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1 2 3 4 5 Research Article: 6 Regression Models and Correlation Analysis for predicting Body Weight of 7 Female Ettawa Grade Goat Using Its Body Measurements 8 9 Akhmad Dakhlani*, Angga Saputra, Muhammad Dima Iqbal Hamdani, and 10 Sulastris 11 Department of Animal Husbandry, Faculty of Agriculture, Universitas Lampung 12 Jl. Prof. Soemantri Brojonegoro No.1 Gedung Meneng Bandar Lampung, Lampung, 13 Indonesia 35145 14 Email: akhmad.dakhlani@fp.unila.ac.id 15 16 17 Abstract 18 19 This research aimed

to find the best regression model for predicting body weight of

20 female Ettawa Grade (EG) using its body measurements. This research used 41 female 21 EG goat aged 3–4 years. The method used was a survey with data collection by census. 22 Body weight (BW) data were regressed and correlated to

body measurements (body 23 length = BL, chest girth = CG and shoulder height = SH) using linear and

multiple 24 linear regression using R program.

Coefficient of determination (R2), adjusted R2,

25 residual standard error (RSE), Akaike information criterion (AIC), Bayesian 26 information criterion (BIC) and step wise regression analysis were used to find the best 27 and parsimonious model for predicting BW. The results showed that body 28 measurements had positive correlation with the BW, which CG had the highest 29 correlation (0.838), followed by BL (0.744) and SH (0.543). Results also showed that 30 CG was the best predictor for BW compared to BL and SH if using single predictor. 31 Combination of CG and BL resulted in the fittest prediction of BW with model 32 regression BW = -67.86 + 0.87*CG + 0.51*BL with the highest correlation coefficient 33 (r = 0.87), R2 (0.76), adjusted R2 (0.75) and the lowest RSE (2.795). AIC (205.51) and 34 BIC (212.36). The result of this study suggested that CG and BL could be used as 35 predictor for body weight and as indicator of indirect selection to improve genetic merit 36 in body weight of EG goat. 37 38 Keywords: Ettawa Grade goat, Correlation and regression model analysis, Body 39 Weight, Body Measurements 40 41 42 INTRODUCTION 43 44 Goat raising is one of the common livestock business carried out by smallholder 45 farmers either as a side job or as a main job. This business of goat continues to increase 46 from year to year. One of the provinces that is developing goat farming in Indonesia is 47 Lampung Province. Lampung Province is an area that has the potential to develop goat 48 farming business. Based on statistics from the Directorate General of Animal 49 Husbandry and Health of Republic Indonesia (2018), the population of goats in 50 Lampung Province has increased from 1,326,103 tails in 2016 to 1,386,009 tails in 51 2018. Whereas district in Lampung Province which has quite large population of goats 52 is Pesawaran Regency. Population of goats in Pesawaran regency reached 44,150 tails, 53 which mostly are Ettawa Grade (EG) goats (Department of Animal Husbandry and 54 Animal Health of Lampung Province, 2017). 55 EG goats are the result of crossing from male Ettawa goats and female Kacang 56 goats so that these goats have properties between the two pedigrees (Setiaji et al., 2013). 57 This goat has been raised by farmers widely in many region in Indonesia because of 58 good adaptability to tropical environment, relatively fast growth, and be utilised as meat 59 and milk producer. Related to the determination of the production of EG goats, it is 60 necessary to weigh the animal's body weight. 61 One effort to develop EG goats is by studying the performance of goats through 62 their body weight. Body weight can determine the value of the livestock which is very 63 important, especially in the selection program of the goats. In addition, knowledge 64 about goat body weight is useful in terms of determining the number of feed needs and 65 determining drug dosages as well as for other management interests. 66 The most accurate determination of a goat's body weight is through weighing. 67 However, in the field conditions, especially on rural farms, scales are difficult to obtain. 68 To overcome this situation, the use of body measurements is an alternative to estimating 69 goat body weight because some research results reported a positive

