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Phenotypic and Genetic Parameter Estimates for Racing Traits of Thoroughbred Horses in Turkey

Abstract

This study was carried out to investigate the fixed effects influencing racing traits of Thoroughbred horses and to estimate the genetic parameters for these traits, which are needed to design breeding programmes. The racing records used in the study were obtained from the Turkish Jockey Club. The traits used in the study were racing time, best racing time, rank, annual earnings, earnings per start, log annual earnings and log earnings per start. Genetic parameters were estimated by REML procedure using DFREML programme. The effects of age and sex were significant for each trait. The effect of year was significant on earning traits and time traits, except for best racing time on turf track. The effects of month on time traits were also significant. Heritability estimates of entire dataset were 0.317, 0.467, 0.132, 0.194, 0.291, 0.188 and 0.341 for racing time, best racing time, rank, annual earnings, earnings per start, log annual earnings and log earnings per start, respectively. Estimates of repeatability varied from 0.293 to 0.465 for racing time, from 0.373 to 0.531 for best racing time and from 0.215 to 0.232 for rank depending on the dataset used in the analyses.

Key Words: thoroughbred horses, environmental effects, heritability, repeatability, racing traits

Zusammenfassung

Titel der Arbeit: **Schätzung phänotypischer und genetischer Parameter für Rennleistungen von Vollblutpferden in der Türkei**

Das Ziel der Studie ist die Untersuchung der Einflüsse fixer Effekte auf die Schätzung phänotypischer und genetischer Parameter von Rennleistungen von Vollblutpferden. Diese Parameter sind bei der Gestaltung von Zuchtprogrammen erforderlich. Die Daten für die Rennleistungen wurden vom türkischen Jockeyclub bereitgestellt. Einbezogen wurden die Merkmale: Rennzeit, beste Rennzeit, Platzziffer, jährliche Gewinnsumme und der Gewinn je Start. Die Parameter wurden mittels der REML-Prozedur unter Nutzung des Programms DFREML geschätzt. Die Einflüsse Alter und Geschlecht waren für alle Merkmale ebenso signifikant wie der Einfluss des Rennjahres auf die Gewinnsumme und die Rennzeiten mit Ausnahme des Merkmals der besten Rennzeit. Ebenso signifikant war der Monatseinfluss auf die Rennzeit. Für die Heritabilität wurden in der Reihenfolge für die Merkmale Rennzeit, beste Rennzeit, Platzziffer, jährliche Gewinnsumme, Gewinnsumme je Start, Log. der jährlichen Gewinnsumme und Log. Gewinnsumme je Start folgende Werte geschätzt: 0,317, 0,467, 0,132, 0,194, 0,291, 0,188 und 0,341. Die Werte für die Wiederholbarkeit variierten für die Rennzeit zwischen 0,293 bis 0,465, für die beste Rennzeit von 0,373 bis 0,531 und für die Platzziffer von 0,215 bis 0,232.

Schlüsselwörter: Vollblutpferde, Umwelteffekte, Heritabilität, Wiederholbarkeit, Rennleistungsmerkmale

1.   Introduction

Horse racing is one of the most popular sports in Turkey. Official racings are organised by Turkish Jockey Club (TJK) since 1954. Although horse racing in Turkey is highly organized; and nutrition, training methods, veterinary procedures and track conditions have been improved, no scientific study has been carried out to improve the racing performance of racehorses by a selection programme.

In order to evaluate racing performance genetically, it is necessary to have a measure of performance. In the literature, various traits like racing time, best racing time, rank,

position rates, annual earnings, earning per start were used to measure racing performance (RICARD, 1998). Racing time in each race is the only direct measure of speed and is a suitable quantitative measure that can be used to evaluate the genetic racing performance of horses (SCHWARK et al., 1992; MORITSU et al., 1994; OKI et al., 1994; RÖHE et al., 2001). However, the reported heritability estimates for time traits were generally low (HINTZ, 1980; MORITSU et al., 1994; MOTA et al., 1998). Therefore, most of the recent studies focused on earning or rank traits, and different transformations of these traits (ARNASON, 1999; BUGISLAUS et al., 2004; SAASTAMOINEN and OJALA, 1991; SOBCZYNSKA and KOWNOCKI, 1997; VILLELA et al., 2002).

The objectives of this study were to investigate the fixed effects influencing racing traits of Thoroughbred horses and to estimate the genetic parameters for these traits, which are needed to design breeding programmes.

