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Assessment of methods for determining body weight based on biometric dimensions in Hucul horses

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The aim of the study was to verify existing methods for determining the weight of adult Hucul horses on the basis of biometric dimensions associated with changes in the conformation of horses of this breed resulting from breeding work. The experiment was performed on 159 adult Hucul horses ≥3 years old (25 stallions, 23 geldings and 111 mares, including 44 barren, 23 in early pregnancy (up to the 7th month) and 43 in late pregnancy (>7 months). Actual body weight, determined using a platform scale, was compared with the weight estimated using selected formulas and with a special measuring tape. The estimation error (%) was calculated, and it was determined whether the estimated body weight was on average over- or underestimated. The most reliable means of estimating body weight proved to be the use of the formulas of Carroll and Huntington (1988) and Sendel (1999), which non-significantly underestimated actual body weight, by an average of 7 and 8 kg, respectively, so that the error resulting from this method was 4.5%. The measuring tape was also found to be a good tool, resulting in an error not exceeding 6%, with a non-significant underestimation of actual body weight. The tendency of various methods to over - or underestimate body weight was similar irrespectively of sex and physiological state, which may indicate that the body weight of Hucul horses changes proportionally with changes in biometric dimensions. Therefore, it can be assumed that the sex and physiological state of the mare, despite their effect on body weight, need not be taken into account when developing new formulas for estimating it.

KEY WORDS: Hucul horse, body weight, biometric dimensions

Hucul horses – native, primitive mountain horses from a region covering part of the Eastern Carpathians, occupy a special place among the many breeds of horses bred and kept in Poland [15]. Although the breed currently has a consolidated genotype, it has been significantly influenced by many other breeds, which means that the origin of Hucul horses still raises many doubts [1]. It is undisputed, however, that this breed was shaped by the

environment, mainly the harsh mountain climate and the primitive housing and dietary conditions [4]. Consequently, Hucul horses were toughened, gaining in endurance, health and disease resistance while developing exceptional adaptability to extreme and variable environmental conditions and to various kinds of use [15, 19]. Living continuously in the conditions described above, they also developed an excellent character, and thus have always had good relations with people [17].

A horse's body weight is an important indicator taken into account when assessing the impact of housing, training and diet on health and physical condition [5, 18, 21, 32]. For example, regular monitoring of the weight of young growing horses is critical to analysis of basic information about the development process. Proper growth and maturation are known to depend in part on suitable nutrition, which can have a significant impact on a horse's breeding and performance results throughout its life. If horses are not provided with an adequate diet during the intensive growth period, they will not be able to fully exploit their development potential. On the other hand, if they are overfed, they may show a predisposition to serious diseases, such as orthopaedic developmental diseases [30].

Regular measurement and monitoring of weight are also extremely important in adult horses, in order to determine the optimal amount of feed and feed additives. Knowledge of weight is also useful in calculating the correct dose of medication when treatment is needed or when deworming agents or dietary supplements are administered. Incorrect doses of such agents, whether too high or too low, may cause a treatment to be ineffective or result in drug resistance, and in extreme cases may lead to the animal's death [26].

Flaga and Waliczek [7] showed in a survey study that only about 60% of owners regularly check the weight of their horses. Tape measures were most often used for this purpose (62%), with only 5% of respondents using special scales. According to Murray et al. [23], a substantial proportion of owners admit that they simply estimate the weight of horses, without using any methods.

One of the most reliable ways to determine body weight is to use special platform scales. However, breeding facilities, sport and recreation centres, and individual horse owners usually do not have such equipment. Alternative methods for determining body weight include visual assessment, which is the simplest method but is usually burdened with a large error. It requires extensive experience supported by repeated previous comparisons of the horse's visually assessed body weight with its weight as determined using special devices, e.g. the platform scales mentioned above. According to some studies, horse owners show a strong tendency to underestimate the weight of their horses, especially when the horses are overweight [8, 33].

Another way is to use measuring tapes, with body weight estimated by measuring the chest girth and, after conversion, reading the result from a special scale [18, 27, 32]. As a rule, however, this method is not highly reliable, because the tapes are universal and are not adapted to horses of different breeds, which often differ in both size and body proportions, or in the ratio of bone and muscle mass to volume.

