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Morphometric Based Estimation of Timor Deer Body Weight

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ABSTRACT
This study aimed to develop a method for estimating the body weight of Timor deer based on morphometric measurements in captivity to facilitate monitoring without direct weighing. The research was conducted from August to September 2025 at the Jatilengger Deer Breeding Center, Blitar Regency. The animals observed consisted of 25 adult males and 22 adult females in good health. Body measurements included chest girth, body length, and body height, while actual body weight was recorded using a digital scale. The data were analyzed using multiple linear regression and compared with several empirical estimation formulas to identify the most accurate model. The results showed a strong correlation between body measurements and actual body weight in both sexes. The multiple linear regression model provided the highest level of accuracy and consistency in estimating body weight compared to empirical formulas. These findings indicate that morphometric parameters can effectively be used as predictors for body weight estimation in Timor deer. The developed model is expected to assist deer breeding centers in monitoring animal growth, evaluating nutritional status, and improving management efficiency without requiring direct weighing.

Keywords: *Timor deer; morphometry; body weight estimation; regression model; captive management*

INTRODUCTION

Timor deer (*Cervus timorensis*) is one of Indonesia's endemic wildlife species with significant ecological and economic roles. This species contributes to biodiversity preservation, ecosystem stability, and provides potential benefits for eco-tourism and sustainable venison production (Amareyao et al., 2021; Riyadi et al., 2021). Despite its ecological and economic potential, comprehensive scientific data on morphometric characteristics and body weight estimation of Timor deer remain limited, especially for individuals kept in captive environments (Maha et al., 2021). Such information is essential to support effective management strategies, particularly for population monitoring, nutritional evaluation, and welfare improvement in breeding programs (Has et al., 2023).

Direct measurement of body weight in deer is often constrained by practical and ethical challenges. The species' sensitive and agile nature makes handling stressful and risky for both animals and handlers (Dakhlan et al., 2021). Consequently, indirect estimation methods using morphometric parameters such as body length, chest girth, and withers height are widely applied in livestock studies and have shown high predictive accuracy (Kusuma et al., 2024; Meidina et al., 2021). Regression-based estimation approaches, particularly multiple linear regression, allow for reliable body weight prediction without physical weighing, offering advantages in terms of efficiency and animal welfare (Ibrahim et al., 2021).

However, such statistical models have rarely been developed specifically for Timor deer, resulting in limited applicability of existing formulas derived from other species.This research addresses that gap by formulating and evaluating a multiple linear regression model for estimating the body weight of Timor deer in captivity based on morphometric measurements. The novelty of this study lies in developing a speciesspecific regression equation tailored to the morphometric characteristics of Timor deer.The findings are expected to enhance monitoring accuracy, support breeding and welfare management, and contribute to the refinement of non-invasive assessment methods for captive cervid populations in Indonesia.

METHOD

This This quantitative research was carried out from August to September 2025 at the Jatilengger Deer Breeding Center, Blitar Regency, East Java, Indonesia. The breeding site is located at an altitude of approximately 177 meters above sea level, covering an area of 23,567 m². The research subjects consisted of 47 adult Timor deer (Cervus timorensis), comprising 25 males and 22 females aged over 2.5 years and in healthy condition. Sampling was conducted using a purposive sampling technique based on animal health and suitability for measurement (Sumanto, 2006).

The tools and materials used included a digital platform scale (capacity 200 kg) for measuring body weight, a livestock measuring tape for body length, chest girth, and withers height, as well as a smartphone for documentation and a laptop for data analysis (Kusuma et al., 2024). Measurements were conducted as follows: (1) Body length from the shoulder point to the base of the tail; (2) Chest girth around the chest behind the forelegs; (3) Withers height from the ground to the top of the shoulder; (4) Body weight measured using a digital scale (Meidina et al., 2021).

The data obtained were analyzed using descriptive statistics (mean, standard deviation, minimum, maximum) and multiple linear regression to determine the relationship between morphometric parameters and body weight. Empirical estimation formulas (Winter, Schoorl, and Modified Ningsih) were compared to evaluate accuracy and predictive bias (Maha et al., 2021).

