Body Dimension Factors Affecting Live Weight Estimation Accuracy of Indonesian Local-Thoroughbred Racing Horse

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Abstract  Study was conducted to estimate live weight of Indonesian Local-Thoroughbred racing horse using their chest girth, body length and body volume represented by chest girth and body length dimensions. Data on animal live weight (LW), body length (BL), chest girth (CG) and body volume were collected from male horses (n=188) kept by the owner club members of North Sulawesi Racing Horse. Animal body volume was calculated using cylinder volume formula with CG and BL as component factors of the formula. Data were classified on animal age basis of five groups. Regression analysis was applied for LW with all linear body measurements. Age significantly influenced all body measurements. Simple regression can be recommended to predict live weight of this animal based on body volume with their average age groups as follows: Live weight (Y in kg unit) = 0.002+1.16 body volume (dm³) with determination coefficient (R²) of 0.98. The multiple regression analysis can also be recommended to estimate accurately live weight of this animal at age average groups as follows: Live weight (Y in kg unit) = -0.11+2.74 chest girth (X1 in cm unit) +4.92 body length (X2 in cm unit) with R² of 0.98.

Introduction

Live weight of horses represented the unique genetic resources for improvement of proper use of related variety, mainly used in agriculture, light traction, riding and leisure activities using racing horses. Often, the marketing of horses was based on visual assessment among horse flocks, while drugs were administrated mostly by estimation. Regularly, the right use of live weight criteria in feeding, marketing and drug administration required sophisticated facilities such as weighing scales (monitor digital electrical scale, Photo 6), which was expensive and not readily affordable by many rural households. Positive correlation between the live weight and most of the body measurements was found in several scientific reports (Afolayan et al.; 2006, Bene et al., 2007; Ozkaya & Bozkurt, 2009; Sawanon et al., 2011; Udeh et al., 2011; Takaendengan et al., 2012).

The Indonesian Local-Thoroughbred racing horse was composed of the Indonesian pure local horse breed proportion about six and twenty five percent and about ninety three and twenty five percent of pure Thoroughbred racing horse breed proportion (Photo 1) by natural grading up breeding system into generation four (G4). The Thoroughbred horse was composed from the England female horse pure breed (Equus caballus gmelini) and the Turkey male horse pure breed (Equus caballus occidentalis) (Adnan, 2014). Moreover, Indonesian local horse is a pure breed of evolutionary importance regarding its direct ancestry from Indonesian Sumbawa horse (Equus caballus orientalis) (Adnan, 2014). The Indonesian Local pure breed was considered as the basic breed for the eligible Indonesian national standard racing horse competition. Fortunately, this pure breed of Indonesian local

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horse is able to be bred with other exotic breeds by the natural mating without any delivery difficulty problem (dystocia). This condition was also occurred in crossbred cattle breeding program as reported by Hendrik & Paputungan (2016). The Indonesian Local-Thoroughbred racing horses play particularly a role for increasing income of smallholder animal agriculture including this location study in North Sulawesi province of Indonesia. These Indonesian Local-Thoroughbred horses (Photo 2) have adapted to harsh environment under hot and humid climate as well as low-quality of grasses to produce higher speed in racing competition and prepare power to plough a farm land prior to planting and to pull the traditional horse-drawn buggy addressing particularly the old horses finishing their periods of racing competitions.

The importance of taking horse body measurement repeatedly calls the attention to offer opportunity for estimating parameters in relation to the various body weight estimation accuracies. Several scientific reports suggested that body measurements have been of recurring interest in horses and other ruminant animals for selection and breeding programs (Bene et al., 2007; Fajemilehin & Salako, 2008; Jimmy et al., 2010; Takaendengan et al., 2011). Body weight of animals was an important factor associated with several management practices including selection for breeding, determining feeding levels and also good indicator of animal condition. Because of limited availability of animal weighing scale machine on the field of rural area, the genetic live weight of horse belongs to local household farmers was difficult to be practically predicted. Animal growth in developed farm system was generally measured by average daily gain. In addition, body size was generally detected by increase of chest girth and body length (Willeke & Dursch, 2002; Bozkurt, 2006; Ozkaya & Bozkurt, 2009).

