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Environmental factors affecting the speed of Thoroughbred horses competing in Poland

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The study was conducted to examine some factors affecting speed of Thoroughbred horses competing at Polish racecourses. Data on horses' speed (m/s) in flat races from year 2001 to 2005 comprised 12,643 records for 1,543 Thoroughbred horses competing in 1,876 races. Statistical analysis accounted for fixed effects of distance, age, sex, trainer, competition (defined as number of horses competing within one horse length from the winner at the moment of crossing the finishing line), track condition, weight carried, number of runners in a race and for the random effect of race, rider and horse. Almost all the factors included in the linear model were highly significant (P<0.01), but distance × competition test revealed a significant difference (P<0.05). Average speed of Polish Thoroughbreds and mean distance of the races was 15.57 m/s and 1509.1 m, respectively. Speed of horses decreased when racing distance increased and males were faster than females. Three-year-old horses ran faster (LSM=15.29 m/s) than the 2-year-olds (LSM=15.26 m/s) but slower than 4-year-old and older horses (LSM=15.36 m/s). Condition of the racing track resulted in a difference in racing speed of 1.13 m/s between fast and heavy assessed track. Least squares mean (LSM) of the speed without competition between horses was 15.23 m/s, and increased to 15.33 m/s and 15.36 m/s when there were one and two competing horses, respectively. The increase in speed due to competition was highest in 1000 m races. Speed did not significantly differ between one or two competing horses, except at the distance of 1200 m. The horses carrying more weight during a race showed a slower speed (P<0.01). Speed was 0.02 m/s higher for each additional horse in a race. The random race effect was the largest, while the random rider effect the smallest component of variance.

KEY WORDS: environmental factors / speed / Thoroughbreds / competition

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Different measures of racing performance are available: earnings, ranking value, handicap weights or racing time with its several variations. These measures create specific problems: ranking does not consider race category, money prize is a non-linear parameter and leads to difficulties in determining the value allocated to non-earning horses, and subjective handicap weight is not available for all horses due to formal restrictions. Considering these performance traits the racing time for a given distance is the only direct measure of speed and it is correlated with racing performance. Racing times, however, recorded during a race are influenced by the sum of all circumstances associated with that race: times vary with distance, course, track condition and trainer's and jockeys' tactics. Moreover quality of racemates and competition between horses may modify speed of the horse in a race and may therefore affect performance records [Tolley *et al.* 1983, Harkins *et al.* 1992, Harkins and Kamerling 1993, Shurink *et al*. 2009]. Tolley *et al.* 1983]. Regardless of these problems, Thoroughbreds win races because they run faster than the other horses in the field. Therefore, racing speed is the most basic determinant of performance. Other parameters used in analysis of performance, such as earnings or finish position, are functions of speed [Martin *et al.* 1996] and more closely measure the ability of the horse to win the finish, whereas speed over the distance reflects more the endurance of the horse. Speed is closely related to success in races, as the winner of a race is the one maintaining the highest average speed throughout the course. Racing time has been extensively studied in trotting races [Thuneberg-Selonen *et al*. 1999, Rőhe *et al*. 2001, Bugislaus *et al*. 2004], in Thoroughbred [Oki *et al*. 1994, Mota *et al*. 1998, Mota *et al*. 2005, Ekiz *et al*. 2005, Bakhtiari and Kashan 2009] and Arab races [Sabeva 2001, Ekiz and Koçak 2005, Köseman and Özbeyaz 2009, Shurink *et al*. 2009].

In Poland the Thoroughbreds have been bred for racing for many years, but little research has been conducted on the possibilities of improving the racing performance through genetic selection [Sobczyńska and Łukaszewicz 2004, Górecka *et al*. 2008]. However, in order to identify genetic differences among animals, records need to be adjusted for environmental factors influencing performance. Polish breeders generally evaluate the horses in terms of earnings or number of races won and use averaged annual performance. No studies on racing time are available in Poland, even though comparison of speed of horses may be valuable information for breeders and trainers in their work. Considering time for a given distance as a measure of racing performance, some of the corrections, e.g. for distance or for competition (rivalry between horses in the same race) may have a great importance in comparison speeds of horses.

