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Evaluation of some morphological measurements of Hungarian Hucul horse mares

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Abstract

This study evaluated four key body measurement traits in Hungarian Hucul mares: height at withers by stick and tape, heart girth, and cannon bone circumference. Data from 623 Hungarian Hucul mares collected between 2002 and 2025 were analysed using a linear animal model including sire line, mare family, year and age as fixed effects and animal as a random additive genetic effect. Genetic parameters (heritability, genetic and phenotypic correlations) were estimated utilizing the REML method via VCE-6 software. The descriptive statistical analysis was performed using the R statistical software. Heritability (h^2) values were above 0.7 for height at withers measured by stick and tape, as well as for heart girth size, while a lower value (0.45) was found for cannon bone circumference. The genetic correlation (r_G) between height at withers measured by stick and heart girth was 0.45, and, as expected, the highest (0.97) was observed between height at withers measured by stick and tape. The lowest phenotypic correlation (r_P) was 0.39, observed between height at withers measured by stick and cannon bone circumference, while the highest value (0.90) was also found between the two withers height measurements. Overall, while the Hungarian Hucul population shows relatively low phenotypic variability in the investigated body measurements, the moderate to high heritability of these traits suggests that corrective mating plans utilizing genetic information can be highly efficient for future breed management.

Keywords: Hucul horses, conformation, genetic parameters

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Introduction

The Hucul horse breed originated in the north-eastern regions of the forested Carpathians. Following the Second World War, only a small number of animals survived, and the regeneration of the breed in Hungary was initiated by Csaba Anghy at the Budapest Zoo (MIHÓK, 2014). From those initial few mares and stallions, the current registered breeding population has grown to over 600 broodmares. Furthermore, all seven recognized sire lines are represented, comprising more than 60 breeding stallions in Hungary. Other substantial and genetically significant populations of the breed are located in Poland, Romania, and Slovakia (POSTA et al., 2020; Database of the National Association of Pony and Small Horse Breeders, 2025).
Since 1992, the National Association of Pony and Small Horse Breeders has been responsible for the maintenance of the breed (MIHÓK et al., 2019).
Before entering the studbook, animals must undergo a conformation evaluation, which includes the recording of specific body measurements. The conformation scoring utilizes a 100-point system, evaluating individual criteria on a scale of 0 to 10. A score below 4 in any criterion disqualifies the horse from breeding. For mares, the desirable optimal body measurements are as follows: 136-142 cm for height at withers measured by Lydtin stick, 146-152 cm for height at withers measured by tape, 160-176 cm for heart girth, and 17-18 cm for cannon bone circumference. Additionally, a minimum overall conformation score of 60 points is required (BREEDING PROGRAM OF HUCUL HORSES, 2020).
The objective of this study was to analyse the body measurements of the Hungarian Hucul mare population. This includes examining the age of entry into the studbook, identifying differences across individual years, sire lines, and mare families, as well as estimating the genetic parameters (heritability, genetic and phenotypic correlations) that can be calculated for these traits. The results of our analysis will establish an objective scientific basis and enable the breeding organization to determine further breeding directions. Quantifying these parameters can assist the breed's organization and provide useful information to breeders for preparing their mating plans.

Material and methods

Data for this study were obtained by digitizing the conformation scoring sheets of which 623 mares had complete records for all body measurements and were therefore included in the analysis. The dataset was kindly provided by the National Association of Pony and Small Horse Breeders. To support the genetic analysis, pedigree information was compiled using Microsoft Access, tracing the lineages

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back to the founder animals, resulting in a comprehensive pedigree file of 1,888 individuals.
The phenotypic evaluation focused on four key morphological traits:
Height at withers by stick (HWS), Height at withers by tape (HWT), Heart girth (HG), Cannon bone circumference (CBC)

To estimate the variance components and genetic parameters, the following linear model was applied:

$$Y_{ijklm} = \mu + Sireline_i + Marefamily_j + Year_k + Age_l + Animal_m + e_{ijklm}$$

Y_{ijklm}	=	measured trait;
μ	=	population mean;
$Sireline_i$	=	sire line of the mare;
$Marefamily_j$	=	mare family of the mare;
$Year_k$	=	effect of mare test's year;
Age_l	=	effect of age at measurement;
$Animal_m$	=	random effect of the mare;
e_{ijklm}	=	random residual term.

