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A Comparison of Weight Estimation Methods in Adult Horses

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ABSTRACT

Weight tapes and body weight estimation formulas are routinely used to determine the body weight of a horse when a scale is not available. The established formula to estimate body weight in mature horses is weight (kg) = (*heartgirth*^{2} × *body length*)/(11,880 cm^3). Two variations of the body length measurement have been used, measuring distance from the point of the shoulder to the ischial tuberosity (Point) or to the midpoint of the distance between the widest part of the stifle and the tail when viewed from the rear (Stifle). The objective of this study was to evaluate the accuracy of a commercial weight tape and the body weight estimation formula using both body length measurements in estimating weight of adult horses. Horses (n = 145) were weighed on a portable livestock scale, and measured for height at the withers, heart girth circumference, and body length by using the Point and Stifle measurements. A commercial weight tape was used to estimate body weight on 110 horses. The two formula weight estimations and the weight tape estimation were significantly different from the actual weight and from each other. The mean difference between actual weight and tape weight (n = 110) was 65.81 kg, whereas the differences between actual weight and the formula estimations (n = 145) were 17.25 kg for the Point measurement and 45.26 kg for the Stifle measurement. The estimation formula using body length measurement with the ischial tuberosity endpoint most closely estimates the actual body weight of the horses.

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1. Introduction

Knowing the body weight of a horse is important in many facets of horse care, including designing feeding programs and administering medication. However, horse owners and veterinarians working in the field generally do not have access to a livestock scale for the purpose of obtaining a horse's weight. Weight tapes and body weight estimation formulas have been developed for estimating a horse's weight under these circumstances. Weight tapes are designed to estimate weight using the circumference of the horse's heart girth. Weight estimation formulas incorporate body length as well as heart girth circumference.

Milner and Hewitt [1] were among the first to compare various methods of estimating body weight, including several estimation formulas and commercially available tapes. The formula used in the present study, in which estimated weight (kg) = (*heartgirth*^{2} × *body length*)/(11,880 cm^3), is commonly attributed to Hall [2]. The formula was evaluated by Carroll and Huntington [3] and found to be more accurate than that published by Milner and Hewitt [1].

Subsequent research has used the same formula, although the definition of body length has differed. The original research defined body length as the distance from the point of the shoulder to the ischial tuberosity [2,3]. Later research used the midpoint of the distance between the widest part of the stifle and the tail when viewed from the rear as the endpoint of the length measurement [4-6]. As a result, both measures of body length have been used in describing the body weight estimation formula in the popular press and other general circulation materials.

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Table 1
Number of horses by breed included in the study

Breed	Number of Horses
Appaloosa	3
Arabian	6
Belgian	1
Gypsy	2
Kentucky Mountain horse	2
Missouri Fox Trotter	5
McCurdy	1
Morgan	9
Morgan—Percheron cross	1
Mustang	2
Paint	13
Paso Fino	2
Quarter Horse	40
Quarter Horse—Arabian cross	1
Quarter Horse—Tennessee walking horse cross	2
Racking horse	1
Rocky mountain horse	3
Saddlebred	1
Spotted saddle horse	5
Thoroughbred	13
Tennessee walking horse	20
Tennessee walking horse—Racking horse cross	1
Tennessee walking horse–Spotted saddle horse cross	1
Warmblood	8
Unregistered stock-type	2

The objective of this study was to evaluate the accuracy of a commercially available weight tape and the body weight estimation formula using the two different body length measurements in estimating weight of adult horses.

2. Materials and Methods

All animal procedures were approved by the Auburn University Institutional Animal Care and Use Committee. Data were collected at seven different farms or equine events between January 2009 and September 2010.

A total of 145 horses were weighed and measured for the purposes of this study. Breeds represented in the study are detailed in Table 1. Horses aged <2 years, as defined by the universal birth date of January 1, were excluded from the study. Mean age of horses was 10.49 ± 5.49 years, with 96 geldings, 46 mares, and three stallions represented. Ponies and pony breeds were also excluded, although several of the light horse breeds represented had individual horses that measured <147.32 cm, which is the upper height limit for ponies as defined by the United States Equestrian Federation.

