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Prediction of body weight through body measurements in Boerawa (Boer × Etawah crossbred) bucks at Tanggamus Regency of Indonesia

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Abstract

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This research was carried out to investigate the estimation of the body weight (BW) of Boerawa (Boer x Ettawa grade) bucks by statistical methods. The bucks (n = 120) falling in two grades (G1 and G2) were included in the present investigation to estimate BW using body measurements. Average BW, heart girth (HG), body length (BL) and withers height (WH) of all goats were 38.00±3.78 kg; 75.07±3.78 cm; 65.02±2.47 cm and 68.47±3.92 cm respectively. Highest and positive correlation coefficient value between BW and HG were observed in G2 bucks (0.69) and all goats (0.85). Independent sample T-test procedure was adopted to eliminate unfit linear regression models in both grades. Model A, D, E and G ($R^2 > 0.70$) were found to be best accounting for prediction the BW in G2 buck. It was concluded that HG is the best trait for the predicting BW in G2 buck. The most appropriate combination of body characteristics was observed between HG, BL and WH (model G with $R^2 = 0.77$) for the prediction of BW in all animals and G2 buck.

Keywords: Boerawa buck; body weight; body measurements; regression; coefficient of determination

Introduction

The biometric measurements are use to assess several characteristic of animals. These measurements provide important evidences for the growth of the breed and the properties that change with environmental effects and feeding factors. In addition, body measurements are important data sources in terms of reflecting the breeds standards and are also important in giving information about the morphological structure and development ability of the animals (Alderson, 1999). Body measurements differ according to factors such as breed, gender (sex), yield type and age (Feyissa et al., 2018; Abd-Allah et al., 2019).

Body weight plays an important role in determining several characteristics of farm animals especially the ones having economical importance. Birth weight, early growth, feed convertion ratio as well as feeding requirements could be predicted by knowing the live weights of several stages of the kids (Tekle, 2014). Several charts that show the estimated weights according to body measurements are established in the countries where animal industry is developed. The variation of the body measurements is used as criteria in classification of the goats. The estimated values of the quantitative characteristics are useful in developing appropriate selection criteria (Bourdon, 2000). The yields and the parameters that effect them are desired to be determined easily and inexpensive in animal breeding. If the data regarding the yield properties are optained with difficult and expensive methods, then using indirect measurements could be an alternative way to be followed (Matsebula et al., 2013).

The relationship between body weight and economiccally important yields is well known in farm animals and body weight estimations using the body measurements is a matter of concern for goat industry. In general the correlation between body measurement and body weight is found to be higher in sheep and goats. (Eyduran et al., 2013). Another important point is the enviromental effects, particulary from sustainability of the breed standards point of view crossing animals. The question of sustaining high yields and standards in different conditions is an essential concern for breeders. Therefore the results of studies regarding the breed standards of the crossing animals reared in their regions attract their attention.

Boerawa goat is one of the most popular meat type goat in Indonesia, especially in Gisting District, Tanggamus Regency, Lampung Province of Indonesia. Boerawa goat is one of crosbred goat in Indonesia which birth from Boer buck and Ettawa grade doe through artificial insemination (AI) technology. Since 2001 AI using Boer straw was done to Ettawa grade in Tanggamus regency. The frozen sperm (straw) of Boer bucks (fullblood) was imported from Australia. The Boerawa goat was decided as one of Indonesian local goat since year 2015 through decision of Mininstry of Agriculture of Republic Indonesia No: 359/Kpts/PK.040/6/2015. Boer goat is one of South African native goat, famous for meat production in the world because of their highly adult weight (45 – 70 kg) and average post-weaning daily gain about 245 to 250 g (Christopher, 2008). Sulastri et al. (2014) reported averages of yearling weight in Boerawa goat were 43.49 kg (grade 1) and 42.27 kg (grade 2). Averages for gestation length, litter size and birth weight of Boerawa doe (grade 1) were 159.31 days, 1.62 and 3.02 kg respectively (Adhianto et al., 2014). Dakhlan et al. (2011) reported averages for reproductive traits in second grade Boerawa doe such as birth weight (2.94 kg), first calving age (13.5 months), service per conception (2.00), conception rate (>70%), kidding rate (100%), kidding interval (11 month) and litter size (2.00).

