Original Research Article

Multivariate Discrimination of Czech Autochthonous Horses

Stepanka Holeckova[1], Richard Policht[1,2], Dominika Polichtova

[1]*Faculty of Tropical AgriSciences, Czech University of Life Sciences Prague, Czech Republic*
[2]*Ethology group, Institute of Animal Science, Praha, Uhříněves, Czech Republic*

Abstract

We have used a discriminant function analysis to compare morphology of five Czech autochthonous breeds (including two colour varieties as independent breeds) to test whether a small number of basic morphological variables (wither height, thoracic, nose and shin perimeter, length of head) can discriminate them. The breeds included Czech Warmblood, black and grey colour variety of the Old Kladruby horse, Czech-Moravian Belgian horse and Silesian Noriker. The tested individuals were assigned with overall 81.9% classification success to correct breed. The best classification result reached Czech Warmblood 95.7%, the black Old Kladruby horse 87.5% and Silesian Noriker, respectively, 85.7%. Czech-Moravian Belgian horse showed a poorer success of classification (60%). Discrimination analysis identified the most important variables related to their head (nose perimeter and length of the head). Based on discrimination model both colour varieties of the Old Kladruby horse clustered more closely. Similarly both cold-blooded breeds (Czech-Moravian Belgian and Silesian Noriker) grouped more together and locations of the Czech warmbloods were more apart from all others. Such result is in concordance with the origin history of these horses.

Keywords: autochthonous horses, discriminant analysis, *Equus caballus*, morphology.

INTRODUCTION

Autochthonous breeds of domestic horses (*Equus caballus*) represent important genetic resources. Their populations are often limited at least during some time of their history and such population decline has several consequences also in inbreeding depression. Analyses of morphological variables help us to save specific traits of autochthonous breeds, with those they greatly differ from another horse breeds. Measurements of horse morphology have been seldom compared between more than two breeds so we know less about inter-breed variation (see Brooks et al. 2010). Phenotype of wild progenitors in horses changed due to human artificial selection (Price 2002); especially body size including some other morphological features were under strong selection as critically important traits during diversification of horse breeds (Brooks et al. 2010).

Most of morphological studies compared not more than two breeds (e.g. Sadek et al. 2006; Druml et al. 2008; Jakubec et al. 2009; Komosa and Purzyc 2009; Vostrý et al. 2009) and used a large number of morphological features (see Druml et al. 2008; Brooks et al. 2010; Gómez et al. 2012). Therefore, we aimed to compare several horse breeds and to test whether morphological variability described by only a few basic morphological traits would be sufficient for a discrimination model.

We included not only commonly used measurements like thoracic perimeter and wither height but also those related to head profile (e.g. nose perimeter) to see whether head morphology will be important for distinction not only of the Old Kladruby horses, with the most pronounced nose profile, but also for other breeds.

We studied the following breeds: Czech Warmblood, Silesian Noriker, and Czech-Moravian Belgian, and black and grey colour variety of Old Kladruby horse. Especially the Old Kladruby horse represents the most important Czech genetic resource (Jakubec et al. 2009). The breeds under study were selected for different functions: the Old Kladruby horse (ceremonial purposes) (Jakubec et al. 2009), Czech Warmblood (sport performance) (Jiskrová et al. 2002), Silesian Noriker and Czech-Moravian Belgian as working breeds. To our knowledge, morphological distinctness among Czech autochthonous breeds was not yet compared using multivariate approach.

MATERIALS AND METHODS

Locations

The data were obtained from several localities of the Czech Republic, including private studs. The horses belonged to state and private owners and lived in social groups, both in the box stalls or on pasture. Localities included several kinds of housing: Pisek (6 individuals of Czech Warmblood, CW), 1 individual of Silesian Noriker (SN) and Tlumacov (4 SN and 5 Czech-Moravian Belgian horse - CMB) kept only stallions of several breeds. These lived in large box stalls with the possibility of moving in paddocks. Slatinany state stud farm, where mostly mares and their foals are kept and breeding stallions of black variety of the Old Kladruby

horses – KB (6 stallions, 7 mares) including one mare of grey colour variety (KG). Stallions were housed in large box stalls, breeding mares without foals were tied in stables and mares with foals in box stalls or in individual housing. Cold blooded horses (Czech-Moravian Belgian horse and Silesian Noriker) were kept in private stud farms Klokocov (7 mares and 1 stallion of SNK) and Janovice (5 mares of CMB). The others represent private farms housing horses for sport, recreation and breeding as well. They were kept in stalls or in pastures: Svincice (8 mares of CW), Sukorady (1 stallion of SNK), Vrchovany (1 mare of CW) and Nebanice (7 stallions of KG), Ctidruzice (3 mares and 1 stallion of CW), Brno (1 stallion of CW) and Krenek (2 stallions of CW).

