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Original Research

Estimation of Live Weight by Body Measurements in the Miranda Donkey Breed

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ABSTRACT

The use of the measurement of heart girth (HG), in locations where a scale is not available, with the application of weight estimation formulas or special weight tapes, is well established as a practical and accurate way to estimate the live weight (LW). Although several studies were performed to correlate donkey body measurements and LW, none of these was done in the large frame European donkey breeds. When using smaller frame breeds formulas, the tendency was to underestimate the live weight of larger frame breeds. The sample used in this study consisted of 65 Miranda breed donkeys, with ages ranging from 4 days to 15.4 years (6.6 ± 4.4 years). The studied population mean LW was 280.8 ± 106.1 kg (32.5 −475.5 kg); the mean height was 127.4 ± 14.7 cm (69−157.5 cm); the mean body length (BL) was 131.4 ± 25.3 cm (59−184 cm); and the mean HG was 143.8 ± 23.1 cm (71−175 cm). All the correlations between LW and the body measurements taken were statistically significant ($P < .001$), but the degree of accuracy was higher in the HG ($r = 0.937$) than in the BL ($r = 0.915$) or height ($r = 0.894$). The formula that best estimates the LW was performed by Quadratic model and was based on the HG measurement: $LW = 98.138 - 3.0386 \times HG + 0.0293 \times HG^2$ (LW in kilogram; HG in centimeter). The formula found can be used to create a weighing tape, adapted to large frame European donkey breeds, to be used to estimate weight and better adapt medication dosages and carried load for each animal.

1. Introduction

In all domestic animals, the knowledge of live weight (LW) is needed for both management and veterinary purposes. Weighing is the most accurate method for obtaining LW of animals; however, weight scales, especially for large animals, are not usually available, and weighing procedure is time consuming, dangerous, and stressful. In these conditions, owners and veterinarians usually rely on their experience to estimate LW by visual assessment, often not with the needed accuracy [1,2].

The use of the measurement of heart girth (HG), in locations where a scale is not available, with the application of weight estimation formulas or special weight tapes, is well established in large animal domestic species, such as cattle [2,3] and horses [1,4], as a practical and accurate way to estimate LW. Also in donkeys, it is fundamental to have a reliable method to assess LW of the animals, in field conditions, where large scales are seldom available. This is important to calculate correct drug dosages of medications, body development, the effect of diet, and the capacity for each animal.

It is known that LW estimation of young and adult donkeys usually needs different formulas based on the HG when using linear regression formulas because of different body proportions between them [5]. However, the use of a single formula and its application in a measuring tape can be of great utility in field conditions. In horses, some of the existing formulas refer to specific horse breeds and may not be directly transferable when animals have different body types [1,4].

Although several studies were performed to correlate donkey body measurements and LW, none of these were done in the large

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frame European donkey breeds, such as *Miranda*, *Zamorano-Leones*, *Catalana*, *Martina Franca*, or *Poitou*. The available studies were done in crossbreed working donkey populations smaller and thinner than the large former mule production Miranda breed; for example, with crossbreed working animals in Morocco [5], *Sub-Saharan Africa* [6–8], and Central Mexico [9] and, more recently, in Brazil, with the *Pêga* breed [10]. To the best of our knowledge, the only study with European donkeys was performed by Eley and French [11], in Britain, but no information on the breed, LW or body condition score was provided.

Donkey populations found on different countries, evolved with different breed characteristic and have quite different management and body types and should have specific formulas to calculate LW based in body measurements. When equations that use body measurements for LW estimation are developed using populations of similar body type and weight characteristics, the estimation tends to be more accurate [5–10]. The objective of the present work was to develop a mathematical formula to calculate LW of the large frame Miranda donkey breed using body measurements.

2. Materials and Methods

2.1. Animals and Management

All animals were housed in AEPGA (Portuguese Association for the Study and Protection of the Donkey) farm, at Miranda do Douro, in the Northeast of Portugal (41° 25′ 0″ N, 6° 29′ 0″ W). The donkeys were kept in a dry paddock. Each adult donkey was group fed 5–7 kg of a mix, roughly in a proportion of 30% of hay to 70% of straw, distributed twice daily. This corresponded to a total dry matter intake of between 1.5% and 2% of body weight. Body condition score was evaluated every month, and feed was increased or reduced according to the results, keeping the donkeys with the same body condition score year-round. Younger animals, till 8 months, were with mothers, drinking milk and fed *ad libitum*. Clean fresh water was always available. All the animals were submitted to the same management. Animal handling was performed in compliance with the national regulations and the European Council Guidelines (Directive 2010/63/EU) for the protection of animals used for scientific purposes, and respecting Animal Care and Welfare protocols.