The aim of this study was to examine the relationships between body measurements and body weight as well as investigate the prediction of live weight using some body measurements in Boerawa bucks reared in village breeding centre (VBC) conditions.

Materials and Methods

Animals

One hudred and twenty records were collected on Boerawa (Boer × Etawah crossbred) bucks kept in village breeding centre (VBC) at Gisting district, Tanggamus Regency, Lampung Province of Indonesia. Two grades of Boerawa bucks (BG1 and BG2) were used in this study and each grade consisted of 60 goats with two pairs of permanent incisors (>2 years age).

Management of animals

All animals were managed under a system that seems exactly like their original habitat under a semi-intensive management system. On arrival the animal were given anti-stress to reduce fatigue and possible losses as a result of stress. Animals were let out to graze freely on the padlock during the day and 5.00 pm where their feeding was supplemented with whole maize and dry grass forage consisting of dried-dropped *Panicum maximum, Gliricidia sepium* and groundnut leaves and stalk as supplement feed to make up for their nutrient requirement. Fresh water was given *ad libitum*. These lasted for twelve weeks after which the various measurements were taken.

Animal measurements

Body weight and body measuements of animals were recorded after eight hours of feed restriction. Linear body measurements were taken by a tape measure and body weight (BW) was taken using a digital scale. Heart girth (HG) was measured just behind the scapula by a tape measure. Body length (BL) was measure as the distance from the occipital joint to the first caudal vertebra. Withers height (WH) was measured as the distance from the surface of a platform to the withers. The scheme of body measurements in Boerawa buck was presented in Figure 1.

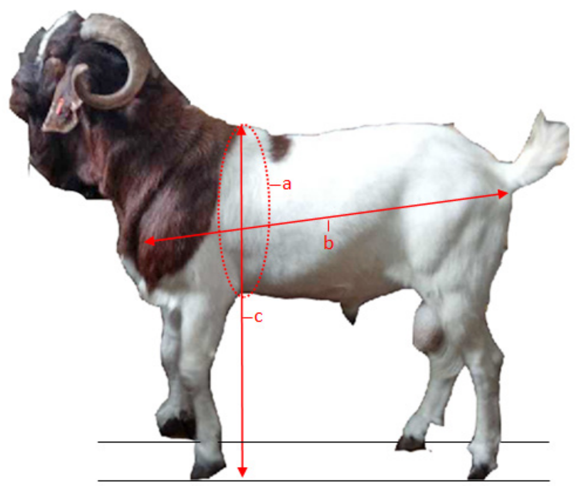

Fig. 1. Scheme of body measurements in the Boerawa buck consisted of heart girth (a), body length (b) and withers height (c)

Statistical analysis

The data were edited using Microsoft Office Excel 2007 computer program. The complete randomized design (CRD) analysis was calculated through SPSS 16.0 software to test the effects of grade in linear models on BW, HG, BL and WH. When significant differences were observed between treatments, the means were compared using Duncan multiple range test (DMRT). The model refering to Steel and Torrie (1995):

$$Y_{ij} = \mu + G_i + E_{ij},$$

where: Y_{ij} is observations; μ is overall mean; G_i is effect of the i^{th} grade, E_{ij} is experimental (residual) error.

Simple and multiple linear regression analysis were fitted to obtain prediction equations of BW from body measurements (HG, BL, WH) variables. Variable were resulted using enter regression method through SPSS 16.0 software and then used to develop the equations for BW. The model used for the linear regression analysis was as follows (Steel & Torrie, 1995):

$$Y = a + b_i X_i + E,$$

where: Y is body weight (dependent variable), a is constanta or intercept, b_i = regression coefficient of the i^{th} independent variable, X_i is the value of the i^{th} independent variable and E is the standard error of regression.

Accuracy of prediction equation for BW was estimated through the coefficients of determination (R^2) and linear relationship between BW and other three body measurements using Pearson correlation coefficients (r) was also calculated. Best-fitted regression equation was developed to estimate BW through different linear regression equation models.