Animals

We selected the following breeds of horses bred in the Czech Republic: Czech Warmblood (13 mares: 12 ± 4.9 years of age, 10 stallions: 8.6 ± 3.3 years of age; mean ± standard deviation), black (7 mares: 13.6 ± 2.8 years of age, 9 stallions: 8.8 ± 1.9 years of age) and grey colour variety (1 mare: 18 ± 0.0 years of age, 8 stallions: 4.3 ± 1.0 years of age) of the Old Kladruby horse, Czech-Moravian Belgian horse (5 mares: 13.3 ± 3.9 years of age, 5 stallions: 6 ± 6.2 years of age) and Silesian Noriker (7 mares: 10.1 ± 3.8 years of age, 7 stallions: 11.7 ± 7.9 years of age). The youngest animals were seven three- year-old horses.

All of them originated from the Bohemian region and the Kladruby horse, Silesian Noriker, and Czech-Moravian Belgian horse represent endangered horse breeds in the Czech Republic (Vostrý et al. 2011). Both colour varieties of the Old Kladruby horse were considered as independent breeds for the purpose of this study. They have been bred separately since 1945 and differ significantly in several morphological traits as shown by Jakubec et al. (2009).

The Old Kladruby horse as the most important Czech genetic resource was established at the end of the 18th and the beginning of the 19th century on the basis of Old Spanish and Old Italian horses (Jakubec et al. 2009). The name of Czech Warmblood was established in 1983 as a new breed for a sport performance and recreation (Jiskrová et al. 2002; Ignor and Cieśla 2009) using mainly Thoroughbred, Hanoverian, Holstein and Trakehnen horses (Ignor and Cieśla 2009). In the last approximately 120 years, the Czech-Moravian Belgian was established by imports of Belgian and Walloon stallions (Vostrý et al. 2011). The second cold blooded horse, the Silesian Noriker has originated from imported original Noriker and Bavarian cold-blooded stallions in the last approximately 100 years (Vostrý et al. 2009).

Data collection

The data of basic morphological measurements (wither height, thoracic, nose and shin perimeter, length of head) from 72 individuals were obtained during two seasons between July 2010 and December 2012. Thoracic, nose and shin perimeter and length of head were measured by tape and wither height by standard measuring stick (see Gómez et al. 2012). Nose perimeter was measure by settling the tape in front of the cheekbones. We also recorded the age and sex in all studied individuals.

Statistical analyses

Highly correlated variables ($r \geq 0.80$) were excluded to minimize loss of information. The raw data were standardized by subtracting the mean from each value and dividing it by the standard deviation. Such transformation brings all measurements to compatible units regardless of their distributions and original units of measurement and forms a distribution with a mean of 0 and a standard deviation of 1. This procedure creates the distributions of values easy to compare across variables and makes the results entirely independent of the ranges of values or the units of measurements (StatSoft, Inc., 2012).

We applied a stepwise discriminant function analysis (DFA) with more conservative cross-validation of group classification using "leave-one-out" procedure in IBM SPSS Statistics 20, based on leaving one variable out of the tested data followed by testing of the ability of discrimination functions to predict group membership (breed). Multi-variate tests were performed by using of IBM SPSS Statistics 20 (IBM SPSS Statistics Base 20 (2011).

