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Phenotypic Characterization and Weight Prediction from Linear Body Measurement of 6-Months-Old Indonesian Etawah Grade Goats

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ABSTRACT

The Etawah Grade (EG) goat is one of Indonesia's local breeds, serves a dual purpose by providing both dairy and meat. Understanding phenotypic characteristics and estimating body weight are crucial for improving production and marketing practices. The objective of this study was to analyze phenotypic characteristics and determine the best body weight predictor of EG goats. Coat color, Body Weight (BW), Body Length (BL), Body Height (BH), and Chest Girth (CG)) were measured on 3168 6-month-old EG goats. Descriptive statistics, t-test, correlation, and regression analysis were used to characterize phenotypic and estimated body weight from linear body measurements. The result showed that three primary coat color patterns were observed: black-white (86.40%), full black (11.24%), and brown-white (2.37%). Male and female EG goats have significantly different (P<0.01) body weight and body size. Strong correlations (r = 0.86–0.88) were identified between body measurements and body weight. The most accurate model for estimating body weight was BW = 0.309 BL + 0.205 BH + 0.399 CG – 32.811 (Adj. R^2 = 84.830%, RMSE = 1.771, MAPE = 6.442). It can be concluded that this study may contribute to increasing selection accuracy, optimizing breeding programs, and improving production strategies in EG goat farming.

Keywords: Body weight, correlation, etawah grade goat, linear measurement, phenotypic

ABSTRAK

Kambing Peranakan Etawah (PE) merupakan salah satu rumpun kambing lokal yang digunakan sebagai penghasil susu dan daging (dwiguna). Karatersisasi fenotipik dan prediksi bobot badan merupakan hal penting dalam meningkatkan produksi dan pemasaran dalam usaha peternakan. Penelitian ini bertujuan untuk mengidentifikasi karakteristik fenotipik dan menentukan prediktor terbaik bobot badan kambing PE. Warna bulu, Bobot Badan (BB), Panjang Badan (PB), Tinggi Badan (TB), dan Lingkar Dada (LD) diukur pada 3.168 ekor kambing PE umur 6 bulan. Analisis statistik deskriptif, uji-t, korelasi, dan regresi digunakan untuk melakukan karakterisasi fenotipik serta mengestimasi bobot badan berdasarkan ukuran tubuh kambing PE. Hasil penelitian menunjukkan terdapat tiga pola warna bulu utama, yaitu hitam-putih (86,40%), hitam polos (11,24%), dan cokelat-putih (2,37%). Kambing PE jantan dan betina memiliki perbedaan bobot badan dan ukuran tubuh yang signifikan (P<0,01). Korelasi kuat (r = 0,86–0,88) ditemukan antara ukuran tubuh dan bobot badan. Model paling akurat untuk mengestimasi bobot badan adalah BW = 0.309 BL + 0.205 BH + 0.399 CG – 32.811 (Adj. R^2 = 84.830%, RMSE = 1.771, MAPE = 6.442). Dapat disimpulkan bahwa penelitian ini dapat berkontribusi dalam meningkatkan akurasi seleksi, mengoptimalkan program pemuliaan, dan meningkatkan strategi produksi pada usaha ternak kambing EG.

Kata kunci: Bobot badan, fenotipik, kambing peranakan etawah, korelasi, ukuran tubuh

INTRODUCTION

In Indonesia, small ruminant significantly contributes to the rural economy and serve as crucial protein source. Small ruminants commonly raised by small holders in rural areas because they are easy to handle, function as savings and fulfilling the nutritional needs (Sujarwanta *et al.* 2024; Gunawan *et al.* 2018). Goats are a widely distributed small ruminant in Indonesia. The goat population in Indonesia increased from 14,374,014 in 2023 to 15,710,055 in 2024, indicating a steady upward trend (Directorate General of Livestock and Animal Health Services 2024). Indonesia possesses a diverse range of local goat breeds. Etawah Grade (EG) goat is the most widely distributed local goat breed in Indonesia, primarily due to its considerable economic value. EG goat is classified as a dual-purpose breed, utilized for both milk and meat production. EG goat has been officially recognized as a local goat breed by the government of Indonesia (Decree of the Minister of Agriculture No.695/Kpts/PD.410/2/2013). The EG goat has been developed over a long period since the Dutch colonial era through the grading up process, which involves the Jamunapari goat from India with Indonesian local goat breed.