Physical measurements included weight, height at the withers, heart girth circumference, and body length. All horses were weighed on a portable livestock scale. Height was determined by standing the horse square on a level surface and measuring the highest point of the withers with an aluminum height stick. A plastic measuring tape was used for body measurements. Heart girth circumference was determined by placing the measuring tape behind the elbow, and passing it in a straight vertical line over the withers and across the sternum. Body length was measured from the point of the shoulder to the ischial tuberosity (Point) and point of the shoulder to the midpoint of the distance between the widest part of the stifle and the tail when viewed from the rear (Stifle) (Fig. 1). A commercially available weight tape (The Coburn Company Inc., Whitewater, WI) was used on 110 horses to estimate weight by placing the tape in the same location as the heart girth measurement, following the instructions provided. The weight tape was randomly selected from a farm and equine supply catalog popular in the region of the United States where the study was conducted.

The same two investigators carried out all the measurements to ensure continuity in the placement of measuring tools. Investigators also evaluated body condition score (BCS) using a nine-point scale [7], and the two scores were averaged to generate a single BCS for each horse. A separate individual recorded all measurements, as a result of which investigators were unaware of the actual scale weight and each other's BCS assessment of the horses.

Statistical analyses were performed using the STATA software program (StataCorp, College Station, TX) [8]. Paired *t*-tests were used to compare actual weight and the three estimated weights, with significance set at $P < .05$.

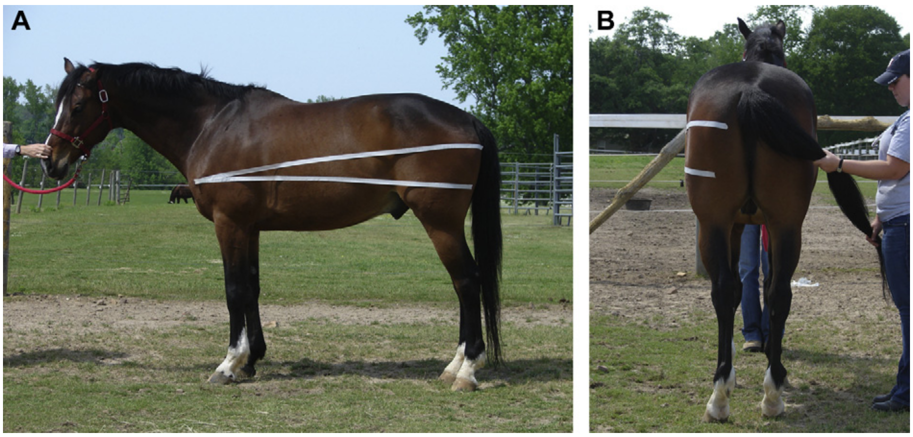

Fig. 1. Placement of measuring tape in determining body length when viewed from the side (**A**) and rear (**B**). The upper, diagonal line corresponds to the body length measurement from the point of the shoulder to the ischial tuberosity (Point), whereas the lower, horizontal line measures to the midpoint of the distance between the widest part of the stifle and the tail when viewed from the rear (Stifle).