Dimensions of animal chest girth and animal body length in cm unit were very simple to be practically applied for measurement of horse body size, mainly by local household farmers. Horse body weight had positive correlation with body dimensions including body length, hip height and chest girth (Takaendengan et al., 2011). In the Indonesian pure local horses, body weight was moderately correlated with chest girth and body length of 0.79 to 0.90 and 0.70 to 0.76, respectively (Takaendengan et al., 2011). Moderate correlation values indicated relatively low accuracy for estimation of animal body weight in case of using single variable of either chest girth or body length as predictor variable (Fajemilehin & Salako, 2008). In this research, chest girth and body length were combined to be applied in a formula of cylinder shape representing animal body volume. Animal chest girth dimension represented circular line of the circle in cylinder shape, and animal body length represented height of cylinder shape. Therefore, cylinder shape volume represented animal body volume that can be calculated by cylinder volume formula (Takaendengan et al., 2012). The cylinder formula using animal chest girth and body length dimensions has not been exploited and applied to estimate animal body weight of the Indonesian Local-Thoroughbred racing horses. In addition, Chest girth (Photo 3) and body length (Photo 4) of the Indonesian Local-Thoroughbred racing horses combined to be applied in a formula of multiple regression models has not been exploited. The objective of this research was to estimate live weight of the Indonesian Local-Thoroughbred racing horse using volume formula of cylinder shape represented by animal chest girth and body length dimensions indicating animal body volume as well as both independent variables combined in the multiple regression model to develop a manual animal body weight prediction method that can accurately be used on the racing horses.
Materials and methods

Location of study

Research was carried out in Minahasa regency, district of Tompasos, North Sulawesi province. This regency is categorized as agricultural areas with altitude of 600-700 m above sea level. It is characterized by cool and humid climate of 25-28°C and 70-80 percents, respectively.

Experimental animals

The number of Indonesian Local-Thoroughbred horses, randomly chosen in this research was 188 male horses. Age was ranged from one to five years old. Age was primarily determined on the record of horse born basis recorded by the owners. This study included only the healthy horses.

Measured traits

Measurements of body dimensions were taken on each horse population including chest girth (CG), measured as body circumference at behind the forelegs (Photo 3) and body length (BL), measured from distance between the site of pins (tuber ischii) to tail drop (tuberositas humeri) (Photo 4). Animal body volume (BV) was estimated by cylinder volume formula. It was theoretically found that cylinder volume was calculated as follows:

\[
V = \pi r^2 h,
\]
where \( r = \text{radius} \) and \( h = \text{height} \) (length).

Animal chest girth (CG) dimension represented circular line of the circle (C) that can be calculated by formula:

\[
C = 2 \pi r, \text{ or } r = \left(\frac{1}{2} C\right)/ \pi
\]

Size squared area (S) of the circle can be calculated by formula:

\[
S = \pi r^2, \text{ or } S = \pi \left(\frac{1}{2} C\right)/ \pi^2
\]

Animal body dimension can be simulated as representation of solid cylinder shape. Volume of cylinder shape (V) can be calculated by formula as follows:

\[
V = H.S = H. \pi \left[\frac{1}{2} C\right]/ \pi^2,
\]
where \( H \) was height of cylinder shape. Volume of cylinder shape (V) can be simulated as representation of animal body volume (BV); and height (H) of cylinder shape can also be simulated as representation of animal body length (BL).

Because volume (V) of cylinder shape represented an animal body volume (BV) and height (H) of cylinder shape represented animal body length (BL), BV can also be estimated by adopting formula of cylinder shape volume by converting cylinder height (H) into animal body length (BL) and converting circular line of the circle (C) into animal chest girth (CG). Therefore, BV can be estimated by formula:

\[
BV = BL.\pi \left[\frac{1}{2} CG\right]/ \pi^2
\]

Because BL was calculated in cm length and CG was calculated in squared cm size (cm²), so BV was calculated in cubic cm (cm³) by formula as follows:

\[
BV (cm³) = BL.\pi \left[\frac{1}{2} CG\right]/ \pi^2
\]

Because BV was found in unit of cm³, this unit can also be converted into unit of liter (l) that was equal to unit of dm³. As a result, BV in unit of dm³ can be calculated in formula as follows:

\[
BV (dm³) = [BL.\pi \left[\frac{1}{2} CG\right]/ \pi^2]/1000
\]

All measurements of animal dimensions were taken in the morning before the animals were fed. Each dimension of CG and BL was recorded in centimeter, while BV and live weight (LW) were recorded in dm³ and in kilogram (Photo 5 and 6), respectively.