2. Materials and Methods

The racing records of Thoroughbred horses used in this study were obtained from the Turkish Jockey Club, and included official racings from January 1998 to December 2003. Information available for each race included the distance, track type and date of the race, and age, sex, official finish time, rank and earnings of the horses. The pedigree information of the horses was also included. Dataset included the racing distances of 1200 m, 1300 m, 1400 m, 1500 m, 1600 m, 1700 m, 1800 m, 1900 m, 2000 m, 2100 m, 2200 m and 2400 m. Horse racings in Turkey were ran both in dirt and turf tracks. The records of horses that could not complete the race were deleted from the dataset. Edited dataset comprised racing records of 4034 horses. 430 horses ran only in dirt track and 324 horses ran only in turf track, while 3280 horses participated in both dirt and turf track races. As prize money is given only to the first four horses in each race in Turkey, 3156 of the horses evaluated in the current study earned money.

The traits used in the study were racing time, best racing time, rank, annual earnings, earnings per start (EPS), log annual earnings (log earnings) and log earnings per start (log EPS).

A horse's best racing time was the fastest time of the horse over several races during a racing year. To compare the racing times of a horse over different distances and to determine the annual best racing time, a linear adjustment for racing distances was used. However, unadjusted data were used in analyses. Dataset for racing time, best racing time and rank were edited and analysed according to dirt races, turf races and entire dataset (dirt + turf). Earnings were in Turkish Lira and so they were firstly changed to US Dollar according to rate of exchange at the race day. The entire dataset used for analyses comprised 75065 racing records for racing time and rank, 8906 records for best racing time and 6410 records for earning traits. The dataset also consisted of 4034 horses from 633 sires and 2171 dams for racing time, best racing time and rank, 3156 horses from 557 sires and 1857 dams for earning traits.

Variance components and genetic parameters were estimated by the Restricted Maximum Likelihood (REML) method for a single trait animal model using derivative-free process. To identify fixed effects to be included in the animal models, preliminary the least-squares analysis of variance was carried out by the GLM procedure in SPSS 12.0 program. The effects of age (2-7 years and older), sex (male or female) and year (1998 to 2003) were fitted to the mathematical model used in preliminary analyses for

each trait. To account the track condition indirectly, the effect of month was fitted to model for time traits. Least-squares models for racing time, best racing time and rank also included the effect of number of competitors in the race (5 to 20). In the analyses of entire dataset for racing time, best racing time and rank, track type (dirt or turf) was fitted to the model as a fixed effect. The preliminary least-squares analyses for time traits also included linear and quadratic covariate due to racing distance. The effects of year on best racing time of turf track and on rank were not significant. The effects of track type on rank for entire dataset and number of competitors on racing time and best racing time were also not significant. Therefore, these effects were dropped from the animal models, which were used to estimate genetic parameters.

The animal model used to estimate the variance components was:

$$Y = X \beta + Z_a a + Z_{pe} pe + e$$

Where Y is the vector of observations; β, a, pe, and e are vectors of fixed effects, direct additive genetic effects (animal), permanent environmental effects and the residual effects, respectively; X, Z_a, and Z_{pe} are incidence matrices relating observations to β, a and pe, respectively.

The DFREML 3.0 program of Meyer (1998) was used to estimate genetic parameters. The search for the maximum of the likelihood was stopped if the variance of the simplex function values were less than 10^{-8}. Restarts were performed to confirm global convergence.

Heritability was estimated by dividing direct additive genetic variance (σ_a^2) by phenotypic variance (σ_P^2) and repeatability was estimated from the ratio between the sum of direct additive genetic and permanent environmental variances ($\sigma_a^2 + \sigma_{pe}^2$) and phenotypic variance.

Table 1
Least-squares means (LSM) of age and sex of horse on racing time and best racing time (LSM für Alter und Geschlecht der Pferde für Rennzeit und beste Rennzeit)