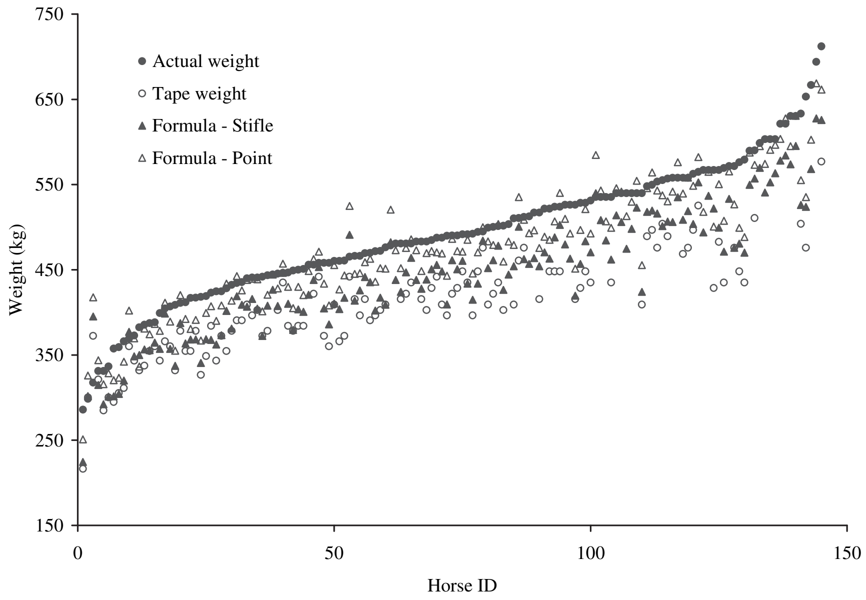

Fig. 2. Actual and estimated weights of horses. Horses were ordered by actual weight, which was plotted along with the animal's respective estimated weights as determined by weight tape (n = 110) and two variations of the Hall formula (n = 145) (See text for details).

Lin's concordance correlation coefficient [9] and limits of agreement for Bland and Altman diagrams [10] for the comparisons were generated using the concord procedure within the software. Other comparisons between predicted and actual values were made using linear regression. Finally, stepwise regression was used to evaluate potential predictors of body weight, including breed, age, gender, height, BCS, heart girth, and body length.

3. Results

Horses included in the study represented a wide range of heights and body types. Mean height was 156.11 cm with a range of 133.35 to 180.34 cm, or 13 to 17.3 hands. In all, 17 light-breed horses measured <147.32 cm, or the height limit for ponies as defined by the United States Equestrian Federation. BCS ranged from 3.75 to 7.5 with a mean of 5.38 ± 0.72, indicating that horses averaged in the moderate category using the descriptions of Henneke body condition scoring system [7].

Actual weight of horses ranged from 285.77 to 712.15 kg, with a mean of 491.94 ± 78.59 kg. Body length as measured by the two endpoints differed significantly, with the Point measurement being 3.92 ± 1.35 cm longer than the Stifle measurement ($P < .05$). Horses were ranked by actual weight, and the data points for actual and estimated weights are plotted in Figure 2. All three estimated weights were significantly different from the scale weight, and from each other ($P < .05$). Estimated weight as derived by the three methods was subtracted from the actual weight to determine the difference (Table 2). All estimation tools underestimated the horses' body weights. Estimation of body weight using the Point measurement in the formula yielded the closest estimate of body weight, and weight tape estimate demonstrated the greatest amount of variation from the actual weight among the three estimation methods.

Bland and Altman diagrams [10] were generated to assess agreement between actual scale weight and each estimated weight (Fig. 3). The difference between the two measurements is plotted against the average of the measurements for each horse. Bland and Altman diagrams are used to visualize the agreement, but not necessarily accept or reject agreement between measurements. In Figures 3B and C, the data points appear to fall symmetrically within the boundaries of their respective 95% confidence intervals, although that does not seem to be the case for the agreement between the actual weight and weight as estimated by use of the commercial weight tape (Fig. 3A). However, in a follow-up analysis, a weak correlation ($r = 0.0279$) was found between the actual weight and the predicted error of the weight tape estimation.

Lin's concordance correlation coefficient was generated for each comparison of actual and estimated weight. The concordance correlation coefficient takes the slope of the line of agreement as well as goodness of fit of the data into account when evaluating reproducibility of measures using two techniques [9]. Although the Pearson's correlations

Table 2
Differences between actual and estimated weights of horses

Estimation Tool	Difference (kg)[a]	SE
Weight tape (n = 110)	65.81	3.14
Formula[b] (n = 145)		
Stifle	45.26	2.24
Point	17.25	2.27

[a]Difference = actual weight—estimated weight; all differences were statistically significant ($P < .000$).

[b]Estimated weight (kg) = (*heartgirth*^{2} × *body length*)/(11,880 cm^3), where body length was measured from the point of the shoulder to midpoint the distance between the widest part of the stifle and the tail when viewed from the rear (stifle) or to the ischial tuberosity (point).