Results and Discussion

Body measurements

Average body measurements and standard deviations of the two different grades are presented in Table 1. Research showed that the average of BW and BL in each grades were similar. The average of body weight (>1.5 years age) in other Indonesian Boer cross (G2) goat was 27.98 kg for Boercang (Boer × Kacang) goats (Dakhlan et al., 2011). Jiabi et al. (2000) and Villiers et al. (2009) reported that BW (>1 years age) of several Boer cross (F1) bucks were 49.95 kg (Boer × Renshou), 49.20 kg (Boer × Jianyang Big-Ear), 55.33 kg (Boer × Chengdu Ma), 43.77 kg (Boer × Lezhi Black), 42.94 kg (Boer × Jialing), 35.71 kg (Boer × Yingshan Black) and 27.60 kg (Boer × KwaZulu-Natal). The values obtained for BW (2PPI) in this study was generally lower than those obtained by Sulastri et al. (2014) in BG1 (43.49±6.15 kg) and BG2 (42.27±2.12 kg) bucks. However, the result obtained in this study as regards the differences of both grades measurements were not similar to those reported by Sulastri et al. (2014) on Boerawa buck and caused by difference of doe (maternal) performance and management system.

Correlation coefficients

The correlation coefficient (r) indicating the relationship between the BW and linear body measurements are shown in Table 2. Highest r value was showed between BL and WH

Table 1. Descriptive statistics for body weight and linear body measurements of Boerawa bucks

Parameters	Mean	SD	CV (%)	Min.	Max.
Grade 1 (N = 60)					
Body weight (kg)	34.85	1.72	4.94	31.50	38.40
Heart girth (cm)	71.99[a]	0.67	0.93	71.00	73.50
Body length (cm)	63.90	2.40	3.75	61.00	71.00
Withers height (cm)	71.17[a]	3.07	4.31	64.00	77.00
Grade 2 (N = 60)					
Body weight (kg)	41.14	2.40	5.84	35.90	48.70
Heart girth (cm)	78.15[b]	3.00	3.84	73.60	86.00
Body length (cm)	66.14	2.00	3.02	62.50	71.00
Withers height (cm)	65.77[b]	2.61	3.97	62.80	75.30
Overall (N = 120)					
Body weight (kg)	38.00	3.78	9.95	31.50	48.70
Heart girth (cm)	75.07	3.78	5.04	71.00	86.00
Body length (cm)	65.02	2.47	3.80	61.00	71.00
Withers height (cm)	68.47	3.92	5.73	62.80	77.00

Means in the same column and parameter with different superscript differ significantly (P<0.05), N: number of observation, SD: standard deviation, CV: coefficient of variance, Min.: minimum value, Max.: maximum value in BG1 buck (0.82). Therefore, negative r value (-0.21) seen between HG and BW in BG1 buck and included low category (0.20 < r < 0.40). High r value (0.60 < r < 0.79) were found between HG and BW in BG2 buck (0.69) and very high r value (0.80 < r < 1.00) were found in pooled (0.85). Several studies reported that the r values between HG and BW (>2.0 years age) in several African native bucks were high i.e. Nigerian Red Sokoto (0.73), Red Sokoto (0.89), Afar (0.51), Abergelle (0.83), Hararghe Highland (0.89), West African Dwarf (0.93), Woyto-Guji (0.85), Mubende (0.79), Teso (0.75) and 0.59 for Lugware (Adeyinka & Ibrahim, 2006; Ibrahim et al., 2014; Tekle, 2014; Tadesse et al., 2012; Tsegaye et al., 2013; Fajemilehin & Salako, 2008; Lorato et al., 2015; Jimmy et al., 2010). Therefore, r values between HG and BW (>1.5 years age) in Asian native bucks such as Beetal (0.71), Malabari (0.91) and 0.90 for Teddi (Khan et al., 2006; Alex et al., 2010; Moaeen-ud-Din et al., 2006). In addition many studies reported that r values between HG and BW (>1.5 years age) were very high in Saanen (0.95), Kilkeci (0.85) and Katjang (0.89) goats (Pesmen & Yamdirci, 2008; Cam et al., 2010; Putra & Ilham, 2019). Adeyinka & Mohammed (2006) reported that the r value between HG and BW in pooled buck (Red Sokoto and White Bomo) was