The descriptive statistical analysis was performed using the R statistical software (R CORE TEAM, 2025). The estimation of genetic parameters (heritability and correlations) was carried out utilizing the Restricted Maximum Likelihood (REML) method, implemented via the VCE-6 software package (GROENEVELD et al., 2008**)**.

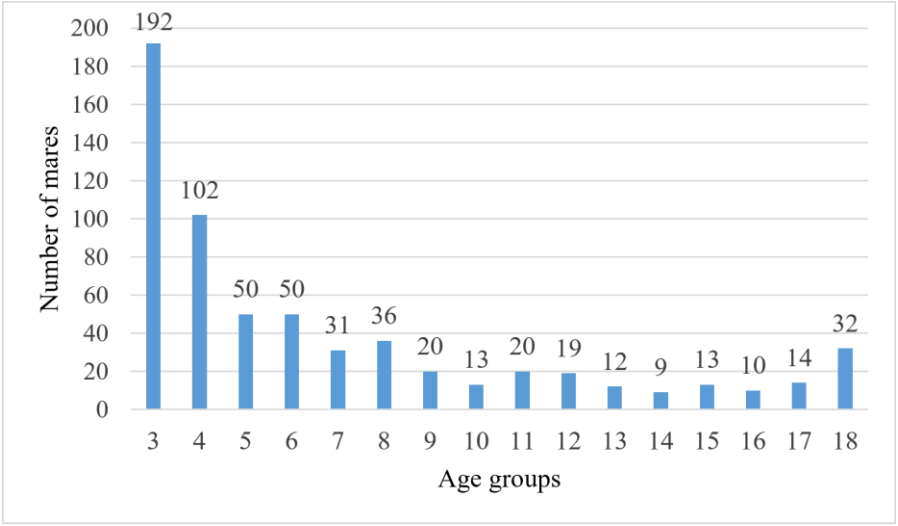


Figure 1: Number of Hucul mares by age (years)

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Figure 1 shows the number of mares by age. The 3-year-old and 4-year-old age groups have the most individuals.

Results and discussion

The fixed effects included in the model were significant for each measurement trait. In the followings, the effect of sire lines and mare families will be shown.
Figure 2 illustrates the distribution of mare families within the evaluated population. Currently, Hungary possesses 27 Hucul mare families. The two largest families are of Hungarian origin: Aspiráns (14%) and Árvácska (20%). Several families are represented by a negligible percentage (0%), indicating that only 1-2 individuals belong to them.