The last group of alternative methods for determining body weight are special formulas that use certain body measurements, e.g. the chest girth, the length or longitudinal circumference of the torso, height at the withers, or other distances between specific body parts. Appropriate coefficients are also included, often taking into account the impact of certain characteristics, e.g. breed, type, gender, age, physiological state or type of use [2, 5, 7, 9, 11, 12, 14, 18, 21, 22, 24, 27].

In view of the multitude of such formulas and the fact that most of them were developed several decades ago, the aim of the study was to verify selected methods for determining the weight of adult Hucul horses on the basis of biometric dimensions associated with changes in the conformation of horses of this breed as a result of breeding work.

Material and methods

The experiment was performed on 159 adult Hucul horses ≥ 3 years old from the Gładyszów Hucul Horse Stud in Regietów – Kombinat Rolny Kietrz Sp. z o.o. (125 individuals) and from the Hucul Horse Conservation Breeding Facility in Wołosate (34 individuals). The group consisted of 25 stallions, 23 geldings and 111 mares, including 44 barren, 23 up to the 7th month of pregnancy, and 43 after the 7th month of pregnancy.

A stable/pasture system was used at the studs. During the summer the horses were on pastures during the day, while in winter they made use of pens and paddocks located by the stables. They were fed in a standard manner with meadow hay, haylage, oats, and pasture forage in quantities and proportions adjusted to sex, season and type of use. Hucul mares were kept in separate open barns depending on their physiological condition, while stallions and geldings were placed in individual boxes.

Hucul horses were measured with a tape measure method according to Komosa and Purzyc [16]. Measurements were made of chest girth (G1), umbilical girth (G2), longitudinal circumference of the torso across the external surfaces of the shoulder joints and points of buttock (O1), distance from the point of shoulder to the point of buttock (L1), and distance from the point of elbow to the point of buttock (L2) – Figure.

The results of the biometric measurements were used to estimate the body weight of the horses based on selected formulas: W1 – according to Marcenac and Aublet [20], W2 – according to Hall [10], W3 – according to Carroll and Huntington [2], W4 – according to Sendel [29], W5 – according to Owen et al. [24], W6 – according to Jones et al. [14], and W7 – according to Sasimowski and Budzyński [28]. The formulas were as follows:

- W1 – body weight (kg) = $G1(m)^3 \times 80$
- W2 – body weight (kg) = $(G1(cm)^2 \times L1(cm))/10{,}787$
- W3 – body weight (kg) = $(G1(cm)^2 \times L1(cm))/11{,}877$
- W4 – body weight (kg) = $(G1(cm)^2 \times L1(cm))/11{,}900$
- W5 – body weight (kg) = $(G1(cm)^2 \times L1(cm))/11{,}069$
- W6 – body weight (kg) = $G2(cm)^{1.78} \times L2(cm)^{0.97}/3{,}011$
- W7 – body weight (kg) = $G1(m) \times O1(m) \times 62$

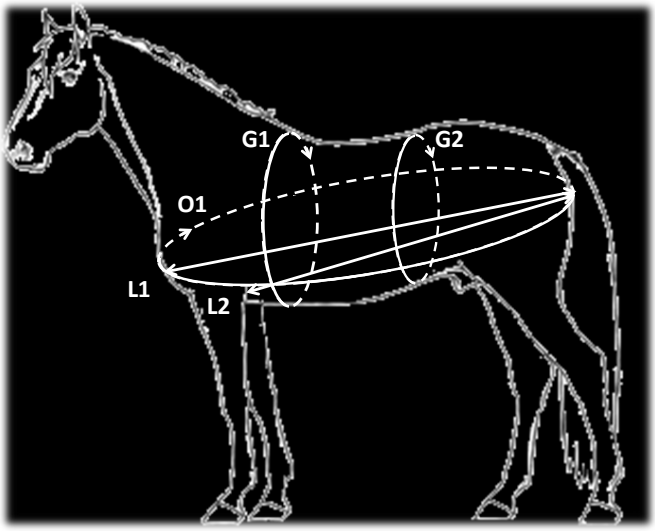

Fig. Diagram of biometric measurements of Hucul horses

The body weight of the horses was also estimated using a measuring tape – TM (HORZE tape for measuring horse weight), on which the result could be read from a special scale based on the chest girth.