Phenotypic characterization is essential to enhance the potential of livestock animals. The information obtained from characterization studies plays a crucial role in designing effective production management and breeding programs for livestock. (FAO 2012). Characterization of qualitative traits such as coat color can affect the economic value and consumer preferences in the livestock market. Body weight is another trait that is directly associated with livestock productivity and economic value. Body weight measurement is relatively easy to perform. However, it is not yet widely implemented by farmers in Indonesia due to limitations in facilities and infrastructure. Goat evaluation in Indonesia is primarily based on traditional methods, relying on visual assessment of body conformation, which may lead to considerable subjectivity. Such limitations can be addressed by estimating body weight through linear body measurements. Santos *et al.* (2020) reported that linear body measurements are positively associated with livestock live weight and can potentially be used as predictors of live weight. A positive correlation indicates the feasibility of indirect selection between the traits (Ehsaninia 2021). Measurement of body size and shape in livestock can enhance growth selection by allowing breeders to accurately distinguish between fast-growing and slow-growing individuals. Measurements of various body conformation traits play an important role in the evaluation of quantitative characteristics in livestock and contribute to the development of effective selection criteria. Phenotypic characteristics and estimating body weight are crucial for improving production and marketing practices.

Several studies related to phenotypic characterization and body weight prediction of goats have been conducted (Ofori *et al.* 2021; Fonseca *et al.* 2020; Assan *et al.* 2024), but remains limited in the Indonesian local goat. Body weight prediction has been conducted in several Indonesian local goat breeds (Lendrawati *et al.* 2022; Dakhlan *et al.* 2021a). There is currently no study that specifically discusses the phenotypic characterization of qualitative and quantitative traits in EG goats. Further studies are required to provide additional information on phenotypic characterization, improve the genetic quality, and production strategies of goat breeding. The objective of this study was to identify phenotypic characteristics of EG goats and analyze the correlation between body weight and linear body measurements to determine the best body weight predictor.

MATERIALS AND METHODS

Location and Animal Management

All experimental animals were raised at the National Breeding Station of Pelaihari, Tambang Ulang District, Tanah Laut Regency, South Borneo (-3.6985366 Latitude, 114.7334453 Longitude) (Figure 1). The air temperature in this area ranges from 25°C to 35°C, with relative humidity ranging from 74% to 84%.

Figure 1. Location of the study (National Breeding Station of Pelaihari)

Animals were raised under a cut-and-carry feeding system in pens with a stocking density of 1.33 m²/animal. The feed consisted of commercial concentrates and forages such as *Pennisetum purpureum cv. Mott, Gliricidia sepium, and Indigofera zollingeriana*, with a forage-to-concentrate ratio of 70:30. Clean water and salt lick mineral were made available without restriction. The animals were regularly vaccinated and dewormed against diseases and pests.

Data Collection

Animal procedures conducted in this study were approved by the Animal Ethics Commision of IPB university (Approval No. 349–2025 IPB). A total of 3168 EG goats aged 6 months were used in this study. Data were obtained from the performance records of EG goats at the National Breeding Station of Pelaihari from 2015 to 2024. Phenotypic characterization was conducted by directly observing the coat color in the existing livestock population. The traits measured in this study were Body Weight (BW), Body Length (BL), Body Height (BH), and Chest Girth (CG). The method for measuring goat body size in this study followed the standards set by the National Standardization Agency of Indonesia (2022) (Table 1 and Figure 2). A digital scale with a 150 kg capacity was used to obtain BW. A measuring tape and stick were used to obtain EG goat's linear body measurements (BL, BH, and CG).