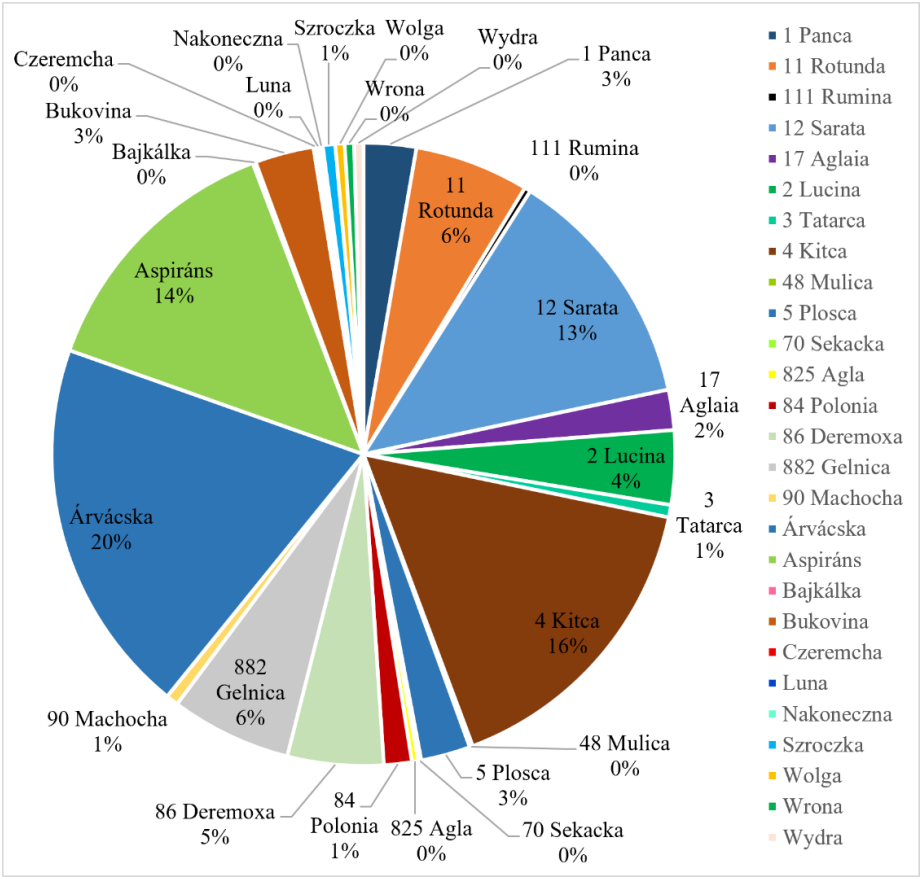


Figure 2: Distribution of Hucul mare families

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Furthermore, all seven recognized sire lines of the Hucul breed are present in Hungary (Figure 3.). The Hroby line represents the largest proportion of the population (24%), whereas the Gurgul line has the smallest representation (6%).

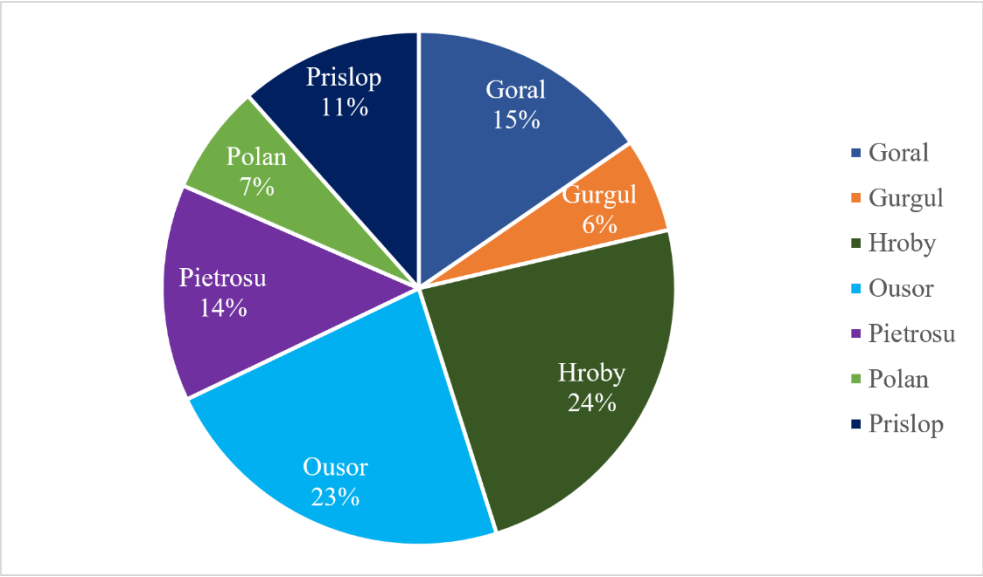


Figure 3: Distribution of Hucul sire lines

Table 1 summarizes the mean values, standard deviations, and coefficients of variation for each investigated trait of Hucul mares. Most of the measured values are between the desirable optimal measurements, although the average heart girth and cannon bone circumference slightly exceed the optimum.