The age records were obtained from the Studbook of the Miranda breed. In this group, 18 animals are juvenile, with less than 3 years (16 castrated males and two females), 28 were adult females, 18 were adult castrated males, and one was a jack at the age of 7 years.

2.2. Body Measurements and Weighing

The sample was collected at the beginning of July 2018. All animals were measured on a flat surface, with its weight equally distributed over the four limbs. The body measurements included height at the withers, HG circumference and body length. The height was measured with an aluminum height stick at the highest point of the withers. The HG was measured around the thorax, passing 3 cm caudally to the highest point of the withers, and the body length was measured as the distance from the point of the shoulder to the point of buttock (Fig. 1). The different measurements were repeated three times, and the average value was used. For HG and body length, a 200 cm measurement tape was used. All measurements were carried out by the same investigator to ensure continuity in the placement of all the measuring tools. The animals were afterward weighted in a large animal scale (Salter Brecknell PS-3000HD Floor – Veterinary Scale, Brecknell Company, Fairmont). All animals were weighted standing, after immobilization.

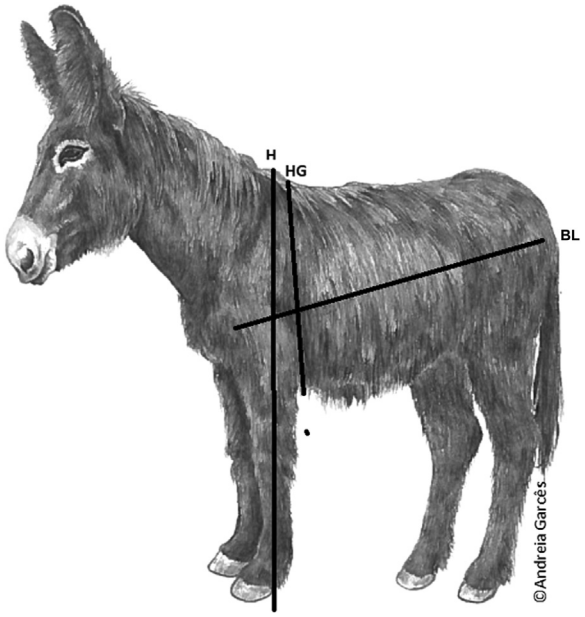

Fig. 1. Body measurements performed on the Miranda donkeys: heart girth (HG), body length (BL), and height (H).

2.3. Statistical Analysis

The data were organized using the software Excel (Microsoft Corporation, USA). All statistical analysis was done using the software JMP 13.0 (SAS Institute, Cary, NC, USA). To predict LW using HG as an independent variable, several models (Quadratic, Probit, Logistic and Exponential) were tested to the best fit. To compare the goodness-of-fit models, the Akaike Information Criterion value (AICc), Root Mean Square Error (RMSE), and coefficient of determination (R^2) were used. The model with the lowest AICc and RMSE values and the highest R^2 was considered the best.

Finally, equations previously described in the literature to predict LW with HG body measurement [5,6,8–10] were compared with those obtained using the proposed equation for Miranda donkeys. The error as the difference between actual Miranda LW values and the predicted LW by models proposed by those authors was analyzed.

3. Results

The sample shows a wide variation of LW, with a coefficient of variation (CV) of 37.8%. For body measurements (height, BL, and HG), the variation was about 2–3 times smaller (CV between 12% and 19%). The studied population mean LW was 280.8 ± 106.1 kg (32.5–475.5 kg); the mean height was 127.4 ± 14.7 cm (69–157.5 cm); the mean body length (BL) was 131.4 ± 25.3 cm (59–184 cm), and the mean HG was 143.8 ± 23.1 cm (71–175 cm). There was no difference between females and castrated males concerning LW ($P = .480$).

Table 1
Values of Akaike Information Criterion value (AICc), Root Mean Square Error (RMSE), and coefficient of determination (R^2) for the curve model to predict live weight with heart girth in the Miranda donkey breed.