Statistical analysis

The data collected on each animal were analysed using the General Linear Model Procedure (PROC GLM) of SAS (2003) to evaluate the significance of sources of variation affecting measurements of each animal. The interrelationship of body weights and body measurements were estimated by simple
correlation and regression. The fixed effect considered was age. The model used was as follows:

\[ Y_{ij} = \mu + \alpha_i + e_{ij}, \]

where, \( Y_{ij} \) = record of live weight (Photo I) and body measurements of each animal; \( \mu \) = overall mean; \( \alpha_i \) = the fixed effect of \( i^{th} \) age of the animal and \( e_{ij} \) = random error associated with record of each animal. Age of the animals consisted of five age groups with the first age group of 1 year to the fifth age group of five years and more. Comparisons between means were determined by Tukey test. Correlation coefficients were also obtained from parameters.

Simple regression model for predicting live weight from chest girth, body length and body volume in each age group of the animals was as follows:

\[ Y = a + b X, \]

where, \( Y \) = dependent variable of the animal live weight, \( a \) = intercept, \( b \) = coefficient of regression, and \( X \) = independent variable of the animal body measurements, either body length, chest girth, or body volume.

The best estimation equations for body weight from other traits (chest girth and body length) as independent variables were determined. Descriptive statistics and regression analysis of body weight on each of the independent variable were performed using the Insert Function Procedure of the related statistical category in datasheet of Microsoft Office Excel (2007) referring to multiple regression model. The multiple regression effects of independent variables on live weight were included in the following model:

\[ Y_i = b_0 + b_1X_1 + b_2X_2 + e_i, \]

where \( Y_i \) is the live weight observation of \( i^{th} \) animal; \( b_0 \) is the intercept; \( b_1 \) and \( b_2 \) are the regression coefficients, \( X_1 \) is the chest girth, \( X_2 \) is the body length, and \( e_i \) is the residual error term.

**Figure 1-6:** Photos of Indonesian Local-Thoroughbred horses: The Pure Thoroughbred racing male horse breed (1) used for natural grading up breeding system of Indonesian Local-Thoroughbred horses producing generation four (G4) of Indonesian Local-Thoroughbred horses (2); Chest girth measurement (3) and body length measurement (4); Live weight weighing process of horse (5) connected to the electrical monitoring screen in kilogram (6).
Results and discussions

The least square means and standard errors from the general linear model analysis of live weight (LW) and measurements of chest girth (CG) and body length (BL) in the Indonesian Local-Thoroughbred racing horse at the various age groups were as presented in Table-1. Age was found to significantly influence (P<0.05) chest girth, body length and live weight up till age groups of 1 to 4 years old, but did not differ significantly at age groups of 4 to 5 years old on trait of these variables.

Animal age strongly affected the live weight and body linear traits in Indonesian Local-Thoroughbred racing horse, as there were changes in all traits studied as the animal aged (Table-1). Therefore, this was not surprising since the size and shape of animal was expected to increase as the animal was growing with age. There was wide variability as the age of the animals increased all particularly in the live weight, body length and chest girth of this Indonesian Local-Thoroughbred racing horse.

| Table 1. Least square means of live weight and body measurements in the Indonesian Local-Thoroughbred racing horse |
|---|---|---|---|---|
| Age (years) | N | CG (cm) | BL (cm) | LW (kg) | BV (dm³) |
| 5 | 42 | 138.86 ± 2.44 a | 122.09 ± 2.35 a | 217.38 ± 11.84 a | 187.61 ± 10.22 a |
| 4 | 44 | 138.25 ± 3.21 a | 120.27 ± 2.79 a | 212.40 ± 14.76 a | 183.31 ± 12.74 a |
| 3 | 33 | 134.53 ± 2.87 b | 112.91 ± 2.42 b | 188.76 ± 12.03 b | 162.91 ± 10.39 b |
| 2 | 37 | 129.49 ± 3.00 c | 105.03 ± 2.86 c | 162.73 ± 11.96 c | 140.44 ± 10.32 c |
| 1 | 32 | 119.23 ± 4.60 d | 89.39 ± 3.11 d | 117.64 ± 12.08 d | 101.53 ± 10.43 d |
| 1 - 5 | 188 | 132.77 ± 7.68 | 111.13 ± 11.94 | 183.46 ± 38.00 | 158.33 ± 32.80 |

