https://doi.org/10.17221/156/2018-CJAS

Maternal effect on sports performance traits in horses

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Citation: Próchniak T., Rozempolska-Rucińska I., Zięba G. (2019): Maternal effect on sports performance traits in horses. Czech J. Anim. Sci., 64, 361–365.

Abstract: The aim of the study was to estimate the direct additive genetic effect and the additive maternal effect on the level of traits estimated during the Polish Jumping Championships for Young Horses. The investigations involved 541 stallions and 353 mares, which in total started in the Championships 1232 times. Variance and covariance components were estimated using the Gibbs sampling method. Heritability (h^2) and repeatability (r^2) coefficients as well as maternal effects (m^2) were calculated for 7 sports performance traits. There was an additive maternal effect, ranging from 0.11 to 0.39, on the level of traits assessed based on achieved scores. The effect was particularly high in the case of traits the level of which was determined by the animal organism performance and stress resistance. It was also noted that the value of the maternal effect in some traits was similar or higher than the coefficient of heritability, which may indicate a high effect of the mare's specific environment in determining sport predispositions in the offspring. There is a need to analyse the cause of trait variability in other equestrian disciplines.

Keywords: sport horses; variance components; genetic parameters

Besides the genetic background and the effect of environmental factors, the specific maternal environment is an important source of variability in performance traits (Strabel et al. 2001). The maternal effect on the offspring's phenotype is associated not only with mitochondrial inheritance (Mannen et al. 1998), but also with the features of the mare's organism, health status, and other factors included in the specific maternal environment. Prenatal and postnatal maternal effects play a fundamental role during the postnatal period when the animal's organism and mind are developing (Becker and Kowall 1977). The maternal environment effect on the animal's phenotype and usability value has been investigated in many animal species (e.g. Bijma 2006; Langlois and Blouin 2012; Soydan and Sahin 2016). There are relatively few available reports in the field of horse breeding although it can be assumed that the features of the mare's organism largely determine the traits in offspring that is predisposed to specific sport disciplines. Torzynski et al. (2005) studied the impact of maternal effect on selected body conformation traits of Polish half-bred horses. There was also an attempt to determine the impact of maternal effect on sports performance traits in Quarter Horses (Willham and Wilson 1991), Arabians (Belhajyahia et al. 2003), and Criollo (Lopez-Correa et al. 2018). French researchers (Langlois and Blouin 2012) showed a significant impact of maternal effect on breeding traits of warm-blooded and cold-blooded horses.

Previous studies indicate that the show jumping predispositions of horses are determined by a number of genetic and environmental factors (Prochniak et al. 2015a, b; Jonsson et al. 2016; Schubertova et al. 2016; Bartolome et al. 2018). However, there is an open question about the maternal effects on the overall variability of these traits. An adequate definition of the magnitude of these effects may significantly impact the breeding values estimation in horses. It seems that the maternal effect in this animal species is an underestimated factor in the assessment of genetic variability of traits. Knowledge of the level of individual components of the sports performance

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traits variability, including the maternal effect, seems to be particularly important in the young horse population assessed in terms of usability value in sports competition conditions. These analyses are necessary to use the results of the Polish Young Horse Championships in the practical evaluation of the breeding value of sport horses in the future.

The aim of the study was to estimate the direct additive genetic effect and the additive maternal effect on the level of traits predisposing horses to the show jumping discipline.

MATERIAL AND METHODS

Sport results achieved by 541 stallions and 353 mares starting in the Polish Jumping Championships for Young Horses were analysed. Totally 1232 starts of the horses in four age groups (4-, 5-, 6- and 7-years-old) were recorded (Table 1). The number of dams of sports horses was 785, while their average number of offspring was 1.14 (min = 1, max = 6).

The analysis was carried out on scores achieved by the horses during "horse style assessment" competitions and in the so-called competitions "against the clock" and competitions "not against the clock" refereed in accordance with the regulations of the Polish Equestrian Federation.

Table 1. Number of horses and starts (in parentheses) in relation to sex and age

Age category	4 years	5 years	6 years	7 years	Total
Sex					
♂♂	264 (265)	161 (242)	89 (155)	27 (71)	541 (733)
♀♀	166 (167)	84 (164)	56 (118)	17 (50)	353 (499)
Total	430 (432)	275 (406)	145 (273)	44 (121)	894 (1232)

In the selection of traits for the model, conclusions from the research by Prochniak et al. (2015a) were used. The following 7 characteristics were analysed (Table 2): (1) horse ranking in the championship – based on the results obtained on each day of the 3-day competition, determined on the basis of the regulations in force in a given year; (2–4) style rating on each competition day, being the sum of penalty points (0.5 point for knocking down, 1 point for the first and 2 points for the second jump refusal, 0.1 point for each second of exceeding the time limit) and bonus points awarded by a two-person commission for the jump style presented by a given horse; (5–7) penalty points on each competition day obtained in the "not against the clock" and "against the clock" competitions (4 points for knocking down the pole, 4 points for the first jump refusal, 8 points for the second break, 1 point for exceeding the time allowed for every 4 s started). The following components of variance were estimated: Vm – maternal additive genetic variance, Va – direct additive genetic variance, Vpe – permanent environmental variance, Vr – variance of riders, Ve – residual variance. The following characteristics were estimated for the listed traits: maternal effect (m^2), heritability coefficients (h^2), repeatability (r^2), and their standard errors (SE).