Table 2. Correlation coefficient between body weight and body measuremets of Boerawa bucks

Variables	Body measurements		
	HG	BL	WH
Grade 1 (N = 60)			
Body weight (BW)	-0.21	0.08	-0.11
Heart girth (HG)	–	0.06	0.18
Body length (BL)	–	–	0.82^{**}
Grade 2 (N = 60)			
Body weight (BW)	0.69^{**}	0.38^{**}	0.19
Heart girth (HG)	–	0.41^{**}	0.28^{*}
Body length (BL)	–	–	0.12
Overall (N = 120)			
Body weight (BW)	0.85^{**}	0.49^{**}	-0.56^{**}
Heart girth (HG)	–	0.51^{**}	-0.48^{**}
Body length (BL)	–	–	0.03

N: number of observation; *(P < 0.05); **(P < 0.01)

Table 3. Simple and multiple linear regression models for predicting body weight (a dependent variable) on body measurements (an independent variables) in Boerawa bucks

Equations	Independent variables	Intercept	Regression coefficient			MSE	R^2	Sig.
			HG	BL	WH			
Grade 1 (N = 60)								
Model A	HG	73.85	-0.54	-	-	2.88	0.05	0.11
Model B	BL	31.31	-	0.06	-	3.00	0.01	0.56
Model C	WH	39.30	-	-	-0.06	2.98	0.01	0.40
Model D	HG,BL	70.72	-0.56	0.07	-	2.91	0.05	0.21
Model E	HG,WH	74.41	-0.51	-	-0.04	2.92	0.05	0.23
Model F	BL,WH	32.51	-	0.38	-0.30	2.77	0.10	0.04
Model G	HG,BL,WH	60.69	-0.40	0.35	-0.27	2.74	0.12	0.06
Grade 2 (N = 60)								
Model A	HG	-1.72	0.55	-	-	3.11	0.47	0.00
Model B	BL	11.22	-	0.45	-	5.04	0.14	0.00
Model C	WH	29.40	-	-	0.18	5.65	0.04	0.14
Model D	HG,BL	-7.95	0.51	0.14	-	3.10	0.48	0.00
Model E	HG,WH	-1.81	0.55	-	0.002	3.16	0.47	0.00
Model F	BL,WH	3.40	-	0.43	0.14	4.99	0.16	0.01
Model G	HG,BL,WH	-8.02	0.51	0.14	0.002	3.15	0.48	0.00
Overall (N = 120)								
Model A	HG	-25.64	0.85	-	-	4.07	0.72	0.00
Model B	BL	-11.12	-	0.76	-	10.92	0.24	0.00
Model C	WH	74.72	-	-	-0.54	9.97	0.31	0.00
Model D	HG,BL	-30.80	0.81	0.13	-	4.03	0.72	0.00
Model E	HG,WH	-5.86	0.76	-	-0.19	3.69	0.75	0.00
Model F	BL,WH	25.00	-	0.78	-0.55	6.30	0.57	0.00
Model G	HG,BL,WH	-10.38	0.63	0.27	-0.25	3.42	0.77	0.00

WH: withers height, BL: body length, HG: heart girth, MSE: mean square error of equation, R^2: coefficient of determination, Sig.: significancy value

Table 4. Difference between actual and predicted body weights using simple and multiple linear regression models (R^2 > 0.70) in Boerawa bucks