Note: Means in the same column with different superscript differ significantly (P<0.05). N = number of animals measured; CG = chest girth; BL = body length, LW = live weight, BV = body volume.

The variability, indicated by the values of standard deviation, as the animals’ aged sharply reduced among age groups of 4 to 5 years old in all traits examined (chest girth, body length, live weight, body volume) as shown in the Table-1, most probably because the matured body weight of the animal was almost fully attained. This finding was in agreement with the study of other big ruminant animals at maturity periods indicating that linear body measurements of animals were essentially a constant, thereby reflecting heritable size of the skeleton (Sawanon et al., 2011).

| Table 2. Coefficients of correlation between the variables in the Indonesian Local-Thoroughbred racing horse |
|---|---|---|---|
| Age (Years) | Variables | BL | LW | BV |
| 5 | CG | 0.91 | 0.92 | 0.92 |
| | BL | 0.94 | 0.94 | 0.99 |
| | LW | - | 0.99 | |
| 4 | CG | 0.90 | 0.91 | 0.91 |
| | BL | 0.90 | 0.90 | 0.90 |
| | LW | - | 0.99 | |
| 3 | CG | 0.89 | 0.90 | 0.90 |
| | BL | 0.89 | 0.89 | 0.99 |
| | LW | - | 0.99 | |

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The animals’ body condition investigated in this study could be good and the skeletal development was normal and consistent with their ages. Correlation between live weight and body linear measurements were positive and highly significant (Table-2). These correlations implied that live weight and all linear body measurements co-varied positively. High correlation was a confirmation of suitability of the parameters as a measure of the other parameter in the Indonesian Local-Thoroughbred racing horse under study. The correlation between all pairs of linear body measurements indicated that frame size of the animals was complementary indicating that the total size of the animals was a function body length and circumference measurements of animal body or chest girth. The correlations between all pairs of measurements of chest girth, body length, live weight and body volume were highly significant (P<0.001) for all age groups.

The summary of simple linear regression analysis and generating models for predicting overall traits from live weight and animal body measurements were presented in Table-3. The analysis showed that overall horse live weight could not also be predicted from the single independent variable of body length measurement indicated by moderate determination coefficients (R²) ranging from 0.76 to 0.88. The multiple regression analysis for combination of chest girth and body length showed that overall horse live weights at the ages of four to five years old can be predicted accurately from combination of chest girth and body length with the highest and consistent coefficients of determination (R²) of 0.98, with the exception for animal age group of one year old with the moderate R² of 0.79.

Based on multiple regression model, live weight changes with linear body measurements of chest girth and body length were strongly predictable with R² values ranging from 0.98-0.99. The R² values showed that 98 to 99 percents of every one kilogram change in live weight was caused by combination of the variables of chest girth and body length, while other factors not considered were responsible for between 1 and 2 percents. Unambiguously therefore, body length combined with chest girth measurements in the arranged order of suitability in multiple regression models could be used to predict the live weight of the Indonesian Local-Thoroughbred racing horse accurately.

| Age (Years) | Variables | BL | LW | BV |
|-------------|-----------|----|----|----|
| 2           | CG        | 0.87 | 0.88 | 0.88 |
|             | BL        | -   | 0.87 | 0.87 |
|             | LW        | -   | -   | 0.99 |
| 1           | CG        | 0.88 | 0.88 | 0.88 |
|             | BL        | -   | 0.86 | 0.86 |
|             | LW        | -   | -   | 0.98 |
| 1 to 5      | CG        | 0.88 | 0.90 | 0.90 |
|             | BL        | -   | 0.87 | 0.88 |
|             | LW        | -   | -   | 0.99 |