Data Analysis

The distribution of coat color patterns within the population and between the sexes was analyzed using descriptive statistics by calculating the percentage of each coat color pattern to the total population. Differences in body weight and linear body measurements between males and females were assessed using an independent-samples t-test. The association between body weight and linear body measurements was analyzed using Pearson's correlation. Regression analysis was performed to identify the best model for predicting body weight using linear body measurement. The regression analysis was performed using pooled data. R program (version 4.6.0) was utilized to conducted all statistical analyses. Statistical significance was declared at $P<0.05$ for all analyses. Body weight prediction models based on linear body measurements were developed following the approach of Bourdon (2014):

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$$

Where Y refer to dependent variable (BW), α refer to the intercept, $\beta_{1\text{-}3}$ refer to regression coefficient, and $X_{1\text{-}3}$ refer to independent variable (BL, BH, CG).

The validity and predictive accuracy of each regression model were evaluated using the adjusted coefficient of determination (Adj. R^2), root mean square error (RMSE), and mean absolute percentage error (MAPE), as described by Chicco *et al.* (2021):

Adjusted coefficient of determinant:

$$\text{Adj. } R^2 = 1 - \frac{(1 - R^2)(n - 1)}{n - p - 1} \text{ where, } R^2 = 1 - \frac{\sum_{i=1}^{n} (X_i - Y_i)^2}{\sum_{i=1}^{n} (\bar{Y} - Y_i)^2}$$

The Adj. R2 ranges from 0 to 100%, with higher values indicating better model performance. In the equation, R2 represents coefficient of determinant, n represents the number of observations, p represents the number of independent variables, Xi represents the predicted value of the ith observation, Yi represents the actual value of ith observation, and Ȳ represents the mean of the observed values.

Table 1. Linear body size measuring method

Variable	Measurement method
Body Length (BL)	Body length was measured as the distance from the point of the shoulder (tuberositas humeri) to the end of the pin bone (tuber ischii) using a measuring stick
Body Height (BH)	Body height was measured as the vertical distance from the ground to the highest point of the shoulder, aligned with the forelegs, using a measuring stick
Chest Girth (CG)	Chest Girth was measured around the chest behind the hump using a measuring tape

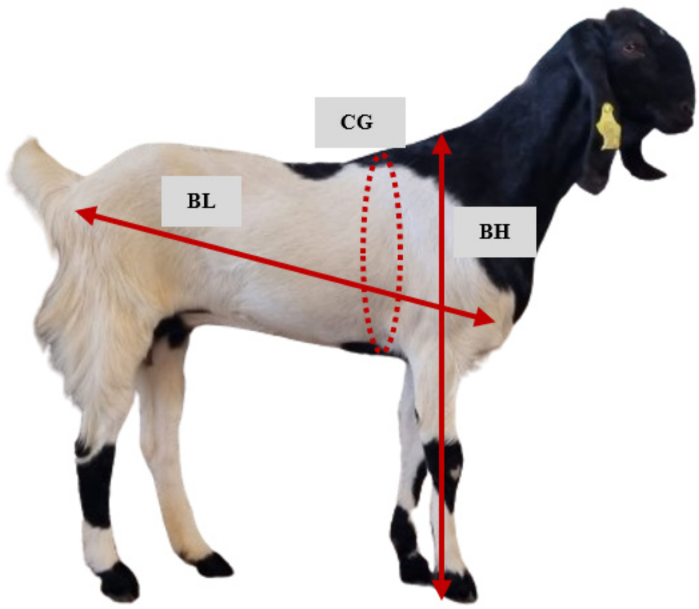

Figure 2. Linear body size measuring illustration

Root Mean Square Error:

$$RMSE=\sqrt{\frac{1}{n}\sum_{i=1}^{n}(X_i-Y_i)^2}$$

Where n denotes the number of observations, Xi denotes the predicted value of the ith observation, and Yi detones the actual value of ith observation. A lower RMSE value reflect a are closer fit between predicted and observed values, suggesting higher predictive performance of the regression model.