Table 1: Descriptive statistics of body measurements in Hucul mares

Body measurements	Mean	SD	CV%
Height at withers (stick)	138.16 cm	3.88	2.81
Height at withers (tape)	146.41 cm	4.52	3.09
Heart girth	177.69 cm	10.23	5.76
Cannon bone circumference	18.02 cm	0.83	4.59

SD – standard deviation; CV% - coefficient of variation

TEIXEIRA et al. (2025) evaluated genetic parameters of morphological traits in Mangalarga Marchador horses. This native Brazilian riding horse breed has similar heart girth (172 cm) and cannon bone circumference (18 cm) values. KOMOSA and PURZYC (2009) reported similar body measurements for Hucul horses, with a mean

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height at withers measured by stick of 138.1 cm, heart girth of 177.5 cm, and cannon bone circumference of 19.1 cm, which are generally comparable to the values obtained in the present study.

The following tables contain descriptive statistics of each body measurement according to sire lines.

Table 2 presents the descriptive statistics of height at withers measured by stick across the different sire lines. The results indicate that individuals of the Prislop sire line have the highest average value (141.04 cm). In contrast, the Polan sire line represents the smallest individuals on average, with a mean height of 137.90 cm.

Table 2: Descriptive statistics of height at withers (by stick, in cm)

Sire line	N	Least-squares means	SE	lower CL	upper CL
Goral	96	139.02	0.64	137.77	140.28
Gurgul	37	138.63	0.81	137.04	140.22
Hroby	148	139.36	0.62	138.14	140.58
Ousor	142	138.87	0.64	137.62	140.11
Pietrosu	85	140.04	0.70	138.67	141.41
Polan	43	137.90	0.78	136.36	139.44
Prislop	72	141.04	0.71	139.65	142.43

SE – standard error; CL – 95% confidence level

Table 3 shows the descriptive statistics for height at withers measured by tape. Consistent with the stick measurements, the Prislop sire line had the largest average value (149.91 cm). The average HWT of the Pietrosu and Prislop sire lines is over 149 cm. The lowest average value was observed in the Polan sire line (146.54 cm).

Table 3: Descriptive statistics of height at withers (by tape, in cm)

Sire line	N	Least-squares means	SE	lower CL	upper CL
Goral	96	147.77	0.73	146.33	149.21
Gurgul	37	147.47	0.93	145.64	149.30
Hroby	148	148.18	0.71	146.78	149.58
Ousor	142	147.74	0.73	146.31	149.18
Pietrosu	85	149.02	0.80	147.45	150.60
Polan	43	146.54	0.90	144.77	148.31
Prislop	72	149.91	0.81	148.32	151.51

SE – standard error; CL – 95% confidence level

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Table 4. details the descriptive statistics of heart girth measurements according to sire lines. The Prislop line again demonstrates the largest average size (184.59 cm). Interestingly, the smallest average heart girth belongs to the Gurgul line (176.08 cm), closely followed by the Polan line (176.72 cm).

Table 4: Descriptive statistics of heart girth (in cm)

Sire line	N	Least-squares means	SE	lower CL	upper CL
Goral	96	179.30	1.67	176.02	182.59
Gurgul	37	176.08	2.13	171.91	180.26
Hroby	148	181.24	1.63	178.05	184.44
Ousor	142	180.85	1.67	177.58	184.12
Pietrosu	85	181.61	1.83	178.01	185.20
Polan	43	176.72	2.06	172.68	180.76
Prislop	72	184.59	1.85	180.95	188.23

SE – standard error; CL – 95% confidence level

Table 5 displays the descriptive statistics for cannon bone circumference across the sire lines. Aligning with the other body measurements, the Prislop sire line has the highest average thickness (18.26 cm). Below 18 cm there are individuals of the Polan and Ousor sire lines. The Polan sire line presents the lowest average value for this trait (17.93 cm).