An OHAUS T32XW portable platform scale was used to determine actual body weight.

In the next stage of the study, the actual body weight of Hucul horses was compared with the weight estimated using selected formulas and the special measuring tape, giving the error of estimation (%) and specifying whether the estimated body weight was on average high or low. Statistical analysis of the results was performed in Statistica for Windows 13.1, using one-way analysis of variance and the Tukey test.

Results and discussion

Analysis of the estimated body weight of the population of Hucul horses showed that for four of the methods used it did not differ significantly from the actual body weight determined on the platform scale (Table 1). The weight tape (TM) and three formulas (W3, W4 and W6) insignificantly underestimated the actual body weight, by about 19, 7, 8 and 15 kg, respectively. The smallest error of 4.5% resulted from the use of formulas W3 and W4 (Table 2). Formula W7 significantly underestimated actual body weight by 45 kg, with 9.9% error. Formulas W1, W2 and W5 significantly overestimated body weight as compared to the actual weight, by about 30-40 kg on average, resulting in an error of about 7-9%.

In the case of Hucul stallions, the use of the weight tape and formulas W3, W4 and W7 insignificantly underestimated body weight, while formulas W1, W2 and W5 insignificantly overestimated it as compared to actual body weight (Table 1). Again, the use of formulas W3 and W4 proved to be the most reliable methods; the error in this case was thetlowest, below 4% (Table 2). The least objective way to determine the weight of Hucul stallions, with over 9% error, was the use of formula W6, which significantly underestimated body weight by an average of 40 kg.

Assessment of the effectiveness of various methods for determining the body weight of geldings showed that the use of formulas W3 and W4 will insignificantly underestimate it, by only 6 kg on average, with the smallest error, 4.1% and 4.2%, respectively (Tables 1 and 2). The weight tape and formula W6 also insignificantly underestimated the actual body weight of geldings, but the error resulting from these methods was greater (5.0% and 5.8%). Significant underestimation of weight, on average by 47 kg, was found using formula W7 (9.9% error). The other formulas overestimated the actual body weight of the geldings. Formulas W1 and W5 overestimated it insignificantly, on average by 29 kg (error from 7.0% to 7.8%), while formula W2 significantly overestimated body weight by 41 kg, with an error of 9.2%.

The body weight of mares estimated using formulas W3, W4 and W6 and the weight tape was insignificantly underestimated with respect to the actual body weight determined on the platform scale (Table 1). As in the case of the stallions and geldings, the use of formulas W3 and W4 resulted in the lowest error, 4.7-4.8% (Table 2); the body weight of mares was insignificantly underestimated by an average of only about 6.5 kg. Significant underestimation of mares' body weight, on average by 50 kg, was noted in the case of formula W7, which generated an error of over 10%. The use of the remaining formulas resulted in significant overestimation of the mares' actual weight. Formulas W5, W1 and W2 overestimated body weight by 28 to 41 kg, which corresponded to an error of 7.0% to 9.2%.

A similar tendency was observed in the analysis of the potential effect of the physiological state of mares on the reliability of the methods used to determine body weight (Table 1). In barren mares and in those in early and late pregnancy, the weight tape and formulas W3, W4 and W6 insignificantly underestimated body weight, while formula W7 significantly underestimated it compared to the actual weight. The other formulas overestimated body weight – in barren mares significantly in each case. In mares in late pregnancy, body weight was significantly overestimated only in the case of formula W2. Irrespective of the physiological state of the mares, as in the previous groups of Hucul horses, body weight was more precisely determined using formulas W3 and W4, which generated the lowest errors, although they increased with the duration of pregnancy: 3.7% in the case of barren mares, 4.4% for mares in early pregnancy, and 5.9% for mares in late pregnancy (Table 2).