correlation between 70 body measurements with goat body weight

(Khan et al., 2006; Musa et al.,

2012; 71 Shirzeyli et al., 2013; Basbeth et al., 2015; Hazza et al., 2017; Berhe, 2017; Habib et 72 al., 2019; Abdallah et al., 2019; Waheed et al., 2020). In addition, predicting goat body 73 weight using its body measurement is relatively easy and very practical especially in the 74 rural condition. 75 On the other hand, weighing the weight of the livestock itself is felt less effective 76 because sometimes farmers commit fraud by providing food or drink as much as 77 possible to increase the body weight of livestock before being sold. Therefore, it is 78 necessary

to estimate body weight through body measurements

that include body 79 length, chest girth, and shoulder height

to estimate the actual body weight of

livestock 80 without weighing. This present study aimed to analysis the correlation and regression 81 models to be used for predicting

body weight using its body measurements of female 82 EG goats.

84 MATERIALS AND METHODS 85 86 This research was conducted in April-May 2019 at the Regional Technical 87 Implementation Unit of Goat Breeding Center, Gedong Tataan District, Pesawaran 88 Regency. A total of 41 female EG goats aged 3-4 years were used in this study. 89 The method used in this study was a survey and data collection was done by 90 census. The research variables measured were body weight (BW).

body length (BL), 91 chest girth (CG), and shoulder height (SH). Body

weight was obtained by weighing 92 female EG goats using a 250 kg capacity scales (Gea brand). Chest girth was measured 93 by wrapping around the chest cavity just behind the forelegs using mater tape. Body 94 length (BL) was measured from the shoulder joint straightly to a lump of sitting bone 95 using a measuring stick. Shoulder height was measured as a distance from the highest 96 part of the shoulder to the ground using a measuring stick. 83 97 Body measurements data obtained were correlated and regressed with body weight 98 data using the R program (R Core Team, 2020). Correlations between variables were 99 calculated using the Pearson correlation. The regression models used to determine the 100 formula of the relationship between body measurements (BL, CG and SH) with the BW 101 of female EG goat were as follows: 102 103 1. BW = a + b1*BL 104 2. BW = a + b2*CG 105 3. BW = a + b3*SH 106 4. BW = a + b1*BL + b2*CG + b2*CG 107 5. BW = a + b1*BL + b3*SH 108 6. BW = a + b2*CG + b3*SH 109 7. BW = a + b1*BL + b2*CG + b3*SH 110 111 where BW is a dependent variable (body weight, in kg), a is a constant or intercept, b1- 112 b3 is the regression coefficient for each independent variable (body measurements), BL, 113 CG and SH are body length, chest girth and shoulder height, respectively, in cm. Based 114 on these regression models, the regression equation with the highest

coefficient of 115 determination (R2) and adjusted R2 and

the lowest residual standard error (RSE), Akaike 116 information criterion (AIC) and Bayesian information criterion (BIC) will be 117 recommended for use in estimating goat body weights. 118 119 120 121 RESULTS AND DISCUSSION

Body Weight and Body Measurements of

Female Ettawa Grade Goat 122 Based on the research that has been carried out, statistics and distribution of body 123

weight and body measurements including body length, chest girth, and

shoulder height 124 can be seen in Table 1 and Figure 1. 125 126 Tabel 1. Statistics of

body weight and body measurements of

female EG goats Variables Mean Standard deviation Median Minimum Maximum Body weight (kg) 37,07 5,58 37,20 23,50 48,30 Body length (cm) 71,27 Chest girth (cm) 78,33 Shoulder height (cm) 73,86 3,60 71,20 3,95 78,30 2,74 74,50 62,00 70,40 67,40 79,00 86,40 79,00 129 130 Figure 1. Boxplot of

body weight and body measurements of

female EG goats 131 132 The data presented in Table 1 reveals that the average body weights of female EG 133 goats were 37.07 ± 5.58 kg with a median value of 37.20 kg, the smallest data 134 (minimum) of 23.50 kg and the biggest data (maximum) of 48.30 kg. The results of this 135 study also indicated that the mean of body measurements of BL, CG and SH were 71.73 136 ± 3.60 cm, 78.33 ± 3.95 cm, and 73.86 ± 2.74 cm, respectively. These results indicated 137 (Figure 1) that in general

the body weight and body measurements of

female EG goats 138 were normally distributed. 139 140

Correlation Between Body Sizes and Body Weight

of Female EG Goat 141 142 Pearson correlation among variables are presented in Table 2. The result of this 143 study showed that body measurements positively correlated to body weight with CG 144 (0.84) showed the highest correlation to BW followed by BL (0.74) and SH (0.54). Among body measurements the correlation was also positive ranged from 0.57 to 0.67 indicating that there was no multicollinearity because of under 0.90 (Dakhlani, 2019). 147 148 Table 2. Correlation coefficient among variables of female EG goats