The following patterns were used:

$$m^2 = Vm/(Vm + Va + Vpe + Vr + Ve)$$

$$h^2 = Va/(Vm + Va + Vpe + Vr + Ve)$$

$$r^2 = Va + Vpe/(Vm + Va + Vpe + Vr + Ve)$$

The lineage of analysed horses comprised 23 242 horses with a minimum depth of five generations.

The model for the estimation of variance and covariance was constructed on the basis of the significance of the fixed environmental effects verified by a mixed-model analysis of variance of the SAS software (Version 9.4, 2013).

Table 2. Simple statistics of traits recorded during the Polish Jumping Championships for Young Horses

Traits (linear)	$\bar{x}$	SD	Min	Max	Horses *n*	Starts *n*
Overall ranking	13.66	10.35	1.00	49.00	894	1232
Day 1 style	7.09	1.08	1.10	8.80	203	388
Day 2 style	7.29	1.02	–0.60	9.20	586	715
Day 3 style	7.18	1.35	–1.90	9.20	527	623
Day 1 penalties	4.21	5.26	0	36.00	247	385
Day 2 penalties	4.52	5.29	0	27.00	252	401
Day 3 penalties	5.52	5.30	0	25.00	191	324

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Table 3. Effects[1] fitted in the models for 2 groups of traits

Traits	Classes n	Type of effect[2]	Ranking	Style score and Penalties for competition days 1, 2, 3
Effect				
Additive effect of the individual	23 244	A	●	●
Additive maternal effect	15 887	A	●	●
Permanent environment of the individual	894	R	●	●
Rider	326	R	●	●
Championship year	9	F	●	●
Championship site	3	F	●	●
Age category	4	F	●	●
Sex	3	F	●	●
Competing horses n		C	●	

[1]● indicates the presence of the effect in the model for a particular trait, [2]A – random, associated with the relationship matrix; R – random, diagonal; F – fixed; C – fixed covariate

The variance components were estimated by Gibbs sampling (THRGIBBS1F90 program – Tsuruta and Misztal 2006) enabling the creation of threshold linear models. Factors included in the mathematical model are presented in Table 3. Totally 300 000 sampling rounds were carried out for the model. Convergence was assessed by visual inspection of trace plots with the first 50 000 iterations discarded and regarded as burn-in.

RESULTS AND DISCUSSION

The analysed traits were found to be largely determined by the additive effect of the individual (Table 4), as evidenced by the heritability coefficient values with relatively low standard errors. Noteworthy is the high value of the maternal effect (m^2), with the highest values recorded for traits characterised by the highest heritability coefficient. For a majority of the traits, the maternal effect was equal to the values of the additive effects of an individual; in turn, it exceeded the coefficient of heritability of these traits in the case of day 2 and 3 style scores.

In light of the current knowledge, the specific maternal environment may be an important source of variability in quantitative traits. The female exerts an effect on the offspring not only by transferred genes, which directly determine the level of specific traits, but also by the health status, uterus size, quantity and quality of compounds provided to the foetus, milk yield, and maternal care.

Table 4. Estimates of maternal effect (m^2), heritability (h^2), repeatability (r^2), and their standard errors (SE) for the analysed traits

Trait	Variances[1]					m^2	SE	h^2	SE	r^2	SE
	Vm	Va	Vpe	Vr	Ve						
Overall ranking	8.58	18.44	6.03	5.12	42.22	0.11	0.04	0.23	0.07	0.30	0.07
Day 1 style	0.44	0.46	0.12	0.01	0.11	0.39	0.15	0.40	0.15	0.51	0.15
Day 2 style	0.22	0.19	0.05	0.21	0.39	0.21	0.07	0.18	0.07	0.23	0.07
Day 3 style	0.50	0.41	0.19	0.28	1.05	0.21	0.07	0.17	0.06	0.25	0.08
Day 1 penalties	10.96	11.57	6.11	0.09	2.03	0.36	0.16	0.38	0.17	0.57	0.17
Day 2 penalties	10.32	12.12	7.13	2.55	5.40	0.28	0.10	0.32	0.13	0.51	0.14
Day 3 penalties	15.90	16.38	8.23	1.80	0.53	0.37	0.17	0.38	0.17	0.57	0.17