Items	Mean (kg)	SD	CV (%)	Min.	Max.	Sig.
Grade 1 (N = 60)						
Model A (R^2 = 0.72)	35.55	0.57	1.61	34.71	36.84	**
Model D (R^2 = 0.72)	35.82	0.64	1.80	34.77	37.58	**
Model E (R^2 = 0.75)	35.33	0.70	1.99	33.85	36.59	**
Model G (R^2 = 0.77)	34.43	0.54	1.56	33.38	35.65	**
Actual	34.85	1.72	4.94	31.50	38.40	-
Grade 2 (N = 60)						
Model A (R^2 = 0.72)	40.79	2.55	6.26	36.92	47.46	ns
Model D (R^2 = 0.72)	41.10	2.55	6.21	37.20	47.97	ns
Model E (R^2 = 0.75)	41.04	2.20	5.35	38.01	46.43	ns
Model G (R^2 = 0.77)	40.27	2.09	5.19	37.43	45.05	ns
Actual	41.14	2.40	5.84	35.90	48.70	-
Overall (N = 120)						
Model A (R^2 = 0.72)	38.17	3.21	8.42	34.71	47.46	*
Model D (R^2 = 0.72)	38.46	3.24	8.42	34.77	47.97	*
Model E (R^2 = 0.75)	38.18	3.30	8.63	33.85	46.43	ns
Model G (R^2 = 0.77)	37.35	3.30	8.84	33.38	45.05	ns
Actual	38.00	3.78	9.95	31.50	48.70	-

*($P < 0.05$), **($P < 0.01$), ns: non significant, N: number of observation, SD: standard deviation, CV: coefficient of variance, Min.: minimum value, Max.: maximum value, Sig.: significance

0.72. Research resulted that HG can be used to predict the BW through simple linear regression for most goat breeds.

Predictor equations

A stepwise multiple regression analysis was carried out. Simple linear regression and partial regression equations for investigated breeds along with their reliability percentage and mean square error (MSE) are shown in Table 3. The coefficient of determination (R^2) indicates that body measurements success to describe variation in BW. Thus HG accounted 5% (BG1) and 47% (BG2) of the variation in BW, together with total variation 72%. The R^2 and MSE can be considered as an important criteria in selection of the appropriate linear model. The equations with high R^2 value ($R^2 > 0.70$) showed arange similar to the range observed in actual weight category (Table 4). The result of the multiple regression analyses indicated that the addition of other measurements (BL and WH) to HG would result in significant improvement in accuracy of prediction even though a small extra gain. This fact is clearly highlighted by the value of the R^2 and by the other statistical parameters. The practical use of HG as a reliable, indirect way to estimate BW in selection work is encouraged by these results.

This results suggest that variables with high R^2 and low MSE might be used to predict body weight. Very low ($0.00 < R^2 < 0.19$) and moderate ($0.40 < R^2 < 0.59$) R^2 values in model A were found in BG1 (0.05) and BG2 (0.47) bucks. Low R^2 value in model A was found in Beetal (0.15) and Afar (0.35) goats (Moaeen-ud-Din et al., 2006; Tekle, 2014). Many studies reported that the R^2 values in model A were various from moderate to very high such as Nguni (0.88), Beetal (0.59), Kilkeci (0.71), Malabari (0.82), Mubende (0.90), Teso or Lugware (0.88), Black Bengal (0.94), Hararghe (0.79), West African Dwarf (0.78), Etawah crossbred (0.84), Maefur (0.93), Shami (0.98) and Katjang (0.69) goats (Slippers et al., 2000; Iqbal et al., 2013; Cam et al., 2010; Alex et al., 2010; Jimmy et al., 2010; Rahman et al., 2008; Tsegaye et al., 2013; Fajemilehin et al., 2008; Hazza et al., 2017; Berhe, 2017; Abd-Allah et al., 2019; Putra & Ilham, 2019). Low and moderate of R^2 values in model G were found in BG1 (0.12) and BG2 (0.48) bucks. Many studies reported that the R^2 values in model G were various from moderate to high such as Red Sokoto (0.56), Abergelle (0.71) and Beetal (0.69) goats (Adeyinka & Mohammed, 2006; Tadesse et al., 2012; Iqbal et al., 2013)

Conclusion

It is concluded that body weight of Boerawa grade 2 bucks (BG2) can be estimated with a high accuracy using some body measurements. Using suitable statistical method can save us from extra expenses and time wasting. The highest R^2 was obtained when all the body measurements were included in linear regression equation. This suggests that weight could be estimated more accurately by combining two or more measurements than by girth only. Using measurements obtained readily and offering accurate prediction of body weight might be considered as a framework for a recording system in rural areas. In this way, the establishment and application of advanced statistical methods may become more practical. Moreover, economic value of crossbred goat allocated to special geographic region may be estimated better. Therefore, with such a management decision system, genetic and performance improvements may be more promising.

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