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Original Article

Body weight estimation in mules by a horse weight tape provided an estimated value close to a real body weight obtained from a digital scale

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Abstract Accuracy of body weight estimation is crucial for equine practitioners. Medical administration and nutritional management need animal body weight (BW) for calculation. Scale is the most reliable method for obtaining BW, but in the field where a scale is not available, weight estimation methods such as using weight tape, using weight equation, or visual estimation are commonly used. Several methods of estimation on horses BW had been studied, but none of which in the mules in Thailand has been published. This article described mule's body weight estimation using fifty-four mules, aged between 2.5-4 years old, both male and female. The body weights obtained from a digital scale were used for references. Four BW estimation methods including horse weight tape (HWT), cattle weight tape, weight estimation equation for horse, and weight estimation equation for donkey were performed to compare their values to the real BW. Mean absolute percent error (MAPE) related to BW from the scale were calculated for each BW estimation method. The results showed that HWT have the least MAPE, which can be implied that it is the most accurate method for body weight estimation. In addition, three equations for mule BW estimation based on the thoracic circumference and the body length were also proposed in this study.

Keywords; Mule, Weight estimation, Weight tape, Weight estimation equation, Thoracic circumference

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บทความต้นฉบับ

การประมาณน้ำหนักตัวล่อโดยการใช้สายวัดน้ำหนักม้าสามารถให้ค่าการประมาณใกล้เคียงกับน้ำหนักที่ได้จากเครื่องชั่งน้ำหนักดิจิตอล

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บทคัดย่อ การประมาณน้ำหนักตัวที่แม่นยำมีความสำคัญต่อผู้ปฏิบัติงานที่เกี่ยวข้องกับสัตว์ในกลุ่มม้า ซึ่งมีผลต่อการคำนวณเพื่อการบริหารยาและการจัดการด้านโภชนาการ การใช้เครื่องชั่งน้ำหนักนั้นเป็นวิธีการที่น่าเชื่อถือที่สุดที่ทำให้ทราบน้ำหนักตัวสัตว์ แต่ในภาคสนามที่ออกปฏิบัติงานนั้นไม่มีเครื่องชั่งน้ำหนัก จึงมีการประยุกต์ใช้วิธีการประมาณน้ำหนักตัวสัตว์ได้แก่ การใช้สายวัดน้ำหนัก การใช้สูตรการประมาณน้ำหนักหรือการประมาณน้ำหนักจากสายตา มีการศึกษาจำนวนมากได้กล่าวถึงการประมาณน้ำหนักตัวในม้าและลา แต่ยังไม่มีการศึกษาวิจัยเกี่ยวกับวิธีการประมาณน้ำหนักตัวในล่อ ดังนั้นการศึกษาวิจัยนี้จึงเป็นการศึกษาวิจัยแรกในประเทศไทยที่ศึกษาวิธีการประมาณน้ำหนักตัวในล่อ ล่อจำนวน 54 ตัว อายุ 2.5 ถึง 4 ปี ถูกใช้ในการศึกษา ซึ่งน้ำหนักที่ได้จากเครื่องชั่งนำหนักจะถูกใช้เป็นค่าอ้างอิง และเปรียบเทียบกับวิธีการประมาณน้ำหนักตัวทั้ง 4 วิธี คือ ใช้สายวัดน้ำหนักม้า ใช้สายวัดน้ำหนักวัว ใช้สูตรการประมาณน้ำหนักตัวม้า และใช้สูตรการประมาณน้ำหนักตัวลา โดยพบว่า mean absolute percent error (MAPE) นั้นจะมีความสัมพันธ์ระหว่างน้ำหนักที่ได้จากเครื่องชั่งน้ำหนักและน้ำหนักที่ได้จากวิธีการประมาณน้ำหนักตัวในแต่ละวิธีการ ซึ่งผลจากการวิจัยพบว่าสายวัดน้ำหนักม้านั้นให้ค่า MAPE ที่น้อยที่สุด และงานวิจัยนี้ยังมีการคิดค้นสูตรการประมาณน้ำหนักตัวล่อออกมาทั้ง 3 สูตร

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Introduction

In veterinary medicine, the accurate body weight (BW) is one most important factor for treatment and management of animal health. For the large animals, such as horse and cattle, a digital scale is usually unavailable in routine work place. Although a well calibrated scale can be used to obtain an actual BW, but it is available only in referral center or in a veterinary teaching hospital. Therefore, several methods had been used for estimating BW of those animals. Examples of method for BW estimation may include visual estimation, weight tape, and formulas for BW calculation.