The multiple linear regression model was formulated according to Darma (2021) as follows:

$$Y = a + b_1X_1 + b_2X_2$$

Description:
Y = Body weight (kg)
a = Constant
b_1, b_2 = Regression coefficients
X_1 = Body length (cm)
X_2 = Chest girth (cm)

In addition to the regression model, several empirical formulas were used for comparison, including:

Table 1. Body Weight Estimation Formulas for Timor Deer

Schoorl Formula	Winter Formula	Modified Ningsih Formula
$BW = \frac{(CG+22)^2}{100}$	$BW = \frac{(CG^2 \times BL)}{10000}$	$BW = \frac{(CG-5)^2}{100}$
Description : BW = estimated body weight (kg) CG= chest girth (cm).	Description: BL = body length (cm) CG= chest girth (cm).	Description : BW = estimated body weight (kg) CG= chest girth (cm).

The accuracy of each estimation method was evaluated using the percentage bias (P) formula, which represents the deviation between the estimated body weight and the actual measured body weight. The formula is as follows:

$$P = \frac{(EWB-AWB)}{AWB} \times 100\%$$

Description:
P = Percentage bias/error
EWB = Estimated body weight (kg)
AWB = Actual body weight (kg).

RESULT AND DISCUSSION

The following section presents the results of morphometric measurements and body weight estimation of Timor deer (Cervus timorensis) in captivity. The data describe body size characteristics of adult males and females, followed by a comparison of several body weight estimation formulas.

Result

A total of 47 adult Timor deer were observed, consisting of 25 males and 22 females maintained under semi-natural captive conditions. The animals exhibited healthy physical characteristics, active behavior, and uniform body condition scores. Morphometric measurements included chest girth, body length, and withers height, which were subsequently used to estimate body weight through both empirical and regression-based models.

Table 1. Morphometric Characteristics and Body Weight of Timor Deer

Parameter	Adult Male Timor Deer (cm) ± SD	Adult Female Timor Deer (cm) ± SD
Chest girth (CG)	92,7 ± 4,21	70,5 ± 3,58
Body length (BL)	78,7 ± 5,80	66,5 ± 5,84
Withers height (WH)	75 ± 5,56	62,4 ± 6,30
Body weight (kg)	77,4 ± 5,05 (Kg)	45,16 ± 5,05 (Kg)

Table 1 presents the average morphometric measurements and body weight of adult male and female Timor deer (Cervus timorensis). The data show clear differences between sexes, with males exhibiting larger body dimensions in all measured parameters. Adult males had greater chest girth, body length, and withers height compared to females, reflecting the typical sexual dimorphism found in cervid species. This difference is closely related to hormonal and physiological factors, where males generally develop larger body frames and musculature due to testosterone influence. The smaller variation (standard deviation) observed in females indicates a more uniform body size pattern among female individuals.

These morphometric differences between male and female Timor deer also provide important implications for management and body weight estimation models. Since most predictive equations rely on linear body measurements such as chest girth and body length, the significant disparity in body proportions between sexes suggests that sex-specific models may yield more accurate weight predictions. The larger size and greater variability observed in males indicate a wider range of growth and physical development, which could influence regression outcomes. Conversely, the more consistent measurements among females may enhance the precision of estimation formulas when applied to female populations. Understanding these morphometric patterns is therefore essential for refining body weight estimation methods and improving the accuracy of management decisions in both wild and captive Timor deer populations.

Table 2. Average Estimated Body Weight of Adult Male

Variable	**Average Estimated Body Weight (kg)**	**Average Percentage Deviation (%)**
Actual Body Weight	77,4	0
Winter Formula	68,04	12,08
Schrool Formula	131,77	70,25
Modified Ningsih Formula	77,11	0,36
Multiple Linear Regression (CG–BL)	77,09	0,38
Multiple Linear Regression (WH–BL)	77,42	0,03

The results presented in Table 2 show variations in the estimated body weight of adult male Timor deer based on different predictive formulas. The Winter formula tended to underestimate body weight by approximately 12.08% compared to the actual measurement, while the Schoorl formula significantly overestimated it by more than 70%. The Modified Ningsih formula produced estimates that were closest to the actual body weight, with a deviation of only 0.36%. Similarly, both multiple linear regression models demonstrated high accuracy, particularly the regression using withers height and body length (WH–BL), which showed the lowest deviation value of 0.03%. These results indicate that models incorporating more than one morphometric parameter yield more precise body weight estimations.

