body weight and body measurements for Bali and Bali cross bulls

Breeds / Parameters	BW	BL	HG	WH
Limousine x Bali (N = 44)				
Mean	176.80[a]	113.93[a]	152.57[a]	110.45[a]
SD	29.27	24.42	29.92	20.10
CV (%)	16.56	21.43	19.61	18.19
Minimum	101.00	87.88	88.12	87.12
Maximum	256.55	189.88	212.23	187.78
Simmental x Bali (N = 36)				
Mean	186.55[a]	109.97[a]	146.80[a]	105.90[a]
SD	34.14	2.57	20.83	2.23
CV (%)	18.30	2.34	14.19	2.11
Minimum	110.12	106.05	87.78	102.32
Maximum	207.00	114.77	160.52	109.56
Bali (N = 36)				
Mean	158.04[b]	99.10[b]	131.15[b]	96.86[b]
SD	25.93	12.95	24.18	12.06
CV (%)	16.41	13.07	18.44	12.45
Minimum	96.66	88.15	88.79	86.54
Maximum	210.13	145.55	189.78	145.55

Means in the same column with different superscript differ significantly (*P* < 0.01); BW= body weight (kg); BL= body length (cm); HG= heart girth (cm); WH= withers height (cm); SD= standard deviation; CV= coefficient of variation;

Pearson's correlation coefficients

Research showed that the BW and body dimensions of cattle which sired by Bos taurus breeds (Limousine and Simmental) were similar and could be grouped into Bali crossbred group. Pearson's correlation coefficient (r) value between BW and HG in both breeds were high as reported in Table 2. The r values between BW and WH in both breeds were low. The r value between BW and BL in both breeds were moderate. Heart girth could be used as independent variable for predicting BW through simple linear regression model because of high r value between BW and HG.

Table 2. Pearson correlation coefficients between variables of Bali and Bali cross bulls

Breeds / Variables	BW	BL	HG	WH
Bali cross (N = 80)				
Body weight (BW)	1.00	0.41**	0.73**	0.32**
Body length (BL)	-	1.00	0.51**	0.89**
Heart girth (HG)	-	-	1.00	0.41**
Withers height (WH)	-	-	-	1.00
Bali (N = 36)				
Body weight (BW)	1.00	0.48**	0.70**	0.33**
Body length (BL)	-	1.00	0.64**	0.80**
Heart girth (HG)	-	-	1.00	0.51**
Withers height (WH)	-	-	-	1.00

**(correlation is significant at $P < 0.05$)

Detecting collinearity

Result showed that only few variable have normal distribution data in both breeds. Furthermore, collinearity analysis was important in this study to investigate the collinearity among variable within high r value (Aziz and Sharabi, 1993). The best regression equation was occured if no intercorrelation (non-collinearity) among independent variable. Based on Table 2, the r value between BL and BW is high (>0.80) and might be risk to collinearity. Furthermore, VIF and T values on each variable were showed non-collinearity (Table 3). It was concluded that three variables that used in this study could be used to predict the BW in both breeds.

Table 3. Varian inflation factor (VIF) and tolerance (T) values for the body measurements

Breeds / Variables	VIF	T	Remarks
Bali cross			
Body length	5.228	0.191	Non-collinearity
Heart girth	1.360	0.735	Non-collinearity
Withers height	4.658	0.215	Non-collinearity
Bali			
Body length	3.444	0.290	Non-collinearity
Heart girth	1.703	0.587	Non-collinearity
Withers height	2.722	0.367	Non-collinearity

Simple and multiple linear regression

Research showed that coefficient of determination (R^2) value in simple linear regression C model (HG as independent variable) was higher than other body dimensions (Table 3). Coefficient of correlation (r) and R^2 values in C model were similar to E, F and G models in Bali crossbred. Moderate value of R^2 ($0.40 < R^2 < 0.60$) and high value of r ($0.60 < r < 0.80$) were found in those models for both breeds. Using HG as independent variable (R^2 = 0.53 and r = 0.73) through simple linear regression (model C) was more accurate to predict BW than other body dimensions in Bali crossbred.