Effects	Racing time, s						Best racing time, s					
	Dirt		Turf		Entire dataset		Dirt		Turf		Entire dataset	
	n	LSM	n	LSM	n	LSM	n	LSM	n	LSM	n	LSM
Age	***		***		***		***		***		***	
2	4371	110.7 [d]	4911	108.4 [d]	9282	108.9 [d]	1750	96.5 [c]	1786	95.9 [d]	2245	94.6 [c]
3	14661	109.7 [c]	13979	106.9 [c]	28640	107.6 [c]	2619	95.3 [b]	2529	94.2 [c]	2857	93.1 [b]
4	9822	108.9 [b]	7864	106.3 [b]	17686	107.0 [b]	1651	94.8 [a]	1411	93.6 [b]	1813	92.4 [a]
5	5593	108.8 [a]	4096	106.0 [a]	9689	106.8 [a]	871	94.6 [a]	713	93.6 [b]	975	92.2 [a]
6	3073	108.9 [ab]	2068	106.0 [a]	5141	106.9 [ab]	469	94.8 [a]	339	93.2 [a]	525	92.3 [a]
7+	3041	109.8 [c]	1586	106.4 [b]	4627	107.5 [c]	442	95.5 [b]	280	93.8 [bc]	491	92.8 [b]
Sex	***		***		***		***		***		***	
Male	24617	109.1	17492	106.5	42109	107.1	4337	94.8	3716	93.9	4878	92.7
Female	15944	109.9	17012	106.9	32956	107.7	3465	95.7	3342	94.2	4028	93.2

***: P<0.001

3.   Results

The least-squares means (LSM) of the fixed effects for racing time and best racing time were presented in Tables 1 and 2. There was a decline in racing time and best racing time from young to intermediate age, and an increase through seven years and older. The effect of sex on time traits was significant, and male horses were much faster than female ones. The effect of year was also significant for time traits, except for best racing time on turf track. Racing time and best racing time on dirt track were shorter in spring and autumn

months than winter and summer months. Both racing time and best racing time on turf track were lowest in January and February, and improved gradually until June. However, they decreased from July to December.

Table 2
Least-squares means (LSM) of year and month on racing time and best racing time (LSM für Jahr und Monat der Rennzeit und beste Rennzeit)

Effects	Racing time, s						Best racing time, s					
	Dirt		Turf		Entire dataset		Dirt		Turf		Entire dataset	
	n	LSM	n	LSM	n	LSM	n	LSM	n	LSM	n	LSM
Year	***		***		***		***		NS		***	
1998	4800	109.2 a	3362	106.6 b	8162	107.1 a	845	95.1 ab	751	94.0	979	92.7 a
1999	5326	109.4 b	4697	106.3 a	10023	107.2 b	1004	94.8 a	945	93.8	1170	92.6 a
2000	6336	109.1 a	5613	106.7 b	11949	107.3 b	1189	95.0 ab	1049	94.1	1340	92.8 ab
2001	7275	109.5 c	6311	107.1 c	13586	107.7 c	1442	95.2 b	1294	94.2	1635	93.0 bc
2002	8492	109.8 d	6990	106.7 b	15482	107.7 c	1616	95.6 c	1458	94.0	1841	93.1 bc
2003	8332	109.8 d	7531	106.7 b	15863	107.8 d	1706	95.7 c	1561	94.1	1941	93.2 c
Month	***		***		***		***		***		***	
Jan.	5293	109.8 ef	622	111.4 j	5915	108.6 g	1126	95.6 d	91	99.4 g	547	94.7 e
Feb.	4246	109.7 e	1160	111.3 j	5406	109.0 h	739	95.4 d	116	99.8 g	335	94.5 e
Mar.	4126	109.5 d	2290	107.8 h	6416	108.4 f	588	95.6 d	266	95.2 e	440	94.6 e
Apr.	3164	109.0 a	1803	106.9 g	4967	107.8 e	612	94.7 ab	248	93.1 d	350	92.4 bc
May	2072	109.2 bc	3979	104.0 b	6051	106.2 a	353	94.7 ab	1009	91.2 a	1040	91.5 a
June	2198	109.8 ef	4096	103.5 a	6294	106.1 a	282	96.2 e	988	91.3 a	1009	92.0 a
July	2258	109.9 f	4209	104.0 b	6467	106.6 b	342	96.7 f	1021	91.8 b	1060	92.5 c
Aug.	2349	109.2 bc	3995	104.3 c	6344	106.5 b	443	95.2 cd	867	92.1 c	926	92.5 c
Sep.	2641	109.1 ab	4455	104.7 d	7096	106.8 c	584	94.8 ab	964	92.0 bc	1038	92.3 bc
Oct.	2919	109.5 d	4549	105.0 e	7468	107.2 d	642	94.5 a	1053	92.0 bc	1141	92.2 b
Nov.	4066	109.3 cd	2087	106.3 f	6153	107.7 e	947	94.6 a	349	92.9 d	567	92.3 b
Dec.	5229	109.4 cd	1259	110.8 i	6488	108.5 f	1144	95.0 bc	86	97.5 f	453	93.4 d

NS: P>0.05, ***: P<0.001

The LSM of age and sex for rank, annual earnings and EPS were presented in Table 3. Seven years and older horses showed the lowest performance for rank. This age group also had the lowest EPS. Although annual earnings of 2-year old horses were lower than those of 3, 4, 5 and 6-year old ones, the differences among these age groups for EPS were not significant. Male horses were significantly superior to the females for rank, annual earnings and EPS.