Table 3. Average Estimated Body Weight of Adult Female

Variable	Average Estimated Body Weight (kg)	Average Percentage Deviation (%)
Actual Body Weight	45,16	0
Winter Formula	33,35	26,15
Schrool Formula	78,72	74,30
Modified Ningsih Formula	42,96	4,87
Multiple Linear Regression (CG–BL)	58,75	30,08
Multiple Linear Regression (WH–BL)	45,35	0,40

The data in Table 3 present the average estimated body weight of adult female Timor deer obtained from several prediction models. The Winter formula produced an underestimation of body weight by about 26.15% compared to the actual measurements, whereas the Schoorl formula largely overestimated the results by 74.30%. The Modified Ningsih formula provided the most accurate estimation with only a 4.87% deviation. Meanwhile, the multiple linear regression models showed variable levels of accuracy; the model combining withers height and body length (WH–BL) achieved the smallest deviation (0.40%), indicating its high precision in predicting actual body weight. Overall, models that integrate more than one morphometric variable tend to produce more reliable estimations for female Timor deer.

Discussion

The findings of this study demonstrate that morphometric characteristics, particularly chest girth, body length, and withers height, have a strong relationship with the body weight of Timor deer (*Cervus timorensis*). The larger average dimensions observed in males compared to females confirm the existence of sexual dimorphism typical of the Cervidae family. This pattern has been similarly reported by Weerasekera et al. (2019) and Saputra et al. (2021), who found that male deer generally exhibit greater body mass and linear body dimensions due to hormonal differences, muscle development, and matingrelated behavioral adaptations. The smaller variability found in females in this study suggests a more stable growth pattern influenced by reproductive energy allocation rather than muscle expansion.

The comparison among several body weight estimation models showed consistent trends between male and female Timor deer. Empirical formulas such as Winter and Schoorl displayed higher levels of bias, either underestimating or overestimating body weight. This outcome aligns with the results of Ningsih et al. (2020), who stated that empirical equations tend to produce less accurate estimates when applied to local deer populations with distinct morphometric characteristics. The Modified Ningsih formula, however, provided improved accuracy, confirming its suitability for tropical deer species maintained under semicaptive systems. This is because the modified model integrates adjustments for chest girth and body length parameters that better reflect the body conformation of Timor deer.

The multiple linear regression models produced the most accurate predictions, with the regression combining withers height and body length (WH–BL) achieving the lowest bias (0.03% in males and 0.40% in females). This finding supports the theory that integrating multiple morphometric variables enhances predictive precision compared to single-variable models (Said et al., 2017; Olatunji et al., 2022). The regression model's superior performance indicates that body weight in deer is determined by complex interactions among several morphometric traits, a pattern also observed in cattle and small ruminants (Hagos

et al., 2021; Kusuma et al., 2024). Therefore, regression-based models are recommended as reliable tools for non-invasive estimation of deer body weight in conservation and breeding management.

From a practical standpoint, the development of species-specific regression equations provides valuable implications for captive management and genetic improvement programs. Accurate body weight prediction is essential for evaluating growth performance, nutritional requirements, and overall animal welfare (Amareyao et al., 2021; Has et al., 2023). Moreover, this study contributes to the refinement of morphometric-based estimation techniques that can be adapted to other deer populations across Indonesia. Future research should consider integrating advanced statistical or machine learning approaches to further enhance predictive accuracy and account for nonlinear growth patterns.

CONCLUSION

This study confirms that morphometric parameters such as chest girth, body length, and withers height are reliable indicators for estimating the body weight of Timor deer (*Cervus timorensis*) in captivity. The clear distinction between male and female morphometric characteristics reflects sexual dimorphism that is strongly associated with physiological and hormonal factors influencing growth and body composition. Among the models evaluated, the Modified Ningsih formula and multiple linear regression models demonstrated the highest accuracy, with the regression using withers height and body length (WH–BL) providing the most precise prediction of actual body weight. These findings indicate that integrating multiple morphometric variables results in better estimation performance compared to single-variable empirical models.

The results of this study contribute to improving non-invasive methods for monitoring the growth and productivity of Timor deer, which can be applied to breeding management, feed evaluation, and animal welfare assessment. Future research should aim to refine regression-based models by expanding the sample size and incorporating additional parameters such as body condition score or age class. Furthermore, the application of advanced analytical approaches such as nonlinear regression or machine learning techniques could enhance predictive accuracy and adaptability across different deer populations in Indonesia.

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