Table 4. Simple and multiple regression models for predicting live weight (dependent variable) from linear body measurements (independent variable) in Bali and Bali cross bulls

Breeds / Models	Independent variables	Intercept	Regression coefficient			MSE	R^2	Sig.
			WH	BL	HG			
Bali cross (N = 80)								
Model A	WH	108.74	0.67	-	-	916.81	0.10	0.004
Model B	BL	101.46	-	0.71	-	849.94	0.17	0.000
Model C	HG	49.37	-	-	0.88	481.33	0.53	0.000
Model D	WH, BL	112.52	- 4.21	1.02	-	851.99	0.18	0.001
Model E	WH, HG	45.34	0.06	-	0.87	487.00	0.53	0.000
Model F	BL, HG	43.83	-	0.09	0.85	485.38	0.53	0.000
Model G	WH, BL, HG	47.88	- 0.14	0.20	0.84	490.74	0.53	0.000
Bali (N = 36)								
Model A	WH	90.20	0.70	-	-	618.57	0.11	0.053
Model B	BL	62.30	-	0.97	-	530.78	0.23	0.003
Model C	HG	59.44	-	-	0.75	351.69	0.49	0.000
Model D	WH, BL	70.29	- 0.34	1.22	-	540.30	0.24	0.010
Model E	WH, HG	64.96	- 0.09	-	0.77	361.48	0.49	0.000
Model F	BL, HG	53.54	-	0.11	0.71	361.09	0.49	0.000
Model G	WH, BL, HG	61.19	- 0.33	0.35	0.71	366.19	0.50	0.000

WH= withers height; BL= body length; HG= heart girth; N= number of observation; MSE = mean square error; R^2 = coefficient of determination; Sig.= significance

The comparisson between predicted and actual BW for each models were not different significantly ($P > 0.05$) in both breeds (Table 4). Overall means, standard deviation (SD), coefficient of variation (CV) for each models were similar in both breeds. Moderate R^2 value in both breeds could be used for predicting BW in both breeds. The average of BW in Bali crossbred (LB and SB) was 181.68 kg and similar to predicted BW in all models.

Table 5. Difference between the actual and predicted body weights using several regression models ($R^2 \geq 0.49$) in Bali and Bali cross bulls

Breeds / Models	Mean (kg)	SD	CV (%)	Range	Sig.
Bali cross (N = 80)					
Model C	181.35	23.08	7.86	126.62 - 236.13	0.096
Model E	182.32	23.20	7.86	127.23 - 241.25	0.094
Model F	181.40	23.17	7.83	126.64 - 240.32	0.085
Model G	181.11	23.09	7.85	123.45 - 238.38	0.082
Actual	181.18	31.73	17.51	101.00 - 256.55	-
Bali (N = 36)					
Model C	157.80	18.14	11.49	126.03 - 201.78	0.249
Model E	157.22	18.10	11.51	125.14 - 201.31	0.238
Model F	157.55	18.12	11.50	126.87 - 205.44	0.253
Model G	157.03	18.25	11.63	125.34 - 205.44	0.245
Actual	158.04	25.93	16.41	96.66 - 210.13	-

N = number of observation; SD = standard deviation; CV= coefficient of variation; Sig. = significance

Discussion

Body weight and dimensions of LB and SB breeds were similar ($P > 0.05$) and may caused by similar sires group (Bos taurus). Depison (2010) reported that yearling weight (kg) in LB and SB at Batanghari regency, Jambi province, Indonesia were 176.80 ± 29.27 kg and 179.21 ± 26.66 respectively and both of them were difference significantly ($P < 0.05$). Meanwhile, BL, HG and WH (cm) in both breeds were 108.58; 147.19; 106.52 respectively (LB) and 111.27; 150.47; 109.23 respectively (SB). Body weight of LB and SB in Muaro Jambi regency were higher than Batanghari regency and caused by different sire (straw), climate and management. Zurahmah and Enos (2011) reported that BW, BL, HG and WH of Bali bulls at Jembrana Regency, Bali Province, Indonesia (± 2 years age) were 170.84 ± 20.52 kg; 100.23 ± 5.15 cm; 106.97 ± 4.93 cm; 138.84 ± 6.82 cm respectively. Body weight and body dimensions of Bali cattle at Muaro Jambi Regency were lower than Jembrana Regency and caused by different of management system. Most Bali cattle in Bali Province were managed into Villager Breeding Centre (VBC) system and caused the performance of Bali cattle in Bali Province better than other place in Indonesia.