Body weight Body length Chest girth

Shoulder height 149 150 151 152 153

Body weight Body length Chest girth

Shoulder height 1.000 0.744 1.000 0.838 0.672 1.000 0.543 0.664 0.565 1.000 Regression Equation

between Body Measurements and Body Weight of

Female EG Goat The regression models resulted from regression analysis

between body measurements and body weight are presented in

Table 3, while the scatter plot and regression line of the regression model using three single predictor are shown in Figure 2. The result of this study showed that CG was the best predictor for BW if using single body measurement with the highest R2 (0.702) and adjusted R2 (0.695) and the lowest RSE (3.09), AIC (212.73) and BIC (217.87). This result indicated that CG influenced 70.20% variation of BW, while the rest was affected by other factors. Step wise regression analysis using all independent variables found that combination of CG and BL was the best predictors for BW with the highest adjusted R2 (0.750) and the lowest RSE (2.795), AIC (205.51) and BIC (212.36) among the seven models, although the R2 (0.762) of this regression model was similar with the regression equation 7 (combination BL, CG and SH) (R2 = 0.763). Furthermore, combination of CG and BL had the highest correlation (0.87) to BW among the seven regression models. This is presumably because the CG is directly related to the chest and abdominal space where most of the body weight of the goat comes from the chest to the base of tail which is BL, so that the greater the CG and the longer the BL, the heavier the body weight. 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 Table 3. Regression equation of body measurements with body weight of female EG goat Regression equations r² Adj. R² RSE AIC BIC BW = -45,672 + 1,154BL 0,744** 0,554 0,543 3,777 229,28 BW = -55,685 + 1,184CG 0,838** 0,702 0,695 3,087 212,73 BW = -44,754 + 1,107SH 0,543** 0,295 0,277 4,748 248,04 BW = -67,860 + 0,512BL + 0,870CG 0,867** 0,762 0,750 2,795 205,51 BW = -52,295 + 1,063BL + 0,179SH 0,719** 0,559 0,535 3,808 230,89 BW = -64,680 + 1,103CG + 0,209SH 0,807** 0,709 0,694 3,090 213,74 BW = -64,687 + 0,549BL + 0,884CG + 0,094SH 0,832** 0,763 0,744 2,825 207,31 Note: BW = body weight, BL = body length, CG = chest girth, SH = shoulder height, r = pearson correlation, R² = determination coefficient, Adj. R² = adjusted R², RSE = residual standard error, ** = significant at level 0.01, 234 242 217,87 253,18 212,36 237,74 220,59 215,88 Figure 2. Scatter plot and regression line of body weight and three single predictor DISCUSSION The result of current study was in accordance with the result of Subagyo et al. (2017) reported that body weight of EG goats in three villages ranged from 34.50 ± 2.67 to 37.60 ± 4.00 kg. The EG goat in this study had a lower body size than that reported by Subagyo et al. (2017) that female EG goats had body measurements of BL, CG and SH of 74.93 ± 3.75 cm, 82.80 ± 4.86 cm, and 77.30 ± 3.47 cm, respectively, with average body weight was relatively the same, namely 35.77 ± 3.14 kg. The difference in

body weight and body measurements of the

present study with the results of previous study are thought to be influenced by differences in the maintenance environment, where the average temperature in the Pesawaran district (the location of this study) reached 29°C, whereas the average temperature in location of the study of Subagyo et al. (2017) was 25°C. This statement is supported by Devendra and Burn (1994) who stated that environmental factors greatly influence the

weight and body measurements of goats, that different

maintenance environments resulted in varying body sizes, even for the same breed. The result of pearson