Model	AICc	RMSE	R^2
Quadratic	616.75	28.66	0.93012
Probit	618.95	28.86	0.93008
Logistic	616.86	28.68	0.93000
Exponential	623.46	30.50	0.91958

All the correlations between LW and the body measurements were statistically significant ($P < .001$), but the degree of accuracy was higher in the HG ($r = 0.937$) than in the BL ($r = 0.915$) or height ($r = 0.894$). Four models were tested, and the best fit was performed by Quadratic model (Table 1).

Equation (1) that best estimated the LW based on HG body measurement was as follows:

$$LW = 98.138 - 3.0386 \times HG + 0.0293 \times HG^2 \quad (1)$$

The formula was calculated from the Quadratic distribution of the LW, as a function of the HG (Fig. 2). The performance of the model and the relationship between actual and predicted LW are shown in the scatter plot (Fig. 3).

The accuracy of LW prediction equations of different authors was determined from the percentage error relative to actual LW (Table 2). In general, the models developed by the various authors with different donkey populations showed that LW of Miranda donkey is underestimated. In fact, the error presents a negative value in the mean (mean between −7.96 and −32.1%) for all formulas, except for that of Nengomasha et al. [6]. The 95% confidence interval (CI) values reinforce this analysis with all error (percentage) values between upper and lower limits with negative value (95% CI: −4.89 to −26.5% and −11.0 to −37.6% for upper and lower limits of LW error percentage, respectively).

Fig. 4 presents the diagrams for comparing residual plots of the bivariate fit of the models of other authors and the actual LW. The residual plots show that, in general, the formulas applied by the other authors to Miranda data present a pattern of underestimation of the LW. The Pearson and Ouassat [5] and Nengomasha et al. [6] models are the ones showing a greater dispersion around 0. The de Aluja et al. [9] model is the one best suited for the Miranda breed but still presents a dominant pattern of underestimation of the LW. The residual plot of the present model does not show a variation pattern, and the values are symmetrically clustered around the −40 and 40%.

4. Discussion

Given the great importance of the ability to estimate a donkey weight in field conditions and the lack of a study in the larger frame donkey breeds, this research reviewed the reliability of available formulas for donkeys and aimed to create one that best fit this body type. It must, however, be always considered that factors such as water or feed intake, defecation, and urination make body weight fluctuate throughout the day, and these differences will never be able to be detected by weight tapes or formulas based on body measurements. Furthermore, subtle differences in tape placement by different individuals can result in differences in the estimated weight [4]. For these reasons, weight estimation by body measurements can never be 100% accurate but can be close enough to render its practical use.

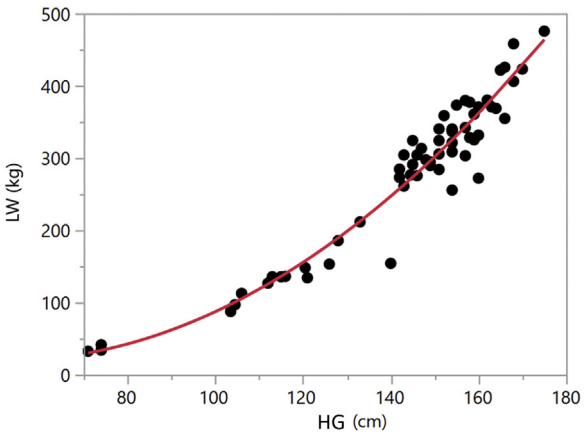

Fig. 2. Scatter plot of live weight (LW) and heart girth (HG) in Miranda donkeys. The expression of the LW as a function of the HG showed a Quadratic distribution of the cloud of points.

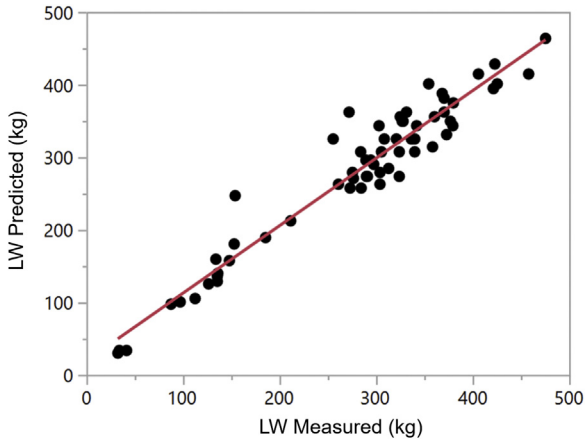

Fig. 3. Measured versus predicted values of live weight (LW) using heart girth (HG) measurements in Miranda donkey breed. $R^2 = 0.930$, RMSE = 27.4 kg.