There are situations in which determination of a horse's exact body weight is useful, and in many cases necessary for proper treatment, nutrition, training, or other specialized use, or for monitoring health requirements. Commercially available horse scales are usually large and not easily portable, and at the same time they are generally expensive and difficult to obtain. In many situations, treatment or veterinary care for horses must be conducted in

Table 1

Comparison of the body weight of Hucul horse as determined using various methods

Method	Body weight (kg)						
	total horses (n=159)	stallions (n=25)	geldings (n=23)	total mares (n=111)	barren mares (n=44)	mares in early pregnancy (n=24)	mares in late pregnancy (n=43)
	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD
RMC	463.1 ±40.6^{a}	426.9 ±25.9^{ab}	466.0 ±29.1^{ac}	470.6 ±41.1^{a}	454.0 ±41.4^{a}	460.0 ±24.8^{ab}	493.5 ±38.1^{ab}
TM	444.2 ±48.2^{a*}	407.0 ±31.3^{a*}	449.4 ±38.6^{ae*}	451.5 ±49.6^{a*}	444.0 ±50.3^{ad*}	436.5 ±39.6^{af*}	467.7 ±50.3^{f*}
W1	490.4 ±61.1$^{b\#}$	442.9 ±39.3$^{bc\#}$	496.4 ±48.7$^{bc\#}$	499.8 ±62.8$^{b\#}$	490.4 ±63.0$^{be\#}$	480.3 ±50.2$^{bc\#}$	520.3 ±64.3$^{b\#}$
W2	502.5 ±56.1$^{b\#}$	457.3 ±38.3$^{b\#}$	507.0 ±47.8$^{bf\#}$	511.7 ±56.5$^{b\#}$	503.1 ±55.1$^{b\#}$	495.4 ±41.1$^{b\#}$	529.7 ±61.3$^{b\#}$
W3	456.4 ±51.0^{a*}	415.3 ±34.8^{ace*}	460.5 ±43.4^{ac*}	464.8 ±51.3^{a*}	450.9 ±50.0^{aef*}	450.0 ±37.3^{acd*}	481.1 ±55.7^{ac*}
W4	455.5 ±50.9^{a*}	414.5 ±34.7^{ac*}	459.6 ±43.3^{ac*}	463.9 ±51.2^{a*}	452.1 ±49.9^{aef*}	449.1 ±37.2^{acd*}	480.1 ±55.6^{ac*}
W5	489.7 ±54.7$^{b\#}$	445.6 ±37.3$^{be\#}$	494.1 ±46.6$^{cf\#}$	498.7 ±55.0$^{b\#}$	490.3 ±53.7$^{bf\#}$	482.8 ±40.0$^{bd\#}$	516.2 ±59.8$^{bc\#}$
W6	447.6 ±57.2^{a*}	386.9 ±25.1^{d*}	444.1 ±36.6^{ad*}	462.0 ±57.0^{a*}	444.9 ±52.0^{ac*}	442.8 ±42.1^{ae*}	490.2 ±58.6^{bf*}
W7	417.6 ±29.2^{d*}	399.9 ±31.3^{a*}	419.4 ±24.4^{e*}	421.2 ±28.4^{d*}	416.4 ±29.8^{d*}	411.7 ±20.0^{f*}	431.2 ±28.4^{f*}

RMC – actual body weight; TM – weight tape; W1 – formula of Marcenac and Aublet (1964); W2 – formula of Hall (1971); W3 – formula of Carroll and Huntington (1988); W4 – formula of Sendel (1999); W5 – formula of Owen et al. (2008); W6 – formula of Jones et al. (1989); W7 – formula of Sasimowski and Budzyński (1987)

Means in columns with different letters are significantly different at $P \leq 0.05$