Visual estimation is quick and easy, but possesses high possibility of error and poor repeatability. The estimated BW obtained by this method depended on the experiences of the estimators. Therefore, estimated BW obtained from inexperience estimator may lead to an inaccuracy of calculated dosage of medication, which can cause failure of the treatment. Previous publication on anthelmintic resistance in veterinary medicine revealed that the under-dosing of anthelmintic drugs is one of the most important factors in the development of anthelmintic drug resistance (Shalaby, 2013).

Weight tape is designed for indirect measuring the BW of the animal. To obtain the BWwith this method, the circumference of the chest must be properly measured. This can be done by placing the tape around the cranial thoracic region of the animal. Over the dorsal midline, the tape should be positioned on the highest point of the wither or just behind the withers. Over the ventral side, the tape should be positioned just caudal to the elbow of the animal. In this position the weight tape almost looks perpendicular to the ground (Wagner and Tyler, 2011). Body weight obtained by this method depends on a single parameter, which is the circumference of the cranial thoracic cavity. Therefore it is also possesses some degree of error. This is due partly to a variation of the anatomical characteristics of each animal. Thus finding a new technique for a better accurate estimation of the BW may benefit to the veterinary practitioners. Several of previous researches aimed to develop equations for BW estimation based on morphometric values of the animals had been done in horses and donkeys (Carroll and Huntington, 1988; Pearson and Ouassat, 1996; Cherdchutham, 2004; de Aluja, 2005).

Cherdchutham and colleagues (2005) compared several available equations for Thoroughbred horse BW estimation including one from their own research in 2004 and found that weight estimation equation derived from girth circumference (CG) and a distance from shoulder to tuber ischii (SL) possessed comparable accuracy to the weight estimation. The equation (Cherdchutham, 2004) is demonstrated in equation I.

$$Weight\ (kg) = [3.339 \times CG\ (cm)] + [3.768 \times SL\ (cm)] - 694.427 \quad \text{I}$$

There was also a studied and designed in weight estimation equation of Moroccan donkeys in Morocco by Pearson and Quassat in 1996. This

weight estimation equation is demonstrated in equation II. However, this weight estimation equation was unable to be applied to a population of donkeys in the central Mexico (de Aluja et al, 2005). Therefore, this publication proposed an alternative weight estimation equation for the donkey population in the central Mexico. The equation is demonstrated in equation III. The results of this study suggested that even the weight estimation equation was specifically designed for donkeys, but may possess variation in the results when applied to a different group of populations.

$$Donkey\ live\ weight\ (kg) = \frac{[heart\ girth\ (cm)^{2.12} \times length\ (cm)^{0.688}]}{380} \quad II$$

$$Donkey\ live\ weight\ (kg) = 0.021179 \times [thoracic\ circumference\ (cm)]^{1.81247} \quad III$$

Mule is a hybrid derived from breeding a male donkey to a mare. Mules in Thailand are bred from native mare and imported donkeys. Two breeds of jack are available in Thailand including the Australian mammoth and the Dengzhou. Mules are used as a packing animal along the country borders where the terrain is mountainous and inaccessible by automobile. They can carry a greater weight when comparing to horses in a same body size. Obtaining BW of the mule serving in those area for medical purposes possess a big challenge for veterinary practitioner. Knowing an accurate BW of the mule is still important, since this information is needed for calculation of medication dosage. Information of BW also is required when treating mules suffered from dehydration. Without BW the veterinarian cannot calculate amount of fluid that the animals need. In the field, the veterinarian may visually estimate BW of the mules because the scale is unavailable and also no specific commercial weight tape for mule. Several equine practitioners in Thailand using weight tape of different species of animals, such as horses and cattle, to measure the body weight of the mules.

