Use of individual race results in the estimation of genetic parameters of trotting performance for Finnhorse and Standardbred trotters

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The heritability and repeatability for trotting performance traits were estimated from individual race results. Data comprised of records from 1991 to 1995 for 4808 Finnhorses and from 1993 to 1995 for 5869 Standardbred trotters. The statistical model included the additive genetic effect of an animal and two permanent environmental effects, and the fixed effects of sex, age, starting method*starting lane combination, driver and race. The first permanent environmental effect described repeatability over a horse's career while the second one characterized repeatability within a racing year. Variance components for three trotting performance traits were estimated by the animal model and the method of restricted maximum likelihood (REML). Heritability and repeatability estimates were moderately high for time at finish (h^2 =0.23–0.28 and r=0.50–0.57), moderate for ranking within a race (h^2 =0.12 and r=0.25) and low for earnings (h^2=0.05–0.09 and r=0.15–0.18). Time at finish seemed to be the most usable measure of trotting performance because of its wide information substance. However, time at finish does not take into account records of disqualified horses or of those which did not finish, but use of earnings, either from individual race results or preferably from annual records, is one possible way to consider records of such horses.

Key words: animal model, best linear unbiased prediction, heritability, racing performance, repeatability, trotting horses

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Introduction

The Finnish Trotting and Horse Breeding Association (Suomen Hippos r.y.) is planning to change the breeding value estimation for trotting horses from a selection index method to the BLUP (Best Linear Unbiased Prediction) -methodology. Presently, breeding value estimation of trotters in Finland is based on annually summarized race records and the selection index method which does not completely take into account information on relatives. Therefore, indices based on performance of an individual and its progeny are calculated separately. Use of animal model BLUP, which has become a standard method for genetic evaluation of all major domestic animal species, allows all known relationships to be potentially accounted for, such that environmental effects and breeding values for animals can be estimated simultaneously.

In many countries the breeding value estimation of trotters is based on annually summarized race records either from individual age classes or pooled career records. Traits, such as best annual racing time, earnings, number of first placings, number of first to third placings and number of disqualified races are utilized to indirectly describe the performance of a horse for each considered year. The most common factors affecting annual records are sex, age, racing or birth year and country of birth (e.g. Ojala and Hellman 1987, Katona and Distl 1989, Minkema 1989). Several other factors that have an effect on individual race events, such as driver or starting lane are assumed to level out.

The main disadvantage of using annual records is that all available information, e.g. level of a race, trainer, driver or race track, can not be utilized since they may change from race to race. Such effects may level out when breeding value estimation of sires with a large number of offspring is considered. However, for individual horses with a limited number of races and with few or no offspring they can have a substantial impact. In a few studies individual race records have been used as a basis of breeding value esti-

mation and the factors affecting single race events have been taken into account. Nevertheless, comparison of horses in these studies has still been conducted indirectly. In German data (Distl et al. 1982) each single racing time was pre-adjusted for the effects of race track, track condition, starting method and distance; the averages of adjusted racing times were subsequently used in the final analyses of separate age classes. Leroy et al. (1989) analysed the best life time of Belgian trotters by animal model from records corrected for the effects of sex, age, race track, date of birth, date of record, type of start and distance.

Yet another possible approach would be to employ individual race results and to compare horses directly within the same race, as happens in practice, by subsuming into the statistical model a factor common to all horses in the race. This would make better use of all the information available: level of the race, driver, trainer, starting method and lane, resulting in a more accurate statistical model. Use of individual race results would allow breeding value estimation in a natural manner that is feasible whenever needed. Moreover, operating with individual results and comparing horses directly against each other may also reduce the number of traits required for evaluation.

The purpose of this study was to define a statistical model and quantify genetic and non-genetic variation in trotting performance traits utilizing individual race results and the animal model. Our aim was also to gain experience on the traits derived from individual race results; the importance of the different traits is discussed.

Material and methods

In Finland, individual race results have been recorded by The Finnish Trotting and Horse Breeding Association since 1984. Data was extracted from the database, which contains individual race results of 14 000 Finnhorses and 21 000

Table 1. Number of horses raced in each age class.

Age-class		Finnhorse				Standardbred trotter		
		Males	Females	Total		Males	Females	Total
1	4-year-olds	628	392	1020	3-year-olds	756	695	1451
2	5-year-olds	1067	728	1795	4-year-olds	1231	1215	2446
3	6-year-olds	1150	769	1919	5-year-olds	1201	1171	2372
4	7-year-olds	1145	695	1840	6-year-olds	930	812	1742
5	≥8 year-olds	1470	843	2313	≥7 year-olds	878	716	1594

Table 2. Average number of observations per horse in two data sets. Number of horses raced in each year is given in parenthesis.