#Estimated body weight overestimated compared to actual weight

*Estimated body weight underestimated compared to actual weight

Table 2

Average error (%) of estimation the weight of Hucul horses by various methods

Method	Estimation error (%)						
	total horses (n=159)	stallions (n=25)	geldings (n=23)	total mares (n=111)	barren mares (n=44)	mares in early pregnancy (n=24)	mares in late pregnancy (n=43)
	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD	$\bar{x}$ ±SD
TM	5.8 ±4.1	5.5 ±3.5	5.0 ±3.5	6.0 ±4.3	4.4 ±3.8	6.6 ±3.9	7.3 ±4.5
W1	7.7 ±5.5	5.1 ±4.5	7.8 ±4.7	8.3 ±5.7	9.0 ±5.6	6.7 ±5.3	8.5 ±5.9
W2	8.8 ±5.3	7.1 ±4.2	9.2 ±4.8	9.1 ±5.6	10.7 ±5.1	8.0 ±5.1	8.1 ±6.0
W3	4.5 ±3.3	3.7 ±3.1	4.1 ±3.5	4.7 ±3.4	3.7 ±2.8	4.4 ±3.3	5.9 ±3.6
W4	4.5 ±3.4	3.8 ±3.2	4.2 ±3.5	4.8 ±3.4	3.7 ±2.7	4.4 ±3.4	6.0 ±3.7
W5	6.7 ±4.5	5.1 ±3.2	7.0 ±4.1	7.0 ±4.8	8.0 ±4.8	6.1 ±4.0	6.4 ±5.1
W6	6.5 ±4.1	9.4 ±4.2	5.8 ±3.9	6.0 ±4.8	5.2 ±2.9	6.4 ±4.6	6.6 ±4.2
W7	9.9 ±3.6	8.0 ±4.1	9.9 ±2.4	10.3 ±3.6	8.1 ±3.0	10.4 ±2.7	12.7 ±3.2

TM – weight tape; W1 – formula of Marcenac and Aublet (1964); W2 – formula of Hall (1971); W3 – formula of Carroll and Huntington (1988); W4 – formula of Sendel (1999); W5 – formula of Owen et al. (2008); W6 – formula of Jones et al. (1989); W7 – formula of Sasimowski and Budzyński (1987)

the field, not in a clinical setting, which makes it difficult to determine the correct dose of medicine, when an overdose may be dangerous to the health or life of the horse. For these reasons, alternative methods for estimating horse weight have been developed for use in the field when platform scales are not available. Visual assessment is considered to be the least accurate. According to Pagan et al. [25], over 90% of veterinarians and over 60% of riders estimate body weight in this manner, often underestimating it. This is confirmed by Johnson et al. [13], who showed that only 12.5% of visual estimations of weight were too high, while as many as 87.5% were too low. There was also no significant correlation between an estimator's years of experience and the accuracy of body weight estimation. Ellis and Hollands [5] showed that the error in visual estimation of horse body weight was over 20% and increased with the height of horses at the withers.

The use of special measuring tapes, with the result based on measurement of chest girth, is believed to be a more accurate method of determining body weight than visual estimation. This method is easy to use in field conditions, and its average error is about 10-12%. This error may be due to the fact that these tapes are most often universal and do not take into account the body proportions of different breeds and types of horses [5, 22]. In this study, the use of this method in Hucul horses yielded good results. The average error when the weight tape was used was 5.8%, ranging from 5.0% for the weight of geldings to 7.3% for mares in late pregnancy.

The body weight of horses is also estimated using specially developed formulas. These are most often based on measurements of chest girth and torso length. They have been used in research carried out to develop an equation that would simultaneously take into account the impact of certain factors, e.g. breed, sex and age [2, 5, 9, 14, 22]. This method is certainly more accurate than the tape measurement, because in addition to chest girth, it also takes into account the length of the torso. However, in this case as well the average error can reach up to 10%. In addition, two people are needed to perform the measurements, because the distance between the shoulder joint and the point of buttock is too great for one person to apply the measuring tape to both points [18].

Hoffmann et al. [12] tested the effectiveness of the tape measure and the formula developed by Carroll and Huntington [2] for estimating the weight of adult Icelandic horses, which are similar to Hucul horses in their conformation and type. Both methods proved useful, but while both insignificantly underestimated the actual body weight by about 5.0%, more reliable results were obtained using the measuring tape. In contrast, Ellis and Hollands [5] claim that the body weight of horses can be more reliably estimated using the Carroll and Huntington formula than by other methods (measuring tape or visual assessment). Wagner and Tyler [32] have also shown that specially developed formulas are more reliable in estimating horse body weight than other methods; at the same time, the authors found significant differences both between the methods used and between the estimated and actual body weight. Reavell [27] reported that the Carroll and Huntington [2] formula can be successfully used to determine the weight of ponies.

The relationships described above are fully confirmed by the results of the present study. The average error in estimating of the weight of Hucul horses using formula W3, develo-

ped by Carroll and Huntington [2], was smaller than for the measuring tape method, although in both cases these methods insignificantly underestimate the actual body weight of horses of this breed. To make the Carroll and Huntington formula [2] even more effective in estimating the weight of Hucul horses, a new divisor can be established based on a non-linear regression model, as described by Hoffman et al. [12]. This would reduce the average difference between the actual body weight and the weight calculated from the revised formula. In this way the authors cited were able to reduce the difference to 0.03 kg.