Estimates of variance components and genetic parameters for each trait were presented in Tables 4 and 5. Heritability estimates of entire dataset were 0.317, 0.467 and 0.132 for racing time, best racing time and rank, respectively. Heritability estimates of dirt track were higher than those of turf track for racing time and best racing time, while they were similar for rank. Estimates of repeatability varied from 0.293 to 0.465 for racing time, from 0.373 to 0.531 for best racing time and from 0.215 to 0.232 for rank depending on the dataset used in the analyses.

Table 3
Least-squares means (LSM) of age and sex of horse on rank and earning traits (LSM für Alter und Geschlecht der Pferde für Platzziffer und Gewinnsumme)

| Effects | Rank | | | | | | Annual earnings, USD | | Earnings per start, USD | |
| | Dirt | | Turf | | Entire dataset | | | | | |
	n	LSM	n	LSM	n	LSM	n	LSM	n	LSM
Age	***		***		***		***		***	
2	4371	6.52 [ab]	4911	6.72 [a]	9282	6.73 [a]	1674	27585.9 [c]	1674	4621.6 [a]
3	14661	6.50 [a]	13979	6.72 [a]	28640	6.72 [a]	2178	47066.8 [a]	2178	4355.7 [a]
4	9822	6.64 [ab]	7864	6.86 [b]	17686	6.85 [b]	1190	49672.7 [a]	1190	4356.6 [a]
5	5593	6.53 [a]	4096	6.62 [a]	9689	6.68 [a]	688	51166.0 [a]	688	4538.5 [a]
6	3073	6.68 [b]	2068	6.54 [a]	5141	6.73 [a]	377	42882.3 [b]	377	4111.7 [a]
7+	3041	7.08 [c]	1586	7.23 [c]	4627	7.25 [c]	303	30472.2 [c]	303	2225.4 [b]
Sex	***		***		***		***		***	
Male	24617	6.35	17492	6.70	42109	6.63	3633	47163.1	3633	4738.4
Female	15944	6.97	17012	6.86	32956	7.02	2777	35785.5	2777	3331.5

***: $P<0.001$

Table 4
Estimates of genetic parameters for racing time, best racing time and rank (standard errors in parentheses) (Schätzung genetischer Parameter für die Merkmale Rennzeit, beste Rennzeit, und Platzziffer (Standardfehler in Klammern))

| Item[a] | Racing time | | | Best racing time | | | Rank | | |
	Dirt	Turf	Entire dataset	Dirt	Turf	Entire dataset	Dirt	Turf	Entire dataset
σ_a^2	6.906	3.369	5.730	6.668	3.071	5.640	1.640	2.180	1.784
σ_{pe}^2	1.201	0.887	0.757	0.634	0.933	0.401	1.131	1.151	1.120
σ_e^2	9.347	10.268	11.602	6.281	6.721	6.043	9.588	11.053	10.598
σ_p^2	17.454	14.525	18.089	13.583	10.725	12.084	12.359	14.385	13.503
h_d^2	0.396 (0.029)	0.232 (0.025)	0.317 (0.022)	0.491 (0.045)	0.286 (0.035)	0.467 (0.044)	0.133 (0.019)	0.152 (0.020)	0.132 (0.016)
pe^2	0.069 (0.025)	0.061 (0.022)	0.042 (0.018)	0.047 (0.040)	0.087 (0.033)	0.033 (0.038)	0.092 (0.016)	0.080 (0.016)	0.083 (0.013)
r	0.465	0.293	0.359	0.531	0.373	0.500	0.225	0.232	0.215

[a] σ_a^2: direct additive genetic variance, σ_{pe}^2: permanent environmental variance, σ_e^2: error variance, σ_P^2: phenotypic variance, h_d^2: direct heritability, pe^2: σ_{pe}^2/σ_P^2, r: repeatability