Note: CG = chest girth; BL = body length, LW = live weight; BV = body volume.
In other big ruminant animals of cattle breeds, Ozkaya & Bozkurt (2009) reported that chest girth was the best parameter of all prediction of body weight for Brown Swiss ($R^2 = 0.91$) and crossbred cattle ($R^2 = 0.89$) in comparison to Holstein cattle breed ($R^2 = 0.61$). In other small ruminant animal of sheep, the linear models produced higher $R^2$ values of 0.91. Linear models using only the chest girth measurement have been used to predict weights of African goats (Alemu Yami et al., 2009) and sheep (Sowande & Sobola, 2008) previously. In the case of small ruminant animals of sheep, the linear models produced higher $R^2$ (0.91-0.94) than the quadratic models used in the study by Chinchilla-Vargas et al. (2018).

A valid option to improve the equations provided in this study may be to consider additional measurements that were not measured in other research such as body volume. Determination coefficient ($R^2$) values of simple regressions using independent variable of body volume were higher and more consistent (0.98) compared with those using independent variables of single chest girth (0.77-0.85) and single body length (0.76-0.88) among animal age groups. Simple regression models that can be used when measurements were to be based on live body weight alone and body volume regression equation, the regression equation would be as follows: Live weight = - 0.002 + 1.16 body volume ($R^2$=0.98). This study revealed that the more the independent variables included in the model for prediction of live body weight either using multiple regression with both chest girth and body length as independent variables or simple regression with body volume (involving chest girth and body length dimension factors) as a single independent variable, the higher the prediction accuracy of body weight of the Indonesian Local-Thoroughbred racing horse.

Table 3. Simple regression models for predicting live weight from chest girth, body length and body volume in the Indonesian Local-Thoroughbred racing horse

| Age (years) | Dependent (Y) | Independent (X) | Regression equation | $R^2$ value |
|------------|----------------|-----------------|---------------------|-------------|
| 5          | LW             | CG, BL, BV, CG = X₁ + BL = X₂ | Y = - 454.87 + 4.84 X | 0.85        |
| 4          | LW             | CG, BL, BV, CG = X₁ + BL = X₂ | Y = - 423.24 + 4.60 X | 0.83        |
| 3          | LW             | CG, BL, BV, CG = X₁ + BL = X₂ | Y = - 375.79 + 4.20 X | 0.81        |
| 2          | LW             | CG, BL, BV, CG = X₁ + BL = X₂ | Y = - 348.92 + 3.95 X | 0.77        |
Based on these results, the body weight estimation of the Indonesian Local-Thoroughbred racing horse using chest girth and body length as independent variables in multiple regression produced the highest accuracies of live weight estimation among all animal ages. Consequently, as one of these measurements was decreased then the animal frame size was also decreased, affecting animal live body weight. The multiple regression models that can be used when measurement is to be based on animal chest girth and body length were shown as follows: Live weight (Y in kg unit) = -0.11 - 2.74 chest girth (X in cm unit) + 4.92 body length (X in cm unit); with R² = 0.98. This high determination coefficient of 0.98 indicated that 98 percent of the changes of horse live weight (kg) were due to changes of the chest girth (cm) and body length (cm) following the equation model with the intercept of -0.11, chest girth coefficient b₁ of -2.74, and body length coefficient b₂ of 4.92; while the rest of 3 percent of horse live weight changes were due to other unknown factors.

**Conclusions**

Body dimension factors involving independent variables of both chest girth and body length in the multiple regression model can be recommended to estimate accurately live weight of the Indonesian Local-Thoroughbred racing horse at age groups ranging from 1 to ≥ 5 years old as follows: Live weight (Y in kg unit) = - 0.11 - 2.74 chest girth (X₁ in cm unit) + 4.92 body length (X₂ in cm unit) with determination coefficient (R²) of 0.98.

Live weight of the Indonesian Local-Thoroughbred racing horse could be estimated more accurately using simple regression from single independent variable of body volume derived from cylinder formula rather than from a single independent variable of either chest girth or body length following the formula: Live weight (kg) = - 0.002 + 1.16 body volume (dm³), with R² = 0.98 at age groups ranging from 1 to ≥ 5 years old.

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