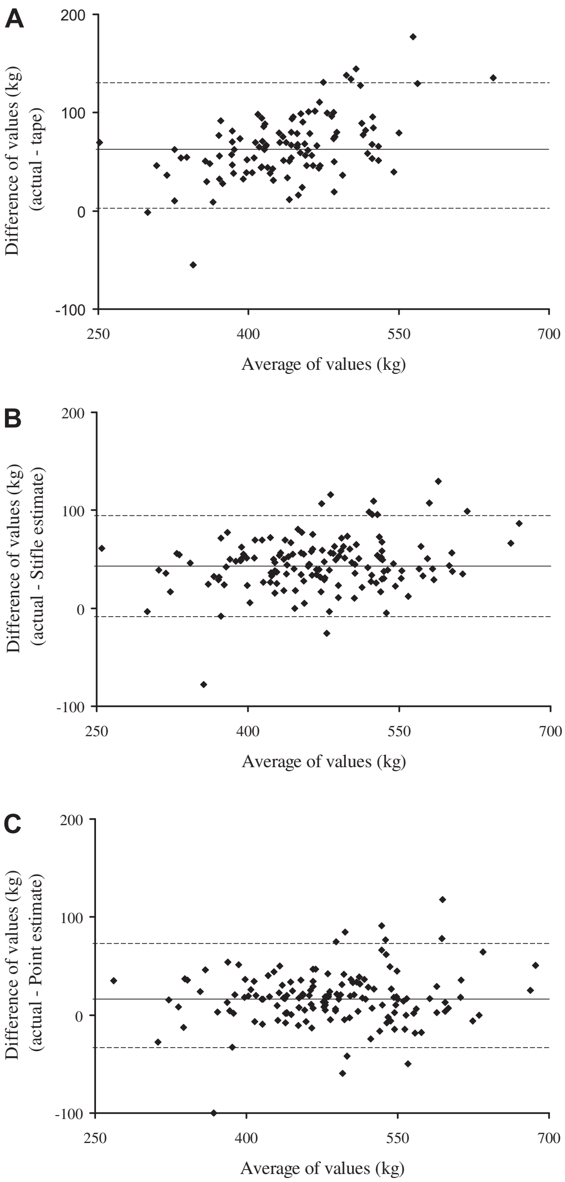

Fig. 3. Bland and Altman diagrams for comparing differences among actual weight and (**A**) tape weight (n = 110), (**B**) stifle formula estimate (n = 145; estimated weight [kg] = [*heartgirth*^{2} × *body length*]/[11,880 cm^3]), and (**C**) point formula estimate (n = 145; estimated weight [kg] = [*heartgirth*^{2} × *body length*]/[11,880 cm^3]). The average of the actual and estimated weight is plotted on the horizontal axes, and the difference (actual—estimated) is plotted on the vertical axes. Mean differences are indicated by the solid line and the 95% confidence interval boundaries (mean ± 2 SD) are indicated by the broken lines on each diagram.

appeared to be strong, slopes and intercepts of the respective lines of agreement varied, contributing to the differences observed with the concordance correlation coefficients (Table 3). The strongest correlation between an estimation tool and actual weight was observed when using the Point measurement in the formula.

Although the closest estimate, the formula using the Point measurement was significantly different from the actual weight. Linear regression was used to generate a more accurate denominator for the formula, and a divisor of 11,481 cm^3 was found. A Wald test was performed by comparing the regression of actual weight and the original formula weight with the regression of actual weight and the revised formula weight. The regression coefficients, and thus, the denominators of 11,880 cm^3 (old) and 11,481 cm^3 (suggested), were different from each other. A stepwise regression model was used to evaluate predictors of bodyweight. The initial model included individual horse, age, BCS, breed, height, heart girth, and body length as measured to the ischial tuberosity as potential factors in predicting actual body weight. Individual factors were removed if $P \geq .05$. The final model included age, gender, body length, and heart girth (Table 4).

Table 3
Coefficients and line of agreement slope and intercept when comparing actual weight with one of three estimated weights of horses

Estimation Tool	Pearson's Coefficient	Lin's Coefficient	Line of Agreement	
			Slope	Intercept
Weight tape (n = 110)	0.903	0.582	0.776	39.877
Formula[a] (n = 145)				
Stifle	0.939	0.793	0.922	−7.082
Point	0.937	0.914	0.964	0.473

[a]Estimated weight (kg) = *(heartgirth*^{2} × *body length)*/11,880, where body length was measured from the point of the shoulder to midpoint the distance between the widest part of the stifle and the tail when viewed from the rear (Stifle) or to the ischial tuberosity (Point).