correlation between body weight and body measurements corroborate to the

result reported by Victori et al. (2016) in EG goats, Nurhayati et al. (2014) in Jawarandu goats, Afolayan et al. (2006) in Yankasa sheep, and by Sabbioni et al. (2019) in Cornigliese sheep reporting that CG had the highest correlation with BW compared to BL and SH. This might be due to the growth of CG was in line with the growth of ribs, muscles and fat of the animals. The finding of regression models of current study confirmed with the result reported by Chitra et al. (2012), Adeyinka and Mohammad (2006), and Sabbioni et al. (2019) that combination of CG and BL was the best predictor for BW of goat or sheep. Iqbal et al. (2013) reported that combination of three

body measurements (body length, withers height and heart girth) was the

best predictors for BW with the R2 of 0.69 in females Beetal goats. Figure 2 shows us regression model between BW and three body measurements (BL, CG and SH) had similar us regression coefficients indicated by parallel position of the three regression lines, but different intercept. Based on quite different determination (R2), the accuracy of BW prediction using the three body measurements was quite different (0.55, 0.70 and 0.30 for BL, CG and SH, respectively) which CG was the best predictor for BW compared to BL and SH. This is supported by there was no collinearity among body measurements in this study which mean for predicting BW we can not substitute a body measurements by other measurement. On the contrary if there was collinearity among body measurements and the regression coefficient were similar, we can use one of the body measurements for predicting BW. CONCLUSIONS

Based on the results of the present study

it can be concluded that chest girth (CG) had the highest correlation (0.838) and the best predictor for body weight (BW) of Ettawa Grade (EG) goats; followed by

body length (BL, 0.744) and shoulder height (SH,

0.543) if using single body measurement. Combination of

chest girth and body length resulted in the

fittest prediction of BW with model regression BW = -67.86 + 0.87*CG + 0.51*BL with the highest r (0.87), R2 (0.76) and adjusted R2 (0.75) and the lowest RSE (2.795), AIC (205.51) and BIC (212.36). The result of this study suggested that CG and BL could be used as predictor for body weight and would be useful indicator of indirect selection to improve genetic merit in body weight of EG goat. ACKNOWLEDGEMENTS The authors thank all staff of the Regional Technical Implementation Unit of Goat Breeding Centers, Gedong Tataan Subdistrict, Pesawaran Regency, Lampung Province for providing facilities and support for this research. AUTHORS CONTRIBUTION All authors contributed to the work, discussed the results and approved the final manuscript. Akhmad Dakhlani designed research, analysed data, and made revision of the manuscript. Angga Saputra collected and tabulated the data. Muhammad Dima Iqbal Hamdani studied literature. Sulastri made interpretation for the result and drafted the manuscript. CONFLICT OF INTEREST The authors declare that there is no conflict of interest. REFERENCES Directorate General of Animal Husbandry and Health of Republic Indonesia (2018). Livestock and Animal Health Statistics 2018. Ministry of Agriculture Republic of Indonesia. Department of Animal Husbandry and Animal Health of Lampung Province (2017). Livestock Population (Goat) by Regency / City in Lampung Province, 2014– 2016. Central Statistics Agency of Lampung Province. Setiaji A, Suparman P, Hartoko (2013). Productivity and color patterns of the Kejombang goats that are maintained by group breeders and individual breeders. Jurnal Ilmiah Peternakan 1(3): 789 – 795. Khan H, Muhammad F, Ahmad R, Nawaz G, Rahimullah, Zubair M (2006). Relationship of body weight with linear body measurements in goats. J. of Agric. and Bio. Sci. 1(3):51-54. Musa AM, Idam NZ, Elaimn KM (2012). 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Prof. Soemantri Brojonegoro No.1 Gedung Meneng Bandar Lampung, Lampung, Indonesia 35145 Email: akhmad.dakhlani@fp.unila.ac.id 334 335 336 337 338 Tabel 1. Statistics of

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Shoulder height 346 347 348 349

Body weight Body length Chest girth

Shoulder height 1.000 0.744 1.000 0.838 0.672 1.000 0.543 0.664 0.565 1.000 Regression Equation