RESULTS AND DISCUSSION

We used five basic measurements (wither height, thoracic perimeter, nose perimeter, length of head and shin perimeter) for the multiparametric comparison of the morphology among Czech autochthonous horse breeds including Czech Warmblood, black and grey colour variety of the Old Kladruby horse, Czech-Moravian Belgian horse and Silesian Noriker. We analysed morphological measurements from 72 individuals belonging to five breeds. The stepwise model of DFA (Wilks' lambda = 0.072) included four variables: wither height, nose and shin perimeter and length of head. Thoracic perimeter was excluded during the stepwise procedure. Tested individuals were assigned with overall 81.9% classification success to correct breed and following the validation procedure classified with all individuals with overall 73.6% result. The first two canonical functions with eigenvalue > 1 explained 96.2% of variation (see Fig. 1). The largest absolute correlation with the first discrimination function showed nose perimeter (r = 0.618). Other traits: length of head (r = 0.399), wither height (r = -0.215) and shin perimeter (r = 0.520). With the second discrimination function mostly correlated length of head (r = 0.775). Other

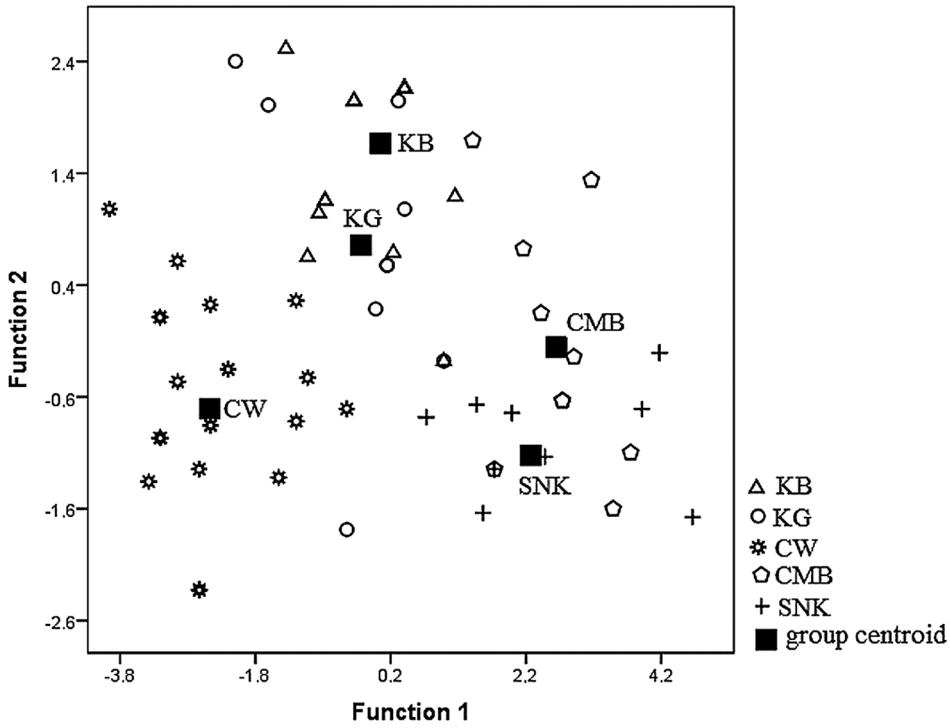

Fig. 1. Individual horses in a space of the first two significant discriminant functions describing 96.2% of variation. *Horse breeds:* (CW) Czech Warmblood, (CMB) Czech-Moravian Belgian horse, (SNK) Silesian Noriker, (KG) Old Kladruby horse – grey colour variety, (KB) Old Kladruby horse – black colour variety.

variables: shin perimeter (r = 0.501), wither height (r = 0.482) and shin perimeter (r = -0.161).

The best classification result reached Czech Warmblood 95.7% (91.3% of validated DFA), the black Old Kladruby horse 87.5% (87.5%) and Silesian Noriker, respectively 85.7% (71.4%). The Czech-Moravian Belgian horse showed a less successful classification 60% (40%) (see Table 1).

Horses of the black Old Kladruby horse were incorrectly classified as individuals of grey colour variety of the Old Kladruby horse (6.3%) and Silesian Noriker's (6.3% as well). Individuals of the grey Old Kladruby horse were mostly misclassified as those of the black Old Kladruby horse (33.3%). The 4.3% of Czech Warmblood were incorrectly recognised as both colour varieties of the Old Kladruby horse, 50% of Czech-Moravian Belgian horses to Silesian Noriker and 21.4% of Silesian Norikers were misclassified as Czech-Moravian Belgian horses (see Table 1).

The results showed significant differences in morphology of the horses. Based on discrimination analysis, the individuals were allocated to the correct breed with probability greater than by chance.

For distinction of breeds, discrimination analysis has identified the most important variables related to their head (nose perimeter and length of the head). In comparison, the study of Brooks et al. (2010) identified mainly measurements related to overall body size and overall bone thickness to be the most important in their morphological analysis. Their study included 35 measurements on 65 breeds. The importance of measurements related to the head in our study probably mirrors the divergence in profile of the head in these breeds.