	Finnhorse			Standardbred trotter		
	Males	Females	Total	Males	Females	Total
1991	7.8 (1539)	6.8 (836)	7.4 (2375)			
1992	8.2 (1453)	7.0 (800)	7.7 (2253)			
1993	8.1 (1379)	7.3 (824)	7.8 (2203)	8.5 (1783)	7.9 (1592)	8.2 (3375)
1994	7.7 (1291)	7.0 (754)	7.4 (2045)	8.2 (1736)	7.5 (1563)	7.9 (3299)
1995	7.3 (1247)	6.4 (794)	7.0 (2041)	7.1 (1892)	6.7 (1693)	6.9 (3585)

Table 3. Structure of pedigree information.

Number of progeny	Finnhorse				Standardbred trotter			
	Sires		Dams		Sires		Dams	
1	172	(40%)	1810	(61%)	208	(38%)	2319	(63%)
2–5	131	(30%)	1139	(38%)	157	(29%)	1316	(36%)
6–15	63	(14%)	17	(1%)	90	(16%)	21	(1%)
16–50	43	(10%)			67	(12%)		
51–100	16	(4%)			14	(3%)		
101–	8	(2%)			11	(2%)		
Total	433		2966		547		3656	

Standardbred trotters with large pedigrees and will be used in prospective BLUP-evaluations. For variance component estimation different data sets were utilized for two breeds: between 1991–1995 for Finnhorses and 1993–1995 for Standardbred trotters. Due to computational limitations, data sets included race results from nine major race tracks in southern Finland. Race records from minor tracks were excluded. Also, races in which the number of trotters was less than six were deleted to ensure big enough comparison groups. This resulted in 81 643 individual race results of 4808 Finnhorse trotters (2899 males and 1909 females) and 78 455 individual race results of 5869 Standardbred trotters (3003 males and 2866 females). Characteristics of the data are presented in Tables 1 and 2. Finnhorse trotters had 433 sires with an average of 11.1 offspring and 2966 dams with an average of 1.6 offspring. The number of Standardbred sires was 547, having on average 10.7 offspring and the number of dams was 3656 with an average of 1.6 offspring. Distribution of the number of offspring is presented in Table 3. When known, pedigree information from minimum of three generations (the animal, its parents and grand-

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Table 4. Classification of driver, driver distribution and driver solutions from the mixed model equations for time at finish in Finnhorse and Standardbred trotter data.

Class	Starts/driver	Finnhorse data		Standardbred trotter data	
		Number of drivers	Solution	Number of drivers	Solution
1	≤5	655 (31%)	0	678 (37%)	0
2	6–15	406 (19%)	–1.84	408 (22%)	–0.71
3	16–30	335 (16%)	–2.36	249 (13%)	–1.02
4	31–50	251 (12%)	–2.64	153 (8%)	–1.39
5	51–100	237 (11%)	–2.95	168 (9%)	–1.45
6	101–500	203 (9%)	–3.46	162 (9%)	–1.80
7	≥500	46 (2%)	–3.85	43 (2%)	–2.25
Total		2133		1861	

parents) was used in the construction of the additive relationship matrix. The pedigree files consisted of 4674 Finnhorse trotters and 6930 Standardbred trotters which did not have a race result of their own in the data set.

To rank horses, individual race results can be used in at least three different ways. Candidate traits analysed were total time at finish, earnings (processed as a fourth root transformation of earnings) and ranking within a race. Horses that did not finish (DNF) or that were disqualified had an observation for earnings, but not for time at finish nor ranking.

The following univariate model for each trait was assumed:

$$y_{ijklmnop} = sex_i + age_j + lane_k + dri_l + race_m + a_n + pe1_n + pe2_{no} + e_{ijklmnop}$$

where $y_{ijklmnop}$ is trotting performance trait (time at finish (s), earnings or ranking within a race); sex_i is the fixed effect of sex, i=1–2; age_j is the fixed effect of age class, j=1–5; $lane_k$ is the fixed effect of starting method*starting lane-subclass, k=1–61 for Finnhorse and k=1–51 for Standardbred trotter; dri_l is the fixed effect of driver class, l=1–7; $race_m$ is the fixed effect of race, m=1–6516 for Finnhorse and m=1–6453 for Standardbred trotter; a_n is the random additive genetic effect of an animal, normally and independently distributed (NID) (0, σ^2_a); $pe1_n$ is the random effect of permanent environment of an animal over the whole racing career, NID (0, σ^2_{pe1});

$pe2_{no}$ is the random effect of permanent environment of an animal within a year, NID (0, σ^2_{pe2}), and $e_{ijklmnop}$ is random residual error, NID (0, σ^2_e).