Several authors have discussed environmental factors affecting the speed of Thoroughbred horses in different countries [Moritsu *et al*. 1994, Oki *et al*. 1994, 1995, Martin *et al*. 1996, Mota *et al*. 1998, 2005, Ekiz *et al*. 2005, Bakhtiari and Kashan 2009]. No research has been reported on this problem in Polish horse race. Therefore, the current study was conducted to fill this gap and to examine some factors than can affect speed of Thoroughbred horses competing at Polish racecourses. Knowledge how some environmental factors may influence the race speed allows better understanding the complexity of factors involved in the racing performance and is crucial for adjustment of most efficient training methods of Thoroughbreds.

Material and methods

In Poland, individual race results are recorded by the National Racecourses Association and Polish Jockey Club since 1946. The information available for each race include sex, age, date and the race number, distance and track condition, rider and trainer, carried weights, time, rank at finish and earnings. Individual race results of Thoroughbred competitions contain only racing times for the winner, but distance to the winner in horse-lengths is recorded for all horses running in a race. To estimate the finish times of non-winners, the finish time of the winner is first converted to seconds. The finish time of a non-winner is calculated by multiplying the horse-lengths between the non-winner and the winner at finish by 0.2 seconds and adding the time to the finish time of the winner [Martin *et al*. 1996].

From year 2001 to 2005 the data on horse's speed (m/s) in flat races comprised 12, 643 records for 1,543 Thoroughbreds (770 males and 773 females) competing in 1,876 races. As the number of geldings was small (25) they were classified together with mares. The horses' age ranged from 2 to 9 years and race distance was from 1,000 to 3,200 m. Horses were trained by 51 trainers and mean number of horses per trainer was 30.8 (range: 1-234). There were 9% of trainers who trained only one horse. These were grouped into one trainer class. At total of 90 riders rode the horses. The average number of animals per rider was 55.5 (range: 1-395). Each race included a minimum of 4 animals, with a mean of 6.7 horses (range: 4-19). The mean number of starts per horse was 8.2, ranging from 1 to 78. Competition was defined as the number of rival horses (0, 1, or 2) competing within one horse length distance for each horse at the moment the winner comes to finish [Shurink *et al*. 2009]. The track surface condition was classified in 5 categories (fast, good, medium, slow, heavy) according to the information given in race programme available.

The data regarding the number of observations in relation to race distances, age of horses, track condition and rivals for each horse are given in Table 1.

Table 1. Number of observations by race distance, sex, competition and track conditio Thoroughbreds

Effect	No. of observations	%
Distance (m)		
1,000	1,467	11.6
1,200	1,716	13.6
1,300	1,391	11.0
1,400	1,757	13.9
1,600	3,124	24.7
1,800	1,611	12.7
2,000	1,035	8.2
≥2,200	542	4.3
Age (years)		
2	3,019	23.9
3	6,683	52.9
≥4	2,941	23.2
Sex		
males	6,306	49.9
females	6,337	50.1
Competition		
0	5,774	45.7
1	5,299	41.9
2	1,570	12.4
Track condition		
1	645	5.1
2	6,015	47.6
3	4,171	33.0
4	1,575	12.4
5	237	1.9

Distribution of horse's speed was examined for normal distribution by estimating of skewness, kurtosis and coefficient of variation.

To identify the environmental factors affecting the speed of Thoroughbreds and estimate random effects, the following mixed model was used:

$$y = X\beta + Z\gamma + \varepsilon$$

where:

- y – vector of speed of a horse in m/s recorded at each individual race;
- X – incidence matrix of fixed effects;
- β – unknown fixed effects parameter vector of distance in meters (1,000, 1,200, 1,300, 1,400, 1,600, 1,800, 2,000, 2200 and longer), age of horse in years (2, 3, 4 and older), sex (males and females), track condition (1 to 5), competition (0, 1, 2), trainer (1 to 51), interaction between sex and age (1 to 6), interaction between the distance and competition (1 to 24) and a linear regressions on carried weights and number of runners in a race;
- Z – incidence matrix for random effects;
- γ – vector of random effects of race (1 to 1876), rider (1 to 90) and horse (1 to 1543),
- ε – vector of residual effects.