Mean Absolute Percentage Error:

$$MAPE=\frac{1}{n}\sum_{i=1}^{n}\left|\frac{Y_i - X_i}{Y_i}\right|$$

Where n represents to the number of observations, Xi represents to the predicted value of the ith observation, and Yi represents to the actual value of ith observation. Lower MAPE values indicates smaller percentage error between predicted and observed values, reflecting higher predictive accuracy of the regression model.

RESULTS AND DISCUSSION

Coat Color Identification

The result showed three primary coat color patterns were observed: black-white, brown-white, and full black (Figure 3). The majority of the coat color pattern of EG goat was black-white (86.40%), with male and female proportions of 43.66% and 42.74%, respectively. Full-black color pattern (11.24%) was the second most common coat color pattern with proportions of 4.70% for males and 6.53% for females. The brown-white color pattern had the lowest proportion in the population (2.37%) with proportions of 1.29% in males and 1.07% in females (Table 2). Coat color patterns in livestock animals have been associated with various physiological traits, including their ability to adapt to high-temperature environments. Goats with a darker color pattern are more adaptable to high-temperature environments than those with a lighter color pattern (Arenas-Báez *et al.* 2023). Coat color patterns in livestock can influence the economic value of the animals, as they are often linked to market preferences (Koseniuk *et al.* 2018). The black-white coat pattern is the most preferred among EG goats. Black-colored goats are commonly favored for use in ceremonial and cultural events in Indonesia. Coat color phenotypes are typically determined by dominant genes, which mask the expression of recessive genes (Eizirik and Trindade 2020). Variations in coat color patterns are caused by evolutionary processes, genetic mutations, and adaptation to different climatic conditions (Andersson 2020; Arenas-Báez *et al.* 2023).

Body Weight, Body Measurements, and Sexual Dimorphism in EG Goats

The average BW, BL, BH, and CG of 6-month-old goats EG were 21.53±0.081 kg; 60.39±0.086 cm; 62.77±0.084 cm; and 58.48±0.090 cm, respectively (Table 3). The overall mean values of BL, BH, and CG in this study were similar to those reported in a previous study on Sirohi goats (Dudhe *et al.* 2015). Fonseca *et al.* (2020) reported that the overall mean of BW, BL, and CG in this study were lower than Saanen (22.99±0.75 kg; 61.71±0.87 cm; and 63.72±0.78 cm) and Boer goat (27.01±1.48 kg; 61.65±1.37 cm; and 65.83±1.24 cm). Differences in body weight and body measurements among different goat breeds may be attributed to genetic and environmental factors. Nugroho *et al.* (2026) reported that both non-genetic and genetic factors significantly influenced goat production performance. Moreover, substantial dietary additions including energy, protein, and mineral supplements can significantly impact livestock productivity and reproductive performance (Gunawan *et al.* 2011).

Male and female EG goat have a significant difference (P<0.01) in BW, BL, BH, and CG, with male EG goats having a greater value of all parameters than female (Table 3). Previous study reported a similar finding with

Table 2. Distribution of coat color pattern of EG goat

Coat Color	Total		Male		Female	
	Freq.	%	Freq.	%	Freq.	%
Black-white	2737	86.40%	1383	43.66%	1354	42.74%
Full black	356	11.24%	149	4.70%	207	6.53%
Brown-white	75	2.37%	41	1.29%	34	1.07%
Total	3168		1573		1595	

Table 3. Mean and standard error of body weight (kg) and linear body traits (cm) of EG goat

Traits	n	Average	Sex		P-value
			Male (n=1573)	Female (n=1595)	
BW (kg)	3168	21.53±0.081	22.47±0.119	20.58±0.104	<0.01
BL (cm)	3168	60.39±0.086	61.13±0.126	59.67±0.115	<0.01
BH (cm)	3168	62.77±0.084	63.70±0.124	61.84±0.108	<0.01
CG (cm)	3168	58.48±0.090	59.31±0.130	57.67±0.121	<0.01