Therefore, this study was conducted in order to test the accuracy of body weight estimation in mule using a horses and ponies weight tape (HWT), cattle weight tape (CWT), weight estimation equation for horse (WEEH), and weight estimation equation for donkey (WEED) compare to body weight obtained from a digital scale.

Materials and Methods

Samples

Fifty-four male and female healthy mules age ranges from 2.5 to 4 years from the Veterinary Remount Department of the Royal Thai Army, Chiang Mai, Thailand, were recruited for this study. A minimum number of 30 samples were required for further statistical analysis with data mining method. Individual identification and information including age, sex, sire, and body condition score were recorded during the study. Body condition score of each mule was evaluated by two independent veterinarians using nine-point system (Pearson, 2005). Protocols for animal handing and usage in this study were approved by the Ethic Committee of the Faculty of Veterinary Medicine, Chiang Mai University.

Weighing the animal

Individual mule was weighted on a portable digital scale constructed from four load cells (34 Engineering Technology Co., Ltd. Chiang Mai, Thailand). The load cells were pre-calibrated by using a 50 kg knob weight. The load cells are capable of measuring weight at the maximum of 2,000 kg with an accuracy of +/- 1.5 kg at the maximum load. The scale was installed in a chute of sorting pen just before the exit of the chute. To install the scale, the four load cells were placed on a flat concrete floor of the chute 1.5 meters apart. A 68.2 kg of 80 × 180 cm of a wooden platform constructed from 2 inches thick of hard wood was place over the load cells. The scale was reset to zero every time prior to weight each individual mule.

Mule was individually weight by encouraging the individual to walk into the chute and stepped on the platform. The researcher then performed a final check that the body of the mule did not lean on the wall of the stall prior to read the value of body weight. Weighing was performed between 01.00 pm to 03.30 pm before the evening meal of the mule.

Measurement of the body proportions

Interested parameters of the body proportions in this study included thoracic circumference (TC) and body length (BL). Theses parameters were measured by HWT (EquiVET®) that also can be used to measure length in centimeter. The TC was measured by placing a weight tape around the cranial thoracic cavity. The measuring tape was placed over the caudal edge of the withers on the dorsal region, and was placed just caudal to the elbow on the ventral region.

The BL is a distance between the mid of the shoulder joint and the bony prominence of the tuber ischia. All the measurements of the body proportions was performed and recorded for three times while the mule was standing on the platform. The TC and BL in all mules was measured by a single person. Average values of the each parameter of the body proportions were used for further statistical analyses.

Measurements of body weight with weight tape

Measurement of BW by weight tape was perform by using a HWT (EquiVET®), and a CWT. To measure the body weight with HWT and CWT, the weight tape was placed around the cranial part of the thoracic cavity at the caudal edge of the withers on the dorsal, and just caudal to the elbow on the ventral part of the body. Measurement of body weight by tapes in all mules were repeated for three times by a single person.

Weight estimation by equations

Data of the TC and BL previously obtained by the above mentioned methods were used for BW calculation. The equations used in this study include the equation designed for Thoroughbred horses in Thailand previously described by Cherdchutham (2004) (I), and equations designed for donkeys in Morocco by Pearson and Quassat (1996) (II) and in the Central Mexico by A.S. de Aluja et al (2005) (III).

$$Weight\ (kg) = [3.339 \times CG\ (cm)] + [3.768 \times SL\ (cm)] - 694.427 \quad I$$

$$Donkey\ live\ weight\ (kg) = \frac{[heart\ girth\ (cm)^{2.12} \times length\ (cm)^{0.688}]}{380} \quad II$$

$$Donkey\ live\ weight\ (kg) = 0.021179 \times [thoracic\ circumference\ (cm)]^{1.81247} \quad III$$

Statistical analysis

Data of BW obtained from digital scale, HWT, CWT, WEEH, and WEED were analyzed using Data Mining method. Data of BW between genders were compared by using the Independent *t-test* to evaluate the difference between the means of two independent groups. Mean absolute error (MAE) and mean absolute percent error (MAPE) were calculated for each method of obtaining BW. Weight estimation method that possesses the lowest MAE and MAPE indicated that the estimated value is closest to the body weigh obtained from the digital scale.