[1]Vm = maternal additive genetic variance, Va = direct additive genetic variance, Vpe = permanent environmental variance, Vr = variance of riders, Ve = residual variance

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The results obtained in this study (Table 4) suggest that the traits predisposing horses to show jumping are largely determined by the maternal effect. A quick assessment of these results may be surprising: How can a mare determine such offspring's traits like the jumping style on subsequent days or penalty scores? However, one should realise what horse's traits are actually evaluated during championships. Both the jumping style and penalty scores reflect a number of physical and psychological traits of the animal. Undoubtedly, show jumping predispositions should be mentioned here, i.e. psychological traits, in addition to anatomical and physiological features. During 3-day championships, the animal needs to exhibit not only endurance and high physical fitness, but also mental strength that allows the quick and accurate performance of competition tasks. Undoubtedly, an important role is played by the nervous system, which develops during pregnancy and in the neonatal period (Becker and Kowall 1977). In this sense, the significant effect of the specific maternal environment on sports performance in young horses is logical. The mare exerts an effect on the phenotype of foals, especially in the first months of life, when a set of traits influencing the organism function is developing. This has been confirmed by numerous animal (Van Der Linden et al. 2009) and human (Curley and Champagne 2016) studies. During the prenatal and postnatal periods, the skeletal and muscle systems develop, which is closely related to the psycho-physical condition of the mare, the function of the mare's hormonal system, and the quantity and quality of produced milk. Only a normally developed horse organism has a potential to cope with the high demands placed by the show jumping discipline. Error-free and ergonomic hurdling of obstacles is facilitated by a well-developed locomotor system, efficient circulatory and respiratory systems, and an appropriate level of sensitivity to stimuli. Simultaneously, a long-term effect of the maternal environment during pregnancy on the function of the locomotor, immune, and hormonal systems in the later periods of offspring life has been evidenced (Peugnet et al. 2016).

The considerable maternal effect may be associated with the transfer of genes located in mitochondrial DNA and its influence on the animal phenotype (Hill et al. 2002; Ladoukakis and Zouros 2017). The mitochondrial genome comprises genes encoding respiratory chain proteins, which exert an effect on metabolic processes associated with the effort made by the animal during equestrian competitions. Harrison and Turrion-Gomez (2006) demonstrated associations between individual haplotypes and racing performance in thoroughbred horses.

Such a high value of the m^2 coefficient obtained in this study (Table 4) implies that the mare has a significant effect on traits allowing horses to be used in sport. The maternal effect noted in the present study was high for all the analysed traits. To some extent, this confirms the thesis that these traits are determined by analogous properties of the animal organism, e.g. the development of the musculoskeletal and nervous systems and respiratory efficiency. Concurrently, as evidenced by the present results, they are modified by the maternal organism. The specific maternal environment and care of the offspring have an impact on the animal psychological status and, hence, animal resistance to stress. This factor determines sports performance (Huizinga et al. 1990) and animal–human relationships (Cameron et al. 2008).

The research results may be of great importance, given the embryo transfer that has been developing in recent years and gaining importance in breeding sport horses (Sitzenstock et al. 2013). The results suggest that the choice of the female recipient may also have a considerable effect on the usability value of the offspring. This is supported by reports from other authors showing differences in the foetal development, post-natal adaptation, and glucose metabolism caused by the embryo transfer between mares of different-sized breeds (Peugnet et al. 2017). In turn, the maternal effect on the level of traits analogous to those assessed in Polish training centres has been evidenced in the investigations of the Holstein horse population.

CONCLUSION

Prenatal and postnatal maternal effects are an important source of variability in traits predisposing sport horses to show jumping. Achievement of high ranks by horses in show jumping competitions, i.e. low penalty scores and high jumping style scores, is largely determined by the maternal effect on the offspring, as evidenced by the high m^2 values. Assessment of the breeding value of horses in the mathematical model should take into account the maternal effect as an important source of variability which may contribute to increased accuracy of BLUP values of sport horses.

https://doi.org/10.17221/156/2018-CJAS

REFERENCES

Bartolome E., Menendez-Buxadera A., Molina A., Valera M. (2018): Plasticity effect of rider–horse interaction on genetic evaluations for Show Jumping discipline in sport horses. Journal of Animal Breeding and Genetics, 135, 138–148.

Becker G., Kowall M. (1977): Crucial role of postnatal maternal environment in expression of prenatal stress effects in male rat. Journal of Comparative and Physiological Psychology, 91, 1432–1446.

Belhajyahia T., Blouin C., Langlois B., Harzalla H. (2003): Breeding evaluation of Arab horses from their racing results in Tunisia by a BLUP with an animal model approach. Animal Research, 52, 481–488.