Pearson's correlation coefficients (r) values for BW and HG or BL and WH were high category. Gunawan and Jakaria (2010) reported that correlation between BW and body dimensions (BL, HG and WH) in Bali cattle at Jembrana District were high. Positive correlation was found between body dimension parameters and BW in Bali and Bali cross indicating as the body dimensions increase the body weight also increases. Among these three measurements, r value between BW and HG was high (0.73 for Bali cross and 0.70 for Bali). Pearsonís correlation coefficients between HG and BW in several breeds of cattle such as Tanzania Shorthorn Zebu (0.94), Kamphaengsaen (0.91), Nyalawi (0.88), Nguni (0.58), Holstein (0.78), Brown Swiss (0.98), Bali (0.87) and Ongole crossbred (0.48) have been reported (Kashoma et al., 2011; Sawanon et al., 2011; Alsiddiq et al., 2010; Nesamvuni et al., 2000; Serkan and Yalzin, 2009; Gunawan and Jakaria 2010; Wijono et al., 2007). However, moderate correlation value between BW and body measurements suggested that HG could provide a good estimate of BW in both Baliís breeds.

Based on the regression models (C, E, F and G), BW could be predicted using parameters that had moderate coefficient of determination (R^2). The equation for BW from body measurement of HG alone (Model C) was BW = 49.37 + 0.88 HG ($R^2 = 0.53$) for Bali cross and BW = 59.44 + 0.75HG ($R^2 = 0.49$) for Bali. This showed that when increasing HG by 1 cm in Bali cross and Bali, the corresponding increase in BW could be about 0.88 kg and 0.75 kg, respectively. Coefficient of determination (R^2) based on the C models in male cattle such as Tanzania Shorthorn Zebu cattle, Nilotic, Kamphaengsaen and Bali were 0.88, 0.95, 0.83 and 0.76 (Kashoma et al., 2011; Milla et al., 2012; Sawanon et al., 2011; Zurahmah and Enos 2011). Furthermore, R^2 values of C models in *Bos taurus* group (Friesian Holstein and Brown Swiss) were 0.61 and 0.91 respectively (Serkan and Yalzin, 2009) and in *Bos indicus* group (Abyssinian and Horro) were 0.65 and 0.87 respectively (Goe et al., 2001). In the present study, HG was the important body measurements required for predicting the BW in both breeds. within moderate R^2 values in simple linear regression equations (Model C). Research shows that the C, E, F and G models produced no significant difference ($P > 0.05$) between actual and predicted BW for both breeds. The R^2 value of C model was similar to E, F and G models for both breeds. The input parameters required can be measured using only HG, which is easy and fast for the farmer, especially for Bali cross ($R^2 = 0.53$) and Bali ($R^2 = 0.49$) at Muaro Jambi Regency.

In conclusion, moderate R^2 value in C, E, F and G models could be used for an alternative method to predict BW in Bali cross and Bali bulls, especially at Muaro Jambi Regency of Indonesia. However, simple and multiple linear regression with R^2 more than 0.70 were more accurate to predict body weight of cattle. High R^2 value in a linear regression model suggested that the prediction of BW could be explained ≥ 70% from the independent variable and 30% from unknown variable (Paputungan et al., 2015).

Acknowledgement

The authors expressed appreciation to the Indonesian Department of Agriculture (IDA) at Muaro Jambi regency and the farmers who involved in the animals for analysis.

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