The expectations of this linear model are:

$$E\begin{bmatrix} y \\ \gamma \\ \varepsilon \end{bmatrix} = \begin{bmatrix} X\beta \\ 0 \\ 0 \end{bmatrix}$$

and the variance-covariance matrix:

$$Var\begin{bmatrix} \gamma \\ \varepsilon \end{bmatrix} = \begin{bmatrix} G & 0 \\ 0 & R \end{bmatrix}$$

where G contains variance components in a diagonal structure and $R=I\sigma^2_e$, where I denotes identity matrix.

The variance components were estimated by the REML method and Wald test was used to determine the significance of random effects.

The fixed effects were tested using type III estimable functions. Contrast tests were used to compare levels of fixed effects of distance, competition, sex, age and track condition. In these tests the contrast value of one level of the effect was compared to the mean for the remaining levels. Moreover, speed of males and females was compared within age groups. Additionally, the speed of horses competing with one or two rivals and without competition at the same distance was compared. The same comparison between 1 and 2 competing horses was done.

Results and discussion

The frequency distribution of horse's speed had a small negative coefficient of skewness (-0.49), reflecting the greater difficulty of running with high speed compared to running with low speed. There were no horses running with a speed of three standard deviations greater than the mean (17.01 m/s) and 74 horses were found running with a speed of three standard deviations less than the mean (14.13 m/s). Positive kurtosis (1.28) indicates that the tails of the distribution curve are relatively long, compared to a normal distribution with the same standard deviation. Coefficient of variation of horses' speed occurred quite small (3.2 %).

Almost all the factors included in the linear model in this study were significant at the 1% level, but distance × competition test revealed a difference significant at the level of 5%. The results of the contrast tests for the effects of distance, age, sex, age × sex interaction, competition, track condition and for the effects of distance × competition are shown in Tables 2 and 3, respectively.

Average speed of Polish Thoroughbreds and mean distance of the races was 15.57 m/s and 1509.1 m, respectively. Average speeds at longer distances (1600 m -2200 m) were higher compared to average speed of Thoroughbreds in Turkey [Ekiz and Koçak 2007]. As expected, the speed of horses decreased when racing distance increased (Tab. 2). The least squares means of the speed and speed difference (0.35 m/s) when racing distance rose from 1,000 m (15.53 m/s) to 2,000 m (15.18 m/s) were higher than those reported by Mota *et al*. [1998] for Brazilian Thoroughbreds (15.3 and 15.06 m/s, respectively), but smaller than values found for the same breed (16.76 and 15.91 m/s, respectively) by Taveira *et al*. [2004]. It should be noticed that only winning times of classic races and the fastest times out of several races won by the same horse were considered by Taveira *et al*. [2004] and Mota *et al*. [1998], respectively. According to Oki *et al*. [1995] and Ekiz and Koçak [2007], effect of environmental factors related to specific race like number and level of competitors, track and weather condition, and tactics of jockey and trainers is greater for long than for short distance races. Oki *et al*. [1995] suggested that the racing performance at different distances might be regarded as different traits. Short races contain not only true sprinters, but also stayers primarily racing to gain fitness for their future races. Furthermore, young horses start their racing in sprint events and compete at short distances before the decision to race them at long-distance categories or to retire from the track is undertaken. Poor performers never progress to longer events.