Table 5
Estimates of genetic parameters for earning traits (standard errors in parentheses) (Schätzung genetischer Parameter für die Merkmale der Gewinnsumme (Standardfehler in Klammern))

Item[a]	Annual earnings	Earnings per start	log earnings	log EPS
σ_a^2	535503981.7	9513452.8	0.0733	0.1152
σ_{pe}^2	342294452.3	5112748.4	0.0469	0.0228
σ_e^2	1886930686.0	18125439.4	0.2696	0.1994
σ_p^2	2764729120.7	32751640.6	0.3897	0.3373
h_d^2	0.194 (0.039)	0.291 (0.046)	0.188 (0.036)	0.341 (0.042)
pe^2	0.124 (0.036)	0.156 (0.043)	0.120 (0.035)	0.068 (0.039)
r	0.318	0.447	0.308	0.409

[a] σ_a^2: direct additive genetic variance, σ_{pe}^2: permanent environmental variance, σ_e^2: error variance, σ_P^2: phenotypic variance, h_d^2: direct heritability, pe^2: σ_{pe}^2/σ_P^2, r: repeatability

Direct additive genetic effect contributed about 19 % of the phenotypic variance for annual earnings and log annual earnings. Estimates of heritability were 0.291 and 0.341 for EPS and log EPS, respectively. Estimates of repeatability for EPS and log EPS were higher than those of annual earnings and log annual earnings.

4.   Discussion

According to the preliminary analyses, which were carried out to determine the fixed effects included in the animal models, the effect of age was significant for each trait. The tendency, which improve with age till six year of age and then decline, was observed for racing time, best racing time and annual earnings. However, similar pattern of change could not be found for rank and EPS. Seven years and older horses showed the lowest performance for these traits, and differences between this age group and others were significant. The significant effects of age was also reported for racing times of Arabian horses (EKİZ et al., 2004), for best racing times of Thoroughbred horses (MORITSU et al., 1994) and for racing times of Thoroughbred horses (OKI et al., 1994). MORITSU et al. (1994) reported that best racing times of Thoroughbred horses tended to become shorter as the horses aged. EKIZ et al. (2004) and MARTIN et al. (1996) also reported similar pattern of changes for racing times of Arabian and Thoroughbred horses, respectively. However, MOTA et al. (1998) for best racing time and VILLELA et al. (2002) for racing time and rank found the effect of age to be non-significant for Thoroughbred and Quarter horses, respectively.

The significant superiority of males for each trait found in the current study were in agree with reports of EKIZ et al. (2004) for racing times of Arabian horses, reports of VILLELA et al. (2002) for racing times of Quarter horses and reports of MOTA et al. (1998) for best racing times of Thoroughbred horses. In the study of MORITSU et al. (1994), the effect of sex was reported to be non-significant for distance of 1200 m and to be significant for distance of 1800 m. In contrast with the current study, VILLELA et al. (2002) reported the non-significant effects of sex on rank.

The effects of month on time traits appear to be different for turf and dirt tracks in the current study. Both racing time and best racing time on dirt track were shorter in spring and autumn months. Otherwise, the shortest racing time for turf track was observed in June, and gradually it became slower by month after and before June. OKI et al. (1994) reported significant effects of month on racing time for both turf and dirt tracks. However, this effect was reported to be non-significant for best racing times of Thoroughbred horses (MOTA et al., 1998).

The significant differences between racing years for time traits found in the current study disagree with the reports for Thoroughbred horses by MOTA et al. (1998) and OKI et al. (1994), and agree with the reports of SUBEVA (1990). Similar to the current study, EKIZ et al. (2004) for racing times of Arabian horses, OKI et al. (1994) for racing times of Thoroughbred horses, MOTA et al. (1998) and MORITSU et al. (1994) for best racing times of Thoroughbred horses reported that horses were faster on turf track than dirt track. The results of the current study showed that the effect of number of competitors in race was not significant for racing time and best racing time, and was significant for rank. MOTA et al. (1998) reported similar result for best racing time.

Estimate of heritability obtained from analyses of entire dataset for racing time (0.317) was higher than those of 0.17 and 0.24 reported for Quarter horses by VILLELA et al.