As already described in other breeds of donkeys, the single body measurement most suitable to introduce in a formula to calculate LW is the HG [5,6,8,10,11]. In previously published studies [5,8], the introduction of further variables just improved the prediction marginally; therefore, it was also not used in the present study. The use of more than two predictor variables is impractical in field conditions, and little value is gained by producing more complex equations, as they do not significantly improve the accuracy of LW prediction [5]. The main objective of computing the predictive equations of LW using body measurements is to produce simple management tools that can be used by any owner or technician in the field. For this purpose, and although the use of more than one variable resulted in a higher R^2, field application becomes more difficult, with the need to use nomograms instead of the practical measurement weigh tapes [6].

When using a wide range of HG and LW on horses, Wagner and Tyler [4] found that the relation between LW and HG is logarithmic. The regression relation found in the present study between LW and HG was also logarithmic. This was caused by the inclusion of animals of different ages in the present study, from newborns to adults, which showed that the relation between HG and LW is logarithmic as donkeys grow, in this breed. The formula developed can therefore be used in any donkey of this breed, independently of their age. The incapacity of linear equations to predict LW of growing donkeys was already observed by Moreira et al. [10], who suggested the use of a different formula for young donkeys.

The divergence of results obtained using different formulas highlights the importance of developing breed-specific models, as it was observed by Moreira et al. [10] in *Pêga* donkeys. In large frame donkeys, such as Miranda, this tendency can cause high miscalculations than in smaller donkey breeds. The other LW prediction equations for donkeys [1,5,8,9] tested on this breed tended to underestimate the weight of this population of donkeys. Most likely, the reason for this underestimation is the different body type (proportion between the different body parts of the animal) of the donkeys, as all other populations previously used were shorter, lighter, and with smaller HG. Different body types, with different

Table 2
Mean, standard deviation (SD), and the upper and lower limit for the mean confidence interval at 95% for percentage error of predicted live weight (LW) using heart girth (HG) of the donkeys used in different studies with other donkey breeds or crossbreed working (CW) animals, relative to actual Miranda donkey LW.

Author	Location	Breed	Age	Model	LW original (kg)	Error (%)[a]			
						Mean	SD	Upper 95%	Lower 95%
Pearson and Ouassat (1996)	Morroco	CW	1–16 y	$LW = (HG^{2.65})/2{,}188$	Not available	7.96	12.3	−4.89	−11.0
Nengomasha et al. (1999)	Zimbabwe	CW	1–25 y	$LW = (HG^{2.8319})/4{,}786$	141	2.48	12.3	5.56	−0.59
Aluja et al. (2005)	Mexico	CW	6 ± 2.6 y (1–17)	$LW = 0.031255 \times (HG^{1.7288})$	50–186	32.1	22.3	−26.5	−37.6
Moreira et al. (2017)	Brazil	Pêga	0–6 mo	$LW = -156.43 + (2.5178 \times HG)$	Not applicable	22.8	15.2	−18.9	−26.6
Nininahazwe et al. (2017)	West Sub-Sahara Africa	CW	6.49 ± 3.6 y	$LW = (2.55 \times HG) - 153.49$	118 ± 22	19.4	16.5	−15.3	−23.5
Present model	Portugal	Miranda	7.56 ± 4.01 y (0–15.4)	$LW = 98.138 - 3.0386 \times HG + 0.0293 \times HG^2$	281 ± 106	0.10	6.23	1.45	−1.66

[a] Error in percentage is calculated as the difference between predicted and actual LW relative to actual LW.

relations between the various body measurements, correlate differentially to LW [9,10]. As expected, predictive equations work better when used to describe the data from which they are derived [6]. However, it was worth noting the underestimation of LW of this population when using all the previously available equations for donkeys. This points out to a specific body type, which needs a new formula.

In some studies, sex is a significant factor for LW variation in donkeys, with jacks being on average heavier [8,9]. On the other hand, other authors did not find any sex differences in LW [5,6,11]. In the present study, there was no difference between females and castrated males. It was not possible to gather a significant number of jacks to assess if there was a sex difference between these and geldings or females.