Based on discrimination model both colour varieties of the Old Kladruby horse clustered more closely. They mutually separated based on the second discrimination function, with which the length of head mostly correlated (r = 0.775). From Czech Warmblood and both cold-blooded horses diverged based on the first two discriminant functions. Nose perimeter mostly correlated with the first discriminant function (r = 0.618).

Similarly, both cold-blooded breeds (Czech-Moravian Belgian and Silesian Noriker) grouped together more but

Table 1. Percentage of classification success (cross-validated DFA) in Czech autochthonous horse breeds into own (diagonal = correct classification) and other breeds (out of diagonal = incorrect classification).

	Predicted breed membership				
Breed	KB	KG	CW	CMB	SNK
KB	**87.5**	6.3	0.0	0.0	6.3
KG	33.3	**44.4**	11.1	0.0	11.1
CW	4.3	4.3	**91.3**	0.0	0.0
CMB	10.0	0.0	0.0	**40.0**	50.0
SNK	0.0	0.0	7.1	21.4	**71.4**

locations of the Czech warmbloods were more apart from all others. These cold-blooded breeds clustered separately from others based on both key discriminant functions. Such result is in concordance with the origin history of these horses.

The breeds under study differed significantly in all variables measured: withers height (Kruskal-Wallis Anova, H (4, N = 72) = 23.5; $p < 0.001$), length of head (Kruskal-Wallis Anova, H (4, N = 72) = 44.76; $p < 0.001$), thoracic perimeter (Kruskal-Wallis Anova, H (4, N=72)=23:89; $p < 0.001$), nose perimeter (Kruskal-Wallis Anova, H (4, N = 72) = 51.25; $p < 0.001$) and shin perimeter (Kruskal-Wallis Anova, H (4, N = 72)=43.67; $p < 0.001$).

Classification results, i.e. the ratio of individual horses that were allocated to the correct breed showed the following: the most successful classification reached the Czech warmblood. However, this horse belongs to the most modern breeds, their morphological traits differ most from both Old Kladruby horses and both cold-blood breeds. The higher classification output of the black variety the Old Kladruby horse in comparison to the grey one, indicates a significant morphological distinctiveness. Such result is in concordance of the study of Jakubec et al. (2009) who found a significant difference in 13 of 32 morphological traits, including head profile. Of the cold-blooded breeds, the better result revealed the Silesian Noriker, whereas half of Czech-Moravian Belgians were misclassified as individuals of the Silesian Noriker.

The age of horses (3-21 years) did not significantly affect the results and to control the effect of sex, we conducted the second discrimination analysis with males only (39 individuals), because there was only one grey Old Kladruby mare.

The resulting output revealed the same pattern. This second discrimination model (Wilks‘ lambda = 0.037) included the same four variables as the previous one and validated procedure showed better validated classification result (76.9%). First two significant discrimination functions with eigenvalue >1 described 90.8% of overall variation.

Classification result (validated DFA) based on males was more successful in grey Old Kladruby horse (increasing from 44.4 % to 62.5%), Czech Warmblood (increasing from 91.3% to 100%) and Czech-Moravian Belgian horse (increasing from 40% to 60%) (see Table 2). In the case of the black Old Kladruby horse the classification success (87.5%, both sexes) decreased (77.8%, males only). Success of classification results of all analyses was much higher than the classification obtained by chance (see Table 3).

It is obvious that these five measurements we used for comparison did not include most of body variation in these breeds, but discrimination model was able to recognise breeds with 82% success.

Table 2. Percentage of classification success (cross-validated DFA) of males into own (diagonal = correct classification) and other breeds (out of diagonal = incorrect classification).

	Predicted breed membership				
Breed	KB	KG	CW	CMB	SNK
KB	**77.8**	22.2	0.0	0.0	0.0
KG	25.0	**62.5**	12.5	0.0	0.0
CW	0.0	0.0	**100.0**	0.0	0.0
CMB	0.0	0.0	0.0	**60.0**	40.0
SNK	0.0	14.3	0.0	14.3	**71.4**

Table 3. Classification results of Czech autochthonous breeds based on two discrimination analysis (DFA):
(1) DFA of individuals of both sex, (2) DFA of males only.
Notes: Prior (prior probability-classification by chance), Validated (cross validated DFA).