(2002) and BUTTRAM et al. (1989), respectively. EKIZ et al. (2004) estimated heritability between 0.175 and 0.304 depending on racing distance for Arabian horses. HINTZ (1980) reported lower estimate (0.15) for Thoroughbred horses and similar estimate (0.32) for Trotters compared with the current study. The estimate of heritability for racing time on dirt track (0.396) in the current study was higher than estimates of OKI et al. (1995) for dirt track, which varied between 0.086 and 0.217 depending on racing distance. On the other hand, estimate of heritability for racing time on turf track (0.231) was within the range of estimates reported by OKI et al. (1995) for racing time on turf track (0.081-0.254).

Estimate of heritability for best racing time (0.467) was also higher than the literature estimates, except reports of OJALA et al. (1987), which varied from 0.28 to 0.50 depending on model for Finnish horses. Estimates of heritability for best racing times of Thoroughbred horses were reported to be 0.12 by MOTA et al. (1998), 0.23 by HINTZ (1980), 0.11 and 0.09 for racing distances of 1200 m and 1800 m by MORITSU et al. (1994). ARNASON (1999), OJALA (1987) and HINTZ (1980) also reported lower estimates for best racing times of Trotters. Relatively higher estimates of heritability for time traits found in the current study than those of literature estimates could be due to the lack of a systematic selection programme, which was based on accurate estimates of genetic parameters, for these traits for Thoroughbred horses in Turkey.

While estimates of heritability for time traits were medium to high, estimates for rank were low. Estimates of heritability for rank were similar to those reported by SAASTAMOINEN and OJALA (1991) and VILLELA et al. (2002). However, SOBCZYNSKA and KOWNACKI (1997) reported estimate of 0.25 for Polish purebred Arab horses.

Estimates of heritability obtained from the analysis of dirt track dataset were clearly higher than those of turf track for racing time and best racing time, whereas they were similar for rank. In contrast with the current study, estimates of heritability for racing time on dirt and turf tracks were reported to be similar by OKI et al. (1995).

Estimates of heritability for earning traits varied from low to medium in literature. OJALA (1987) reported estimates of 0.07 and 0.17 for earnings, 0.19 and 0.12 for log earnings, 0.13 and 0.25 for EPS and 0.22 and 0.16 for log EPS of Finnish and Standardbred horses, respectively. ARNASON (1999) estimated heritability to be 0.36 for earnings and 0.23 for EPS of Swedish Standardbred Trotters. BUGISLAUS et al. (2004) found a heritability of 0.097 for Log of earnings of German thoroughbreds. SOBCZYNSKA and KOWNACKI (1997) also reported estimates to be low (0.22) for log annual earnings of Polish purebred Arab horses. Estimates of heritability obtained in the current study for earning traits were within the range of literature estimates summarised above. However, HINTZ (1980) reported relatively higher estimates for log earnings of Thoroughbred horses (0.49) and Trotters (0.41). Estimate of heritability for EPS (0.291) was higher than that of annual earnings (0.194). OJALA (1987) also reported that transformations applied to earning traits increased the heritability estimates.

Estimates of repeatability for racing time in the current study were in agree with those of BUTTRAM et al. (1989), who reported estimates of 0.32 for Quarter horses and GROSU et al. (2000), who reported estimates of 0.29 for Romanian Trotters. However, current estimates were lower than those of VILLELA et al. (2002) for Quarter horses, SAASTAMOINEN and OJALA (1991) for Trotters and OKI et al. (1995) for

Thoroughbred horses. The repeatability estimates for final rank were lower than 0.44 reported for Quarter horses (VILLELA et al., 2002), 0.29 reported for Trotters (SAASTAMOINEN and OJALA, 1991) and 0.25 reported for Polish Purebred Arab horses (SOBCZYNSKA and KOWNACKI, 1997).

Permanent environmental effects on racing performance may include such factors as early nutrition, injury, owner and trainer (BUTTRAM et al., 1989). In the current study, estimates of pe^2 for time traits were lower than those of rank and earning traits, except log EPS. These results do not agree with the results of VILLELA et al. (2002), who reported higher estimates for racing time.

According to the results of the current study, the lowest heritability was estimated for rank. Annual earnings and log earnings have also lower estimates compared with time traits, EPS and log EPS. Best racing time has yielded the highest estimates of heritability. Furthermore, time traits have nearly normal distribution and are a better quantitative measure for statistical analysis than earning traits that differ greatly from a normal distribution. These facts suggest that best racing time is the most appropriate trait among that investigated in the current study, and selection for this trait might result in more genetic improvement than other traits.

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