As expected, fast track surfaces resulted in higher speed than heavy track surfaces. Condition of the racing track led to a difference in racing speed of 1.13 m/s between track categories classified as fast and heavy. Similar results were reported by Gallagher *et al*. [1997] for race times achieved by winners of Australian and American Thoroughbreds, by Moritsu *et al*. [1994] for best racing times of Japanese Thoroughbreds, by Mota *et al*. [1998] for best racing times of Thoroughbred horses in Brazil, as well as by Misař *et al*. [2000] for speed of Czech Thoroughbreds. The latter authors reported that horses were faster when tract surface was classified as "fast" than "heavy" one.

Table 2. Contrast values, their standard errors (SE) and P-values for the classes of fixed effects of distance, age, sex, age × sex interaction, competition and track condition for speed in Thoroughbreds

Effect	Contrast (m/s)	SE	P value
Distance (m)			
1,000	0.251	0.031	<0.0001
1,200	0.121	0.024	<0.0001
1,300	0.197	0.023	<0.0001
1,400	0.104	0.021	<0.0001
1,600	-0.043	0.018	0.0171
1,800	-0.163	0.023	<0.0001
2,000	-0.138	0.026	<0.0001
≥2,200	-0.311	0.038	<0.0001
Age (years)			
2	-0.063	0.027	0.0215
3	-0.018	0.014	0.2094
≥4	0.081	0.016	<0.0001
Sex[a]	0.025	0.009	0.0080
Age × sex			
2M *vs* 2F	-0.002	0.013	0.8883
3M *vs* 3F	0.052	0.011	<0.0001
4M *vs* 4F	0.025	0.013	0.0610
Competition			
0	-0.105	0.005	<0.0001
1	0.033	0.005	<0.0001
2	0.072	0.007	<0.0001
Track condition			
1	0.664	0.033	<0.0001
2	0.491	0.019	<0.0001
3	0.043	0.019	0.0289
4	-0.454	0.025	0.0001
5	-0.744	0.051	<0.0001

[a]Value corresponds to males.
M – males, F – females.

The age variable represents the influence of accumulated training effects and racing experience upon racing performance. The racing performance would improve with progressing age as the result of selective pressure placed on the horses by owners, additional training, experience as to the racing tactics, and better decisions by trainers as to the selection of particular horses for particular race. Young, unexperienced 2-year old horses improve their speed as their racing experience increases and the population as a whole improves as owners remove horses from competition [Martin *et al*. 1996]. The present study indicates that 3-year-old horses ran faster (15.29 m/s) than the 2-year-olds (15.26 m/s) but slower than 4-year old and older horses (15.36 m/s). The significant effect of age was also reported for racing times and best racing times of Thoroughbreds in Japan [Moritsu *et al*. 1994, Oki *et al*. 1994], Turkey [Ekiz *et al*. 2005], and Iran [Bakhtiari and Kashan 2009]. However, Mota *et al*. [1998] found the effect of age to be not significant for racing times of Thoroughbreds in Brazil. Also Sobczynska [2003] found the effects of age in question to be non-significant. This difference might be partly due to the fact, that in the mentioned study considered was only the racing time of winners and not that of all participants in the race as done here.

The effect of sex on speed was significant and male horses were faster than females. The significant superiority of males found in the current study is in accordance with reports of Mota *et al*. [1998] for best racing times of Thoroughbred horses. In contrast, Bakhtiari and Kashan [2009] reported no significant effect of horse sex on racing time. Oki *et al*. [1994] observed mixed results on turf and dirt tracks (the latter are considered slower): mares were faster than stallions on turf at all distances, but on dirt track the stallions were faster than mares, except for 1,200 m. Moritsu *et al*. [1994] reported the effect of horse sex to be non-significant for 1,200 m and significant for 1,800 m while Mota *et al*. [2005] identified the significant sex effect at all distances. The results of the present study did not confirm the significance of sex × distance interaction and this effect, therefore, was excluded from the model analysis. Differences in racing time and speed between sexes may reflect different physiological characteristics of males and females while racing [Jelinek 1988, Mota *et al*. 2005]. Males were significantly superior to females only at the age of three years. The differences between sexes at the age of two and four years were not confirmed as significant.