One of the most commonly used formulas, due in part to its simplicity (it uses only the chest girth), is the formula devised by Marcenac and Aublet [20]. Gharahveysi [9] compared its effectiveness with that of other formulas in determining the weight of Arabian horses. The year of birth and origin of the horses were found to be important factors influencing the reliability of the results, unlike age and sex, which did not have a significant relationship with the estimated body weight. It was determined that owing to the lack of significant differences, the formulas of Marcenac and Aublet [20] and Ensminger [6] were more reliable than the formulas of Hapgood [11] and Jones et al. [14], which resulted in significant differences between actual and estimated body weight. In the research presented in this paper, the use of the Marcenac and Aublet formula [20] overestimated the actual weight of the Hucul horses, and the difference was statistically significant.

Flaga and Waliczek [7] attempted to analyse the available formulas in terms of their effectiveness in estimating the body weight of adult horses of the Malopolski breed, Polish Half-Bred horses, and ponies. The authors showed that irrespective of breed, the formulas developed by Martinson et al. [21] were the most accurate, most likely because they take into account the girth of the neck, in which fat deposits may accumulate [3, 31]. However, it was stressed that the research had been carried out on a small sample of animals and should be repeated in a much larger population.

In the present study, no equations taking into account the neck girth were used, and thus the most reliable formulas for estimating the weight of Hucul horses were W3 by Carroll and Huntington [2] and W4 by Sendel et al. [29], based on the measurement of chest girth and distance from the point of shoulder to the point of buttock. The use of these formulas insignificantly underestimated the actual body weight by about 7-8 kg, which meant that the average error was lower than 5%. In addition, the tendency to overestimate or underestimate the weight of horses when using various methods was similar irrespective of sex and physiological condition. The formulas developed by Marcenac and Aublet [20], Hall [10], Owen et al. [24] and Jones et al. [14] in each case overestimated the body weight of Hucul horses relative to the actual weight, in contrast to the weight tape and the formulas of Carroll and Huntington [2], Sendel [29] and Sasimowski and Budzyński [28], which underestimated it irrespective of whether they were used in stallions, geldings, barren mares, or mares in early or late pregnancy. This may indicate that the body weight of Hucul horses changes proportionally with changes in biometric dimensions. Therefore, it can be assumed that although the horse's gender and the physiological state of the mare influence body weight, they need not be taken into account in developing new formulas for estimating it. Of course, confirmation of this hypothesis requires further detailed analysis.

The 10% error underestimating the weight of Hucul horses using the formula developed by Sasimowski and Budzyński [28] indicates that many years of breeding work have increased the size and hence the weight of horses of this breed in the Polish population. This formula is very simple to use (compared to other formulas containing an exponent), because it is the product of only three factors: chest girth, the longitudinal circumference of the torso, and the coefficient typical for the breed. In the future, based on the analysis of the current population of Hucul horses in Poland, research should be carried out to determine the correct coefficient for Hucul horses, and perhaps for other breeds as well, so that this formula can be successfully used to estimate body weight.

To sum up, the most reliable means of estimating the weight of Hucul horses was to use the Carroll and Huntington [2] and Sendel [29] formulas, which insignificantly underestimated the actual body weight, by an average of 7 and 8 kg, respectively, with an error of 4.5%. In both formulas, the multiplication of two measurements expressed in centimetres (the square of the chest girth and the distance from the point of shoulder to the point of buttock) is divided by the appropriate coefficient – 11,877 in the first formula (W3) and 11,900 in the second (W4). The special measuring tape also proved to be a good tool, generating an error not exceeding 6% and insignificantly underestimating weight. The tendency to overestimate or underestimate body weight using various methods was found to be similar irrespective of gender and physiological condition, which may indicate that the body weight of Hucul horses changes proportionally with changes in biometric dimensions. It can therefore be assumed that while the gender of the horse and physiological state of the mare influence body weight, they need not be included in new formulas for body weight estimation. Due to breeding work, which leads to changes in the size and body proportions of different horse breeds, new formulas should be developed or those in use for many years should be modified to improve the reliability of body weight estimation.

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