Figure 3. Coat color pattern of Etawah Grade Goat at the National Breeding Station of Pelaihari, (A); Black-white coat color pattern, (B); Brown-white coat color pattern, (C); Full Black coat color pattern.

present study, showing that sex had a significant effect on body weight and body measurement in several goat breeds (Sarma *et al.* 2021; Vázquez-Armijo *et al.* 2021; Zhang *et al.* 2009). Phenotypic differences between male and female are referred to as "sexual dimorphism" (Suhendro *et al.* 2024). Differences between body weight and body measurements between sexes may be caused by the endocrine condition which influence the growth pattern and nutritional requirements of each sex (Ghafouri-Kesbi and Baneh 2018). The effects of sex in body weight and body linear measurement are due to the influence of androgen in male goats, which enhances muscle development, while in female estrogen detain growth, leading to a smaller body weight and size than males (Baneh and Hafezian 2009; Mustefa *et al.* 2024). Sexual dimorphism between sexes has important implications for breeding strategies. Considering performance differences between sexes is essential for establishing sex-specific selection strategies aimed at enhancing the genetic potential of both male and female (Husen *et al.* 2024).

Body Weight Association with Linear Body Measurements

BW and BL, BH, and CG showed a significant (P<0.05) association, as presented in Table 3. BW positively correlated with BL, BH, dan CG, with correlation coefficients (r) ranging from 0.86 to 0.88. CG has the highest correlation among other linear body measurements (r = 0.88), followed by BL (r = 0.86) and BH (r = 0.86). A significant (P<0.05) correlation were also observed among other linear body measurements, with value of correlation coefficients ranging from 0.81 to 0.86. The value of correlation coefficients between BL – BH, BL – CG, and BH – CG were 0.86; 0.81; and 0.84, respectively. Previous studies have shown that BW is positively correlated with BL, BH, and CG, in Indonesian local goat breeds (Lendrawati *et al.* 2023; Dakhlan *et al.* 2021a). A strong correlation between BW and BL, BH, and CG was also found in exotic goat breeds (Mokoena *et al.* 2022; Singh *et al.* 2020; Dudhe *et al.* 2015). The significant and strong association between BW and CG suggests that CG has potential to be used as predictor of BW in EG goat. The substantial correlation coefficient values associated with chest girth were possibly due to chest girth reflect body volume and overall body mass more efficiently compared to body length and body height, which are based on a single cross-sectional dimension (Firdaus *et al.* 2025).

Body Weight Prediction Using Linear Body Measurement

Regression analysis showed linear model of association between BW and linear BL, BH, and CG of EG goat (Figure 4). All regression models of body weight prediction obtained in this present study were statistically significant (P<0.05), with Adj. R^2 values ranging from 74.34% to 84.83%, RMSE values ranging from 1.77 to 2.30, and MAPE values ranging from 6.44% to 8.39% (Table 4). The result of this study showed that for a single predictor, CG has the highest value Adj R^2 (77.11%) and the lowest value of RMSE (2.18) and MAPE (7.83%) among other body measurements. Previous studies reported findings consistent with the present study, showing that CG is the primary predictor for estimating BW in several goat breeds

Figure 4. Scatter plot and regression model of body weight and body measurement (Body Height (BH), Body Length (BL), and Chest Girth (CG)) using single predictor

Table 4. Pearson' correlation between body weight and body measurements of EG goat

	BW	BL	BH	CG
BW	1			
BL	0.86*	1		
BH	0.86*	0.86*	1	
CG	0.88*	0.81*	0.84*	1

BW=Body weight, BL=Body length, BH=Body height, CG=Chest girth, *=P-value <0.05

Table 5. Regression equation of linear body measurements with body weight EG goat