Speed of horses occurred significantly higher when the interindividual competition was applied. Average speed without competition between horses was 15.23 m/s, and increased to 15.33 and 15.36 m/s, respectively, with one and two competing horses. Speed increase with increase in number of competitors in a race is in accordance with the reports by Shurink *et al*. [2009] for Arab horses in the Netherlands. In contrast with the current study, Harkins and Kemerling [1993] reported the higher speed of horses during the individual races (with no competitors) compared to the competitive races (another horse participated). In the study of Harkins and Kemerling [1993], the correlation between mean run times for the competitive races was stronger than the correlations between competitive and individual races at the same distance, indicating that competition has an important influence on racing performance of Thoroughbreds. In males, Harkins *et al*. [1992] showed no significant difference between competitive and single run times, whereas females were consistently slower during competition. This difference reflects distinct psychological traits (willingness to compete and win) of the sexes at racing and may be the reason for worse racing performance in females than in males. Poor quality of horses and higher plasma lactate values during competitive races may explain the contrary effect of competition on speed between this study and study by Harkins *et al*. [1992]. The increase in speed due to competition was highest in 1,000 m races (Tab. 3). The competition at all the distances is similar but not the same – the level of competitors increases at long distance races, as prestigious races are performed at long distances. Furthermore, there is a better opportunity to utilize tactics by jockeys or trainers at longer distance races. This tactics may result in smaller difference between speed of horses competing and not competing with other horse at longer distances compared to shorter distances. Changing the rhythm and speed during long distances are frequent as showed by Dušek [1965]. The effect of competition indicated that the presence of rivals within a horse length distance increases speed. The time a horse can run on its own may not be comparable to what

Table 3. Contrast values, their standard errors (SE) and P-values for the classes of fixed effect of distance × competition interaction for speed in Thoroughbreds

Effect	Contrast (m/s)	SE	P value
No competing horse *vs* one or two competing horses at the distance of (m)			
1,000	-0.141	0.014	<0.0001
1,200	-0.103	0.013	<0.0001
1,300	-0.116	0.013	<0.0001
1,400	-0.108	0.011	<0.0001
1,600	-0.093	0.001	<0.0001
1,800	-0.090	0.012	<0.0001
2,000	-0.084	0.016	<0.0001
≥2,200	-0.109	0.021	<0.0001
One *vs* two competing horses at the distance of (m)			
1,000	0.001	0.022	0.9478
1,200	-0.052	0.017	0.0032
1,300	-0.036	0.019	0.0554
1,400	-0.035	0.017	0.0351
1,600	-0.020	0.012	0.0991
1,800	-0.015	0.018	0.3942
2,000	-0.021	0.021	0.3160
≥2,200	-0.028	0.029	0.3307

it can produce in competition. Speed did not significantly differ between one or two competing horses, except at the distance of 1,200 m (contrast value = -0.052). The highest differences were found at the shorter distances (1,000-1,400 m) and at distance of 2,200 m and longer.

The results of this study indicate that for each additional horse in a race the speed was by 0.02 m/s higher (P=0.003). In contrast with the current study, Gallagher *et al*. [1997] and Ekiz *et al*. [2005], reported the non-significant effect of number of competitors on the speed in a race. In the report of Mota *et al*. [1998], the best time declined with increasing number of competitors, although there were no significant differences in time between races with a larger or smaller competitors number. Martin *et al*. [1996] indicated that finish times were by 0.23 s greater for each additional horse probably as a result of increasing interference among the competitors. Results of this study allow to anticipate that the number of runners in a race would be positively related to speed, as in races with high number of competitors (high-status races) high performing horses take part.

The horses carrying more weight during a race showed a slower speed. The linear regression of speed on weight carried (-0.01) was highly significant. The weight carried was not enough to compensate for the differences in the Japanese Thoroughbreds, as horses carrying heavier weight had lower racing times than those with less weight carried [Oki *et al*. 1994, 1995]. On the other hand, Gallagher *et al*. [1997] claimed that the weight carried does not significantly affect the winning time in classic races conducted in Australia (the Golden Slipper) and in the United States (the Kentucky Derby).