Data of TC and BL were used as predictors with simple linear regression to generate an equation for BW estimation in tested mules. Statistical analyses were performed by using the R program (version2.15.2). *P*-value equal or less than 0.05 was considered to be statistical significant.

Results

Demographic information indicated that the mules being used in this study include 25 male and 29 female mules age ranged from 2.5-4 year-old. Five mules were derived from Australian Mammoth, and 49 mules were derived from Dengzhou sire. The body condition score were ranged from 3-5. Real body weights obtained from digital scale ranged from 150-339 kg with an average of 204.53 kg. Average body weights of male and female mules were 205.44 and 203.76 kg, respectively. There were not statistical difference in the real body weight between male and female mules being used in this study (*p= 0.8475*). Details of the body weight statistic of the male and female mules are showed in table 1.

Table 1. Mean and Standard deviation (SD) of the body weight of mules being used in this study

Gender	*N*	Mean	S.D.
Female	29	203.76	25.96
Male	25	205.44	36.15

p-value = 0.8475

Thoracic circumferences ranged from 121.67–164.67 cm with an average of 136.77 cm. The body lengths ranged from 111-145 cm with an average of 123.44 cm. Body weights obtained from HWT ranged from 153.67–337.33 kg with an average of 210.12 kg. Body weights obtained from CWT ranged from 159.33–376.33 kg with an average of 217.67 kg.

Body weights calculated from WEEH ranged from 130.06–401.75 kg with an average of 227.36 kg. Body weights obtained from WEED ranged from 127.41–220.51 kg with an average of 157.83 kg.

Accuracy of body weight estimation method

Data mining analysis for accuracy indicated that body weight obtained by HWT possessed the lowest MAE and MAPE when compared to others methods of body weight estimations. Body weight obtained from WEED possessed the highest MAE and MAPE. This indicated that body weight obtained from WEED was not close to the body

weight obtained by digital scale. Details of accuracy prediction parameters of each method of body weight estimation are showed in table 2.

Table 2. Accuracy prediction parameters of each method of weight estimation compared with the body weight obtained from digital scale calculated by Data Mining method using R-program.

Methods	MSE	RMSE	MAE	MAPE
Horse & Pony weight tape	146.15	12.09	10.26	5.27
Cattle weight tape	315.80	17.77	14.14	7.03
Horse equation	882.46	29.71	25.10	11.90
Donkey equation	2477.12	49.77	46.71	22.23

*MSE: Mean Square Error; RMSE: Root Mean Square Error; MAE: Mean Absolute Error; MAPE: Mean Absolute Percent Error

A graphic comparison of estimated body weight obtained from different methods demonstrated in figure 1 suggested that body weight obtained from HWT, CWT, and WEEH yielded a concordant result with the real body weight obtained from digital scale.

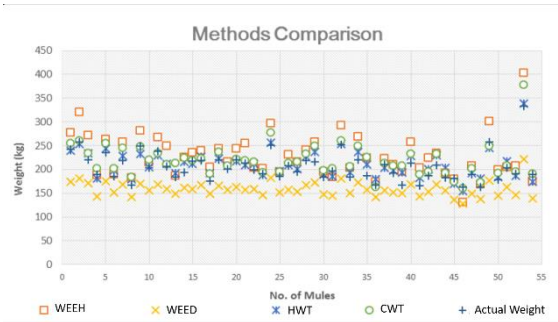

Figure 1: Distribution of individual body weight obtained from different methods (WEEH: weight estimation equation for horses, WEED: weight estimation equation for donkeys, HWT: horse weight tape, CWT: cattle weight tape)

Results from the regression analysis indicated that the coefficient of determination of TC and BL for determining the body weight were 0.8153 and 0.7732, respectively. This indicated that both TC and BL can be used for body weight estimation in mules. When incorporate both parameters into the regression analysis, the coefficient of determination of the equation increase to 0.8718. Details of the regression analysis and the coefficient of determination for each parameter and their combination are showed in table 3.