The age effect was classified into one-year-periods so that 4-, 5-, 6-, 7- and ≥8-year-old Finnhorses and 3-, 4-, 5-, 6- and ≥7-year-old Standardbred trotters established five classes within two breeds. Results of the horses from the youngest age classes (three-year-old Finnhorses and two-year-old Standardbred trotters) were excluded from the variance component estimation due to the scarcity of such observations. Starting method*starting lane effect was a combination of two starting methods (auto versus volt start) each with the starting lanes. Auto start destines a start behind a car (flying start) and volt start is known as handicap race. Starting lanes in the two starting methods differ according to trotting race regulations; therefore, starting method and lane had to be taken into account together. We renumbered starting lanes so that lanes from 1 to 12 of each volting group had the following codes: lanes in the first volting group coded 1–12, lanes in the second volting group coded 21–32, lanes in the third volting group coded 41–52, and so on. The auto start included only lanes 1–12. For Finnhorses, 35% of the races were auto and 65% volt starts. Corresponding values for Standardbred trotters were 52% and 48%, respectively. The driver effect was divided into seven classes according to the number of starts of each driver (Table 4). The race effect was a com-

bination of race track, date of race and race number.

Variance components were estimated with animal model and restricted maximum likelihood (REML) method using the AI (average information) algorithm (Johnson and Thompson 1995). Analyses were conducted within the DMU package (Jensen and Madsen 1994).

Results and discussion

Fixed effect solutions

Male horses were superior to females, but the magnitude of difference in time at finish between the sexes was larger for the Finnhorse (1.0 s) than for the Standardbred trotter (0.5 s). However, based on earnings and ranking within a race, differences between sexes were greater for Standardbred trotters. For time at finish, older Finnhorses were faster than the younger ones with diminishing superiority by age. Similar results of sex and age effects have been reported in several studies (Rönningen 1975, Katona and Osterkorn 1977, Ojala 1982, Physick-Sheard 1986, Ojala and Hellman 1987). In contrast, for Standardbred trotters the 4-year-olds were the best, while the oldest horses (≥7-year-olds) had the slowest times. For each breed, both in terms of earnings and ranking within a race, the youngest age classes were more successful than older ones (Fig. 1). For earnings, one reason for the superiority of the youngest horses could be differences in prize level, since young trotters compete in races with the biggest prizes. Ranking within a race should behave as time at finish, and therefore the superiority of the young horses is difficult to reconcile. However, the small size of data sets did affect the results; when observing fixed effect solutions from larger data sets used for breeding value estimation, the solutions were slightly different though the general tendency remained the same.

In both breeds, the starting method*starting lane subclass affected these three traits in a similar manner. The effect of the starting lane for the time at finish in auto and volt start for Finnhorse trotters is presented in Fig. 2. For the auto start, the difference between the best and worst lanes was 0.5 s while for the volt start, the difference between the best and worst lanes was 1.7 s (in first volting group). In the two starting methods it can be seen that horses which started on inside lanes performed better than those starting on outside lanes. Generally, for the volt start horses in the sixth and seventh lanes are assumed to have an advantage, because as a result of trotting regulations they have a special position in volting system and can therefore carry more speed at the start line. Our study does not support this argument (see Fig. 2.). This can be caused by the fact that not all drivers nor horses are able to exploit this opportunity at the start of a race.