The results of Wald test (Tab. 4) indicate that all the parameters studied significantly differed from 0. The random race effect was the largest, while the random jockey effect – the smallest component of variance. The largest variance component of race effects is in accordance with results obtained by Shurink *et al*. [2009] in Arab horses. Individual race effect enables to compare horses directly within the same race, as it happens in practice. After taking into account the distance, age, sex, and track condition the race comprises genetic differences between horses and eventually changes to the race track surface and temperature during a day.

Table 4. Variance estimates, their standard errors (SE), Wald-Z statistic and P-values of random effects

Random effect	Estimate (m/s)	SE	Wald-Z	P-value
Race	0.086	0.003	26.66	<0.0001
Horse	0.029	0.002	17.23	<0.0001
Rider	0.001	0.000	2.93	0.0017
Residual	0.035	0.001	65.10	<0.0001

Summarizing, the speed of horses was significantly higher when there was competition between horses. It is concluded that competition should be taken into account when making genetic and performance prediction of speed in Polish Thoroughbreds. Competition effects, till now not analysed in Polish Thoroughbreds, seem necessary to correct the speed for unbiased estimates of the horse's performance. The appropriate assessment of horse's speed can help in making decisions by horse owners and trainers concerning the training and use of horses in different races.

REFERENCES

1. BAKHTIARI J., KASHAN N.E.J., 2009 – Estimation of genetic parameters of racing performance in Iranian Thoroughbred horses. ***Livestock Science*** 120, 151-157.
2. BUGISLAUS A.E., RŐHE R., KALM E., 2004 – Comparison of two different statistical models considering individual races or race tracks for evaluation of German trotters. ***Livestock Production Science*** 32, 69-76.
3. DUŠEK J., 1965 – Evaluation of times reached by thoroughbreds in flat races at the state owned race course in Chuchle. ***Bulletin Vyzkumna Stanice pro Chov Koni***, 143-160.
4. EKIZ B., KOÇAK Ö., 2005 – Phenotypic and genetic parameter estimates for racing traits of Arabian horses in Turkey. ***Journal of Animal Breeding and Genetics*** 122, 349-356.
5. EKIZ B., KOÇAK Ö., 2007 – Estimates of genetic parameters for racing times of Thoroughbred horses. ***Turkish Journal of Veterinary and Animal Sciences*** 31, 1-5.
6. EKIZ B., KOÇAK Ö., YILMAZ A., 2005 – Phenotypic and genetic parameter estimates for racing traits of Thoroughbred horses in Turkey. ***Archiv für Tierzucht*** 48 (2), 121-129.
7. GALLAGHER J.R., FLEET M.R., HINTZ H.F., 1997 – Selective breeding for racing performance in horses. ***Proceedings of the Association for the Advancement of Animal Breeding and Genetics*** 12, 140-144.
8. GÓRECKA A., GERINGER DE OEDENDERG H., GUZIK E., 2008 – Genetic and phenotypic parameters of racing performance in Thoroughbred horses in Poland. ***Roczniki Naukowe PTZ*** 4, (3), 11-20.
9. HARKINS J.D., KAMERLING S.G., 1993 – Effect of race distance and competition on performance of thoroughbred racehorses. ***Journal of Equine Veterinary Science*** 13 (1), 41-45.