4. Discussion

The ability to accurately estimate a horse's body weight in the field has many applications. This research sought to compare the reliability of a commercial weight tape and an estimation formula in estimating body weight, and to clarify the best measurements to use in the formula.

In this study, the commercial weight tape (The Coburn Company Inc.) was the least accurate method in determining a horse's body weight. It was noted that the weight tape used for this study was one of several tapes available to horse owners and caretakers. During the course of data collection, a few participating horse owners also asked to have their horses evaluated using their own weight tapes as a reference for their personal use. There were several observations in which other weight tapes were more or less accurate in predicting the horse's scale weight when compared with the tape used for this research. These data, and the manufacturers of these tapes, were not recorded or subjected to statistical analysis. It became apparent that each brand of weight tape uses a different measurement system for estimating body weight based on heart girth circumference. How each company designs and validates their particular formula is proprietary information and not available through the scientific literature. Additional research comparing multiple weight tapes would be necessary to draw a conclusion regarding the reliability of all weight tapes.

Measuring body length from the point of the shoulder to the ischial tuberosity was determined to be the most accurate body length measurement for use when estimating body weight by the established formula, where

Table 4
Stepwise regression analysis of predictors of body weight in horses

Factor[a]	Coefficient	SE	P-value
Age	−1.411	0.449	.002
Gender	−11.782	4.538	.010
Body length[b]	2.382	0.469	.000
Heart girth	5.279	0.383	.000

[a]Full model included individual horse ($P = .771$), height ($P = .741$), breed ($P = .646$), and body condition score ($P = .084$).
[b]Measured from the point.

estimated weight (kg) = (*heartgirth*^{2} × *body length*)/(11,880 cm^3) [2]. This is the same measurement that is referenced by Hall [2], and later by Carroll and Huntington [3]. A review of literature did not determine the origin or rationale for the other body length measurement. Measuring to the ischial tuberosity (point of the buttock) does have the advantage of less subjectivity in determining body length when compared with using the midpoint of the distance between the widest part of the stifle and the tail when viewed from the rear. Care was taken in the present study to have the same researcher assigned to locating the anatomical landmarks for measurements. Future research may consider exploring repeatability of the measurements, and therefore weight estimation, when performed by a variety of individuals.

Even when the more accurate body length measurement was used, estimation of body weight by using the formula was significantly different from the actual body weight. Although there was a difference, the authors do not suggest an adjustment of the formula. The mean difference in weight between the actual and formula methods was 17.25 kg, or about 3.5% of the mean scale weight of the sample population. Factors such as water or feed intake, defecation, and urination will cause fluctuations in body weight throughout the day. Subtle differences in tape measure placement by various individuals can result in different body measurements which subsequently affect the results of the equation. The present denominator used in the equation (11,880 cm^3) has been in place for about 40 years. It is not feasible to recommend adjustment of this established denominator without further research using multiple investigators and more horses to evaluate repeatability and accuracy of the suggested new denominator. Finally, the stepwise regression analysis showed age and gender, along with heart girth and body length measurements, to have an influence on predicting body weight. Including those factors in the formula, or creating additional formulas for multiple sub-groups of horses, would further complicate matters.

5. Conclusion

Some body weight estimation techniques produced more accurate results than others. This is a concern when veterinarians and horse owners use these methods to calculate feeding needs, medication dosages, and general horse-keeping practices. The commercial weight tape used in this study yielded the least accurate weight predictions, underestimating the horses' weights by a mean of 65.81 kg. Measuring from the point of the shoulder to the ischial tuberosity yielded a body length measurement that produced the most accurate estimation of body weight using the formula method. No method is perfect, but when a scale is unavailable for determining a horse's weight, the formula, where estimated weight (kg) = (*heartgirth*^{2} × *body length*)/(11,880 cm^3), appears to be the best choice for estimating body weight.

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