Table 5: Descriptive statistics of cannon bone circumference (in cm)

Sire line	N	Least-squares means	SE	lower CL	upper CL
Goral	96	18.08	0.14	17.81	18.36
Gurgul	37	18.24	0.18	17.89	18.59
Hroby	148	18.15	0.14	17.88	18.42
Ousor	142	17.97	0.14	17.69	18.24
Pietrosu	85	18.18	0.15	17.87	18.48
Polan	43	17.93	0.17	17.59	18.27
Prislop	72	18.26	0.16	17.96	18.57

SE – standard error; CL – 95% confidence level

Table 6 presents the estimated heritabilities (on the diagonal), genetic correlations (above the diagonal), and phenotypic correlations (below the diagonal) for the evaluated body measurements. Heritability (h^2) estimates were high for height at withers measured by stick (0.73), height at withers by tape (0.70), and heart girth (0.73). However, a moderate heritability (0.45) was observed for cannon bone circumference. Regarding genetic correlations (r_G), the strongest relationship was

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found between the two withers height measurements (0.97), while the lowest was between height at withers by stick and heart girth (0.45). Similarly, the highest phenotypic correlation (r_P) was observed between the two height measurements (0.90), whereas the lowest (0.39) was recorded between height at withers by stick and cannon bone circumference.

Table 6: Estimated heritabilities and correlations for body measurements

	1	**2**	**3**	**4**
1 Height at withers (stick)	**0.73**	*0.97*	*0.45*	*0.50*
2 Height at withers (tape)	0.90	**0.70**	*0.62*	*0.67*
3 Heart girth	0.42	0.58	**0.73**	*0.72*
4 Cannon bone circumference	0.39	0.49	0.48	**0.45**

heritabilities on the diagonal (bold), genetic correlations above the diagonal (italic), and phenotypic correlations are below the diagonal

When comparing our findings to the literature, TEIXEIRA et al. (2025) reported lower heritability values (0.29–0.50) for morphological traits in Mangalarga Marchador horses. In contrast, VOSTRY et al. (2017) calculated a similar h^2 value for cannon bone circumference (0.427) in three Czech Draught Horse Breeds. JÖNSSON et al. (2014) calculated 0.55 h^2 value for CBC. For withers height, lower heritability estimates were reported by JÖNSSON et al. (2014) in Swedish Warmblood horses (0.67) and VICENTE et al. (2014) in Lusitano horses (0.61). ZIADI et al. (2025) estimated a comparable h^2 value for HWS in Pura Raza Española horses (0.76), though their estimates for HG and CBC values were different, 0.57 and 0.33. MOLINA et al. (1999) estimated 0.58 for height at withers, for HG a moderate value of 0.48, for CBC 0.35 in the Andalusian horse.
Regarding correlations, POSTA and KOMLÓSI (2007) measured r_P and r_G in Hungarian Sporthorses. Between HWS and HWT the r_P value was 0.97. All other phenotypic correlations were stronger. Between HWS and HG, CBC and between HWT and HG the r_G values were similar. Other r_G values in sporthorses were weaker. VOSTRY et al. (2017) also found similar genetic correlation values, except for the relationship between cannon bone circumference and heart girth (0.359).

These differences in the literature can be explained by the fact that the traits were evaluated across different breeds, populations, and environmental conditions. Nevertheless, the moderate to high heritability coefficients observed in our study suggest that corrective mating for conformation and type characteristics, utilizing genetic information, can be highly efficient in the Hungarian Hucul population.

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Conclusion and recommendation

The investigated body measurements showed relatively low phenotypic variability in the Hungarian Hucul mare population. The highest mean values were generally observed in the Prislop sire line, whereas the lowest mean values were generally observed in the Polan sire line. These findings may have practical applications in breed management. If a breeder aims to adjust the size of their horses (whether to increase or decrease the overall frame in relation to the breed's optimal expectations) the descriptive phenotypic data provided in this study can serve as a valuable tool for designing targeted mating plans.
The moderate to high heritability estimates indicate that the investigated traits may respond to selection and could therefore be considered in corrective mating strategies. The very high genetic correlation between stick and tape measured height at withers indicates that the two measurements are largely controlled by the same genetic factors. Additionally, heart girth and cannon bone circumference showed a relatively high genetic correlation. Overall, integrating these genetic parameters with the current sire line statistics will assist both the breeding organization and individual breeders in maintaining and improving the optimal conformation of the Hucul breed.

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