Model	Relationship between variables	Regression Equation	Adj R2 (%)	RMSE	MAPE (%)
1	BW – BL*	0.809 BL – 27.312	74.37	2.302	8.274
2	BW – BH*	0.832 BH – 30.718	74.34	2.303	8.386
3	BW – CG*	0.789 CG – 24.603	77.11	2.176	7.827
4	BW – BL + BH*	0.434 BL + 0.446 BH -32.731	79.81	2.043	7.366
5	BW – BL + CG*	0.414 BL + 0.468 CG - 30.938	83.96	1.821	6.596
6	BW – BH + CG*	0.408 BH + 0.469 CG -31.512	82.29	1.914	6.988
7	BW – BL + BH + CG*	0.309 BL + 0.205 BH + 0.399 CG – 32.811	84.83	1.771	6.442

BW=Body weight, BL=Body length, BH=Body height, CG=Chest girth, Adj R2= Adjusted Coefficient of Determination, RMSE= Root Mean Square Error, MAPE= Mean Absolute Percentage Error. *=P-value <0.05

including as Kacang (Lendrawati *et al.* 2023), Matebele (Assan *et al.* 2024), Boer, and Saanen goats (Fonseca *et al.* 2020). Previous studies have shown that incorporating chest girth (CG) into prediction models yields Adj, R2 from 0.46 to 0.77 (Assan *et al.* 2024; Pelotshweu *et al.* 2025). Using a single body measurement for body weight prediction is a simple and easily adoptable approach for smallholders. Atta *et al.* (2024), reported that since one linear body measurement may serve as an effective selection criterion for the indirect improvement of BW.

The regression model incorporating two body measurements showed that the combination of BL and CG (Model 5) was the best predictor of goat body weight among all two-trait combinations, with an adjusted R^2 of 83.96%, an RMSE of 1.821, and a MAPE of 6.596%. The findings of the present study are consistent with previous studies, which reported that the combination of BL and CG is the most effective predictor of body weight when using two body measurements. (Karna *et al.* 2020; Dakhlan *et al.* 2021b). Chest girth reflects thoracic circumference and trunk diameter, whereas body length represents body size of animal (Nugriatiningsih *et al.* 2025; Putra *et al.* 2019; Anzai *et al.* 2017). These two measurements (BL and CG) describe the overall body frame and trunk volume, which are closely associated with muscle mass, organ size, and body tissue accumulation. Consequently, the combination of chest girth and body length provides a more accurate estimation of body weight. The combination of three body measurements (Model 7) for predicting body weight (BW) produced the best performance, with the highest adjusted R^2 and the lowest RMSE and MAPE compared to the other models. The best body weight estimation of EG goat in this study can be performed using the regression model: BW = 0.309 BL + 0.205 BH + 0.399 CG – 32.811 (Adj. R^2 = 84.830%, RMSE = 1.771, MAPE = 6.442). However, from a practical perspective, Model 5 (BW = 0.414 BL + 0.468 CG − 30.938) produced an Adj. R^2 = 83.96%, RMSE = 1.821, and MAPE = 6.596%, which were not substantially different from those of Model 7, despite using only two body measurements. The use of Model 5 can be considered for estimating goat body weight, as it provides relatively high accuracy while requiring only two body measurements.

CONCLUSION

EG goats were characterized by three main color patterns such as black-white, brown-white, and full black. Black-white (86.40%) was the most common coat color pattern, followed by full-black (11.24%) and brown-white (2.37%). Male EG goats exhibited significantly higher BW, BL, BH, and CG compared to female. CG had the highest correlation (0.88) with BW among other linear body measurements. The most accurate model for predicting body weight of EG goat at 6 months of age was BW = 0.309 BL + 0.205 BH + 0.399 CG – 32.811 (Adj. R^2 = 84.830%, RMSE = 1.771, MAPE=6.442). It can be concluded that this study may contribute to increasing selection accuracy, optimizing breeding programs, and improving production strategies in EG goat farming.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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