10. HARKINS J.D., KAMERLING S.G., CHURCH G., 1992 – Effect of competition on performance of Thoroughbred racehorses. ***Journal of Applied Physiology*** 72 (3), 836-841.
11. JELINEK J., 1988 – Differences in the manifested racing performance of the English Thoroughbred: evaluation of horses of different sexes and years of birth by parametric and nonparametric test. ***Scientific Agricultural Boheaca*** 2, 131-138.
12. KÖSEMAN A., ÖZBEYAZ C., 2009 – Some phenotypic and genetic parameters of racing performance in Arabian horses. ***Ankara Üniversitesi Veteriner Fakültesi*** Dergisi 56, 219-224.
13. MARTIN G.S., STRAND E., KEARNEY M.T., 1996 – Use of statistical models to evaluate racing performance in Thoroughbreds. ***Journal of American Veterinary Medicine Association*** 209 (11), 1900-1906.
14. MISAŘ D., JISKROVÁ I., SOMERLIKOVÁ K., 2000 – The effect of course surface quality on development of speed in some French flat races. ***Czech Journal of Animal Science*** 45, 309-312.
15. MORITSU Y., FUNAKOSHI H., ICHIKAWA S., 1994 – Genetic evaluation of sires and environmental factors influencing best racing times of Thoroughbred horses in Japan. ***Journal of Equine Science*** 5(2), 53-58.
16. MOTA M.D.S., ABRAHAO A.R., OLIVEIRA H.N., 2005 – Genetic and environmental parameters for racing time at different distances in Brazilian Thoroughbreds. ***Journal of Animal Breeding and Genetics*** 122, 393-399.
17. MOTA M.D.S., OLIVEIRA H.N., SILVA R. G., 1998 – Genetic and environmental factors that affect the best time of Thoroughbred horses in Brazil. ***Journal of Animal Breeding and Genetics*** 115, 123-129.
18. OKI H., SASAKI Y., LIN C. Y., WILLHAM R.L.,1995 – Influence of jockeys on racing time in Thoroughbred horses. ***Journal of Animal Breeding and Genetics*** 112, 171-175.
19. OKI H., SASAKI Y., WILLHAM R.L., 1994 – Genetics of racing performance in the Japanese Thoroughbred horse: II. Environmental variation of racing time on turf and dirt tracks and the influence of sex, age, and weight carried on racing time. ***Journal of Animal Breeding and Genetics*** 111 (2), 128-137.
20. RŐHE R., SAVAS T., BRKA M., WILLMS F., KALM E., 2001 – Estimation of genetic parameters for racing performances in German Trotters. ***Archiv für Tierzucht*** 44, 579-587.
21. SABEVA I., 2000 – Estimation of the breeding value of stallions from Arabian breed regarding the race abilities. ***Bulgarian Journal of Agricultural Science*** 6, 473-476.
22. SHURINK A., THEUNISSEN M.C.J., DUCRO B.J., BIJMA P., VAN GREVENHOF, 2009 – Identification of environmental factors affecting the speed of purebred Arabian racehorses in the Netherlands. ***Livestock Science*** 125, 97-100.
23. SOBCZYŃSKA M., 2003 – Wpływ niektórych czynników na parametry genetyczne cech wyścigowych koni pełnej krwi angielskiej i czystej krwi arabskiej (Influence of some effects on genetic parameter estimates for racing performance in Thoroughbreds and Arabian horses). In Polish with English summary. ***Roczniki Naukowe Zootechniki*** 30 (2), 223-231.
24. SOBCZYŃSKA M., ŁUKASZEWICZ M., 2004 – Genetic parameters of racing merit of Thoroughbred horses in Poland. ***Journal of Animal Breeding and Genetics*** 121, 302-306.
25. TAVEIRA R.Z., MOTA M.D.S., OLIVEIRA H.N., 2004 – Population parameters in Brazilian Thoroughbred. ***Journal of Animal Breeding and Genetics*** 121, 384-391.
26. THUNEBERG-SELONEN T., PÖSÖ J., MÄNTYSAARI E., OJALA M., 1999 – Use of individual race results in the estimation of genetic parameters of trotting performance for Finnhorse and Standardbred trotters. ***Agricultural and Food Science in Finland*** 8, 353-363.
27. TOLLEY E.A., NOTTER D.R., MARLOWE T.J., 1983 – Heritability and repeatability of speed for 2- and 3- year old Standardbred racehorses. ***Journal of Animal Science*** 56, 1294-1305.