Table 3. Equations for estimation the bodyweight of mule age range from 2.5-4 years in Chiang Mai province based on thoracic circumference in (TC) and body length (BL), when a unit of measurement is centimeter and their adjusted R^2 values.

Equations	Adjusted R^2
Weight = 4.0980(TC) -340.6918	0.8153
Weight = 4.5295(BL) -339.3183	0.7732
Weight = 2.5156(TC) + 2.1790(BL) - 393.2388	0.8718

Discussion

The studies of BW estimation had been done in several equids such as horses and donkeys. In Thailand, some studies of body weight estimation have been done in Thoroughbred by using equation based on parameters derived from chest circumference and body length (Cherdchutham, 2004). The BW derived from this equation was close to a BW obtained from a scale

with a deviation approximately 1.6%, while BW from HWT had a deviation approximately 10%. Results from our study suggested that estimation of mule BW using HWT possessed a better accuracy than that of the horses, with a 5.26% deviation from the value obtained from digital scale. Even though the body weight estimated by WEEH provided a concordant result to the real body weight, from our results, we suggested that this equation tended to over-estimate the BW. But the reason that the HWT yielded a better estimated-weight in mule than that of the Thoroughbred is unknown and may need further investigation.

The BW estimation in donkeys had been reported since 1990 in several countries. Eley and French (1993), Pearson and Ouassat (1996) and de Aluja et. al., (2005) had developed equations to predict the live BW of donkeys in Great Britain, Morocco, and the Central Mexico, respectively. Each equation incorporated different variables. Eley and French (1993) used heart girth and height, Pearson and Ouassat (1996) used heart girth and body length and De Aluja et.al., (2005) used only TC to predict the body weight of donkeys. Results of the above mentioned studied also suggested that equations developed based on information derived from one population may not suitable to be applied in other populations. These can explain the reason why the WEED tended to under estimate the body weight of the mules in Thailand.

Based on the breed of sire that the mule in our study derived from, we may able to divide our samples into two groups. The first group was mules derived from Dengzhou sire (n=49). The second group was mules derived from Australian Mammoth sire (n=5). Because the huge different on the number of the samples of these two groups, we were unable to determine the effect of different populations in our study and requires further study.

Results from our study also suggested that body weight obtained from digital scale of male population were not different from female population. Mules being used in our study were immature with age ranged from 2.5-4 year-old. At this age the sex dependent anatomical characteristics may not fully developed and may possess little to no effects on BW.

The estimation of BW in large animal is very important for medical purposes especially in the facilities where a scale is unavailable. Either overestimate or underestimate of the BW can lead to an inaccurate dosage calculation of medications. This can be dangerous to the animals in several circumstances. According to The United States Pharmacopeial Convention (2007), a foal receiving high dosage of gentamicin is at risk of nephrotoxicity. Overestimation of its BW will definitely increase this risk and may cause fatal condition to the foal.

Based on the previous studied in Thoroughbred and donkey, three equations that have potential to be used in mule population in Chiang Mai was developed and proposed in this article as showed in table 3. Results from the adjusted R^2 analysis suggested that TC possessed the highest R^2 and may be used as a single parameter to estimate the body weight of

the mule. Combination of TC and BL parameters in the equation increased the predictive capability, but also increased a complexity of the application. The small difference of the estimating values among the three equations may be considered that the more complicated estimation method is unworthy to practice especially for wide-safety dosage range medications such as ivermectin. Therefore, further development is required to simplify the application of these equations.

Conclusion

Results in our studied suggested that the horse weight tape provided a value of estimated-BW closest to the real BW obtained from the digital scale, followed by the cattle weight tape, weight estimation equation for horse, and weight estimation equation for donkey, respectively. The results also suggested that genders did not affect the weight of the mules in our experimental groups. According to data from thoracic circumference and body length, an equation was also generated with high predictive value but it still need further development in order of convenience in the field application.

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