In the two breeds, the effect of a driver was significant: increased driving experience, assessed as an increase in the number of starts per driver, was associated with greater racing success (Table 4). Logically the effects of trainer and driver are random, and a statistical model in which the driver effect was assumed random was also tested. However, this approach inflated the variance parameter estimates due to the confounding effects of driver, additive genetic and permanent environment, since the best horses are more likely to be assigned to professional drivers and trainers. Furthermore, several horses are driven only by one driver, and therefore the effects of driver and permanent environment are difficult to distinguish. Consequently, in the final model the effect of a driver was described through a classified fixed factor based on driver experience. Information of the trainer was not available in the database, and therefore could not be included in the model. As a result, the effects of trainer and management have probably to some extent influenced the variance components for breeding value and permanent environment.
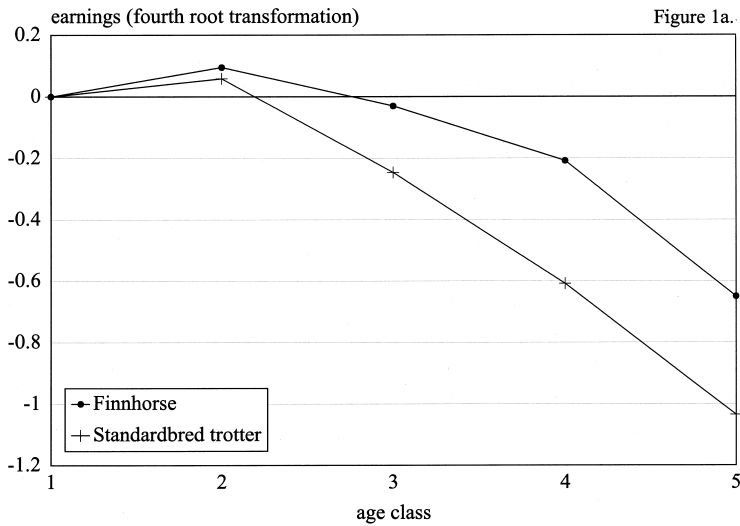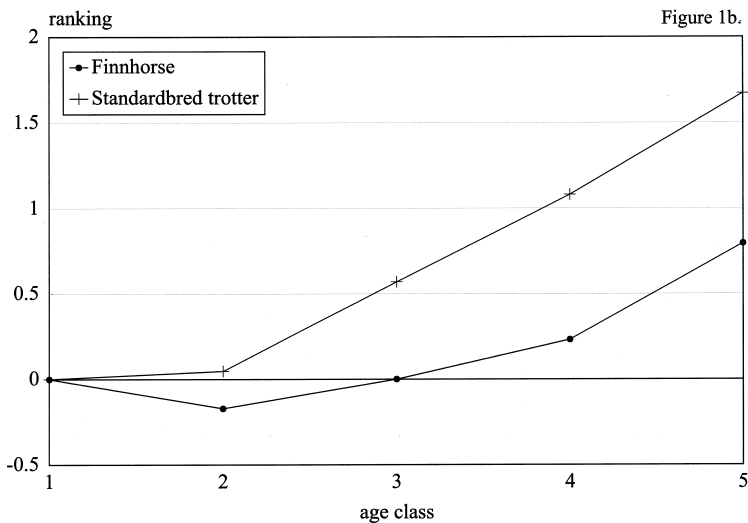
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earnings (fourth root transformation)   Figure 1a.

age class

ranking   Figure 1b.

age class

Fig. 1. The effect of age on earnings (1a) and ranking within a race (1b).

Heritabilities and repeatabilities

Heritability and repeatability estimates for the three traits were of same magnitude for the two breeds, indicating a moderately high genetic variation for the time at finish and low genetic variation for earnings and ranking within a race (Table 5). Higher heritability estimates for the time at finish is likely to reflect the amount of

information for a trait. Time at finish is a comprehensive measure of racing success. Even though racing time is of no importance itself, it contains information on both the order between horses and distances between them within a race, while ranking within a race provides only information of the order in ordinal scale. Earnings is likely to be the least complete measure of trotting performance, since it wastes information due
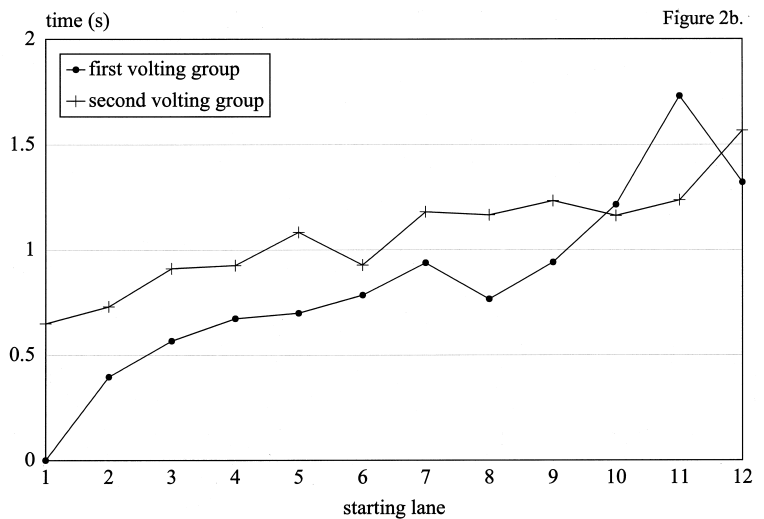