Bijma P. (2006): Estimating maternal genetic effects in livestock. Journal of Animal Science, 84, 800–806.

Cameron E.Z., Linklater W.L., Stafford K.J., Minot E.O. (2008): Maternal investment results in better foal condition through increased play behaviour in horses. Animal Behaviour, 76, 1511–1518.

Curley J.P., Champagne F.A. (2016): Influence of maternal care on the developing brain: Mechanisms, temporal dynamics and sensitive periods. Frontiers in Neuroendocrinology, 40, 52–66.

Harrison S.P., Turrion-Gomez J.L. (2006): Mitochondrial DNA: An important female contribution to thoroughbred racehorse performance. Mitochondrion, 6, 53–66.

Hill E.W., Bradley D.G., Al-Barody M., Ertugrul O., Splan R.K., Zakharov I., Cunningham E.P. (2002): History and integrity of thoroughbred dam lines revealed in equine mtDNA variation. Animal Genetics, 33, 287–294.

Huizinga H.A., Boukamp M., Smolders G. (1990): Estimated parameters of field performance testing of mares from the Dutch Warmblood riding horse population. Livestock Production Science, 26, 291–299.

Jonsson L., Madsen P., Mark T. (2016): Modelling repeated competition records in genetic evaluations of Danish sport horses. Journal of Animal Breeding and Genetics, 133, 291–302.

Ladoukakis E.D., Zouros E. (2017): Evolution and inheritance of animal mitochondrial DNA: Rules and exceptions. Journal of Biological Research-Thessaloniki, 24, 2.

Langlois B., Blouin C. (2012): Genetic parameters for gestation length in French horse breeds. Livestock Science, 146, 133–139.

Lopez-Correa R.D., Penagaricano F., Rovere G., Urioste J.I. (2018): Genetic parameter estimation for long endurance trials in the Uruguayan Criollo horse. Journal of Animal Breeding and Genetics, 135, 186–193.

Mannen H., Kojima T., Oyama K., Mukai F., Ishida T., Tsuji S. (1998): Effect of mitochondrial DNA variation on carcass traits of Japanese Black cattle. Journal of Animal Science, 76, 36–41.

Peugnet P., Robles M., Wimel L., Tarrade A., Chavatte-Palmer P. (2016): Management of the pregnant mare and long-term consequences on the offspring. Theriogenology, 86, 99–109.

Peugnet P., Wimel L., Duchamp G., Sandersen C., Camous S., Guillaume D., Chaffaux S. (2017): Enhanced or reduced fetal growth induced by embryo transfer into smaller or larger breeds alters postnatal growth and metabolism in weaned horses. Journal of Equine Veterinary Science, 48, 143–153.

Prochniak T., Rozempolska-Rucinska I., Zieba G., Lukaszewicz M. (2015a): Genetic variability of show jumping attributes in young horses commencing competing. Asian-Australasian Journal of Animal Sciences, 28, 1090–1094.

Prochniak T., Rozempolska-Rucinska I., Zieba G., Łukaszewicz M. (2015b): Evaluation of breeding value based on scores achieved in the Polish Championships for Young Horses. Annals of Animal Science, 15, 879–887.

Schubertova Z., Candrak J., Rolinec M. (2016): Genetic evaluation of show jumping horses in the Slovak Republic. Annals of Animal Science, 16, 387–398.

Sitzenstock F., Rathke I., Ytournel F., Simianer H. (2013): The potential of embryo transfer in a German horse-breeding programme. Journal of Animal Breeding and Genetics, 130, 199–208.

Soydan E., Sahin A. (2016): Estimates of genetic parameters for direct and maternal effects with six different models on birth weight of Brown Swiss calves. Journal of Animal and Plant Sciences, 26, 577–582.

Strabel T., Misztal I., Bertrand J.K. (2001). Approximation of reliabilities for multiple-trait model with maternal effects. Journal of Animal Science, 79, 833–839.

Torzynski G., Wolc A., Szwaczkowski T. (2005): Maternal effects on the conformation traits in half-bred horses. Journal of Animal and Feed Sciences, 14, 595–605.

Tsuruta S, Misztal I. (2006): THRGIBBS1F90 for estimation of variance components with threshold and linear models. Journal of Animal Science, 18(1), 15.

Van Der Linden D.S., Kenyon P.R., Blair H.T., Lopez-Villalobos N., Jenkinson C.M.C., Peterson S.W., Mackenzie D.D.S. (2009): Effects of ewe size and nutrition on fetal mammary gland development and lactational performance of offspring at their first lactation. Journal of Animal Science, 87, 3944–3954.

Willham R.L., Wilson D.E. (1991): Genetic predictions of racing performance in quarter horses. Journal of Animal Science, 69, 3891–3894.

Received: 2018–08–28

Accepted: 2019–07–12