Both sex				**Males only**		
Breed	Prior	DFA	Validated	Prior	DFA	Validated
KB	0.22	87.5	87.5	0.23	77.8	77.8
KG	0.13	55.6	44.4	0.21	75.0	62.5
CW	0.32	95.7	91.3	0.26	100.0	100.0
CMB	0.14	60.0	40.0	0.13	60.0	60.0
SN	0.19	85.7	71.4	0.18	71.4	71.4

ACKNOWLEDGEMENTS

We thank to the management and staff of both state and private stud farms in Tlumačov, Písek, Slatiňany, Janovice and Klokočov including private breeding farms in Svinčice, Sukorady, Nebanice and Vrchovany. Special thanks are due to Jan Navrátil and Lucie Starostová (CULS), Antonín Černocký (Tlumačov), Kateřina Pernicová (Dvorka Janovice), Jan Pellar (Písek), Karel Brendl (Klokočov), Eva Šimáčková (Nebanice), Tomáš Calta (Sukorady), Pavel and Martina Studničkovi (Vrchovany) and Jaroslav Podolan, Ivana Staňková and Martin Vávra (Svinčice). The study was supported by the Internal Grant of the Czech University of Life Sciences Prague IGA ITS 51120/1312/51/3109.

REFERENCES

Brooks S.A., Makvandi-Nejad S., Chu E., Allen J.J., Streeter C., Gu E., McCleery B., Murphy B.A., Bellone R., Sutter N.B. (2010): Morphological variation in the horse: defining complex traits of body size and shape. Animal Genetics, 41(Suppl. 2): 159-165.

Druml T., Baumung R., Sölkner J. (2008): Morphological analysis and effect of selection for conformation in the Noriker draught horse population. Livestock Science 115: 118-128.

Gómez M.D., Azor P.J., Alonso M.E., Jordana J., Valera M. (2012): Morphological and genetic characterization

of Spanish heavy horse breeds: Implications for their conservation. Livestock Science 144(1): 57-66.

IBM SPSS Statistics Base 20 (2011). IBM Corporation.

Ignor J., Cieśla A. (2009): Comparison of the exterior variables and breed structure of ancestors of the Polish Noble Half-breed and the Czech Warm-blood stallions. Acta Scientiarum Polonorum - Zootechnica, 8(3): 11-18.

Jakubec V., Vostrý L., Schlote W., Majzlík I., Mach, K. (2009): Selection in the genetic resource: genetic variation of the linear described type traits in the Old Kladrub horse. Archiv Tierzucht, 52(4): 343-355.

Jiskrová I., Glasnák V., Misař, D. (2002): The use of blood protein polymorphism for determining the genetic distance between the Moravian warm-blooded horse and the Czech warm-blooded and Trakehner horses. Czech Journal of Animal Science 47(3): 98-105.

Komosa M., Purzyc H. (2009): Konik and Hucul horses: a comparative study of exterior measurements. Journal of Animal Science 87(7): 2245-2254.

Price E.O. (2002): Animal Domestication and Behavior. CABI Publishing, CAB International, Wallingford, UK.

Sadek M.H., Al-Aboud A.Z., Ashmawy A.A. (2006): Factor analysis of body measurements in Arabian horses. Journal of Animal Breeding and Genetics 123(6): 369-377.

StatSoft, Inc. (2012): Electronic Statistics Textbook. Tulsa, OK: StatSoft. http://www.statsoft.com/textbook/.

Vostrý L., Čapková Z., Andrejsová L., Mach K., Majzlík I. (2009): Linear type trait analysis in colblood breeds: Czech-Moravian Belgian horse and Silesian Noriker. Slovak Journal of Animal Science 42(3): 99-106.

Vostrý L., Čapková Z., Přibyl, J., Hofmanová B., Vostrá Vydrová H., Mach K. (2011): Population structure of Czech cold-blooded breeds of horse. Archiv Tierzucht, 54(1), 1-9.

Received for publication: August 10, 2013
Accepted for publication: October 7, 2013

Corresponding author:

Richard Policht
Faculty of Tropical AgriSciences
Czech University of Life Sciences Prague
Kamýcká 129, 165 21
Praha 6, Czech Republic
E-mail: richard.policht@seznam.cz