5. Conclusions

The formula developed can be used to create a weighing tape, adapted to large frame donkey breeds, to be used to estimate weight and better adapt medication dosages and load for each

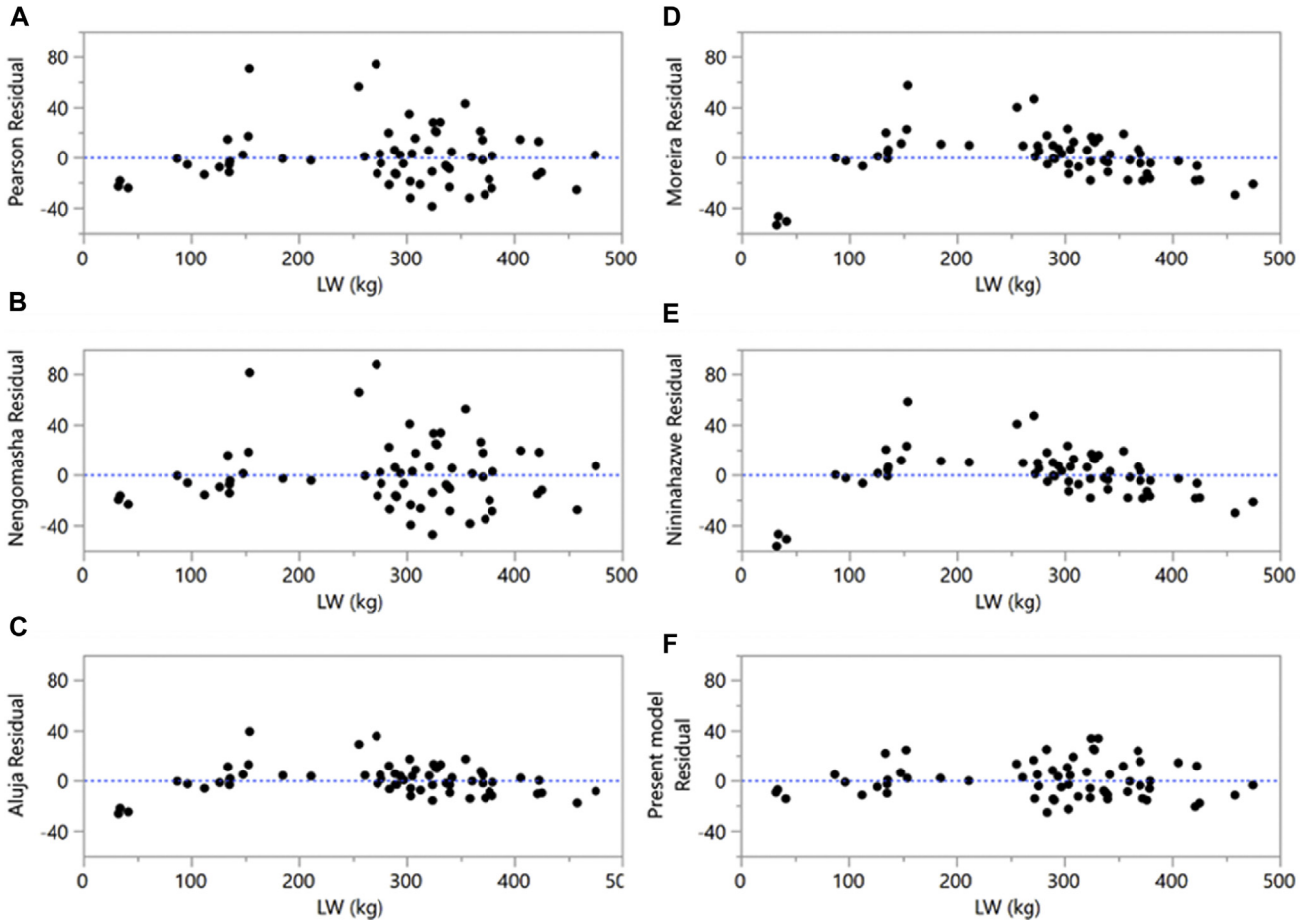

Fig. 4. Diagrams for comparing residual plots of the bivariate fit of the models of other author formulae with actual data to predict donkey live weight (LW). (A) Pearson and Ouassat [5]; (B) Nengomasha et al. [6]; (C) de Aluja et al. [9]; (D) Moreira et al. [10]; (E) Nininahazwe et al. [8]; and (F) present model of Miranda donkey breed. In the y-axis, the residual values are presented in kilogram.

animal. The adequacy of the equation derived in the present study should be further tested in populations of similar body type and a wide range of ages to establish its adequacy for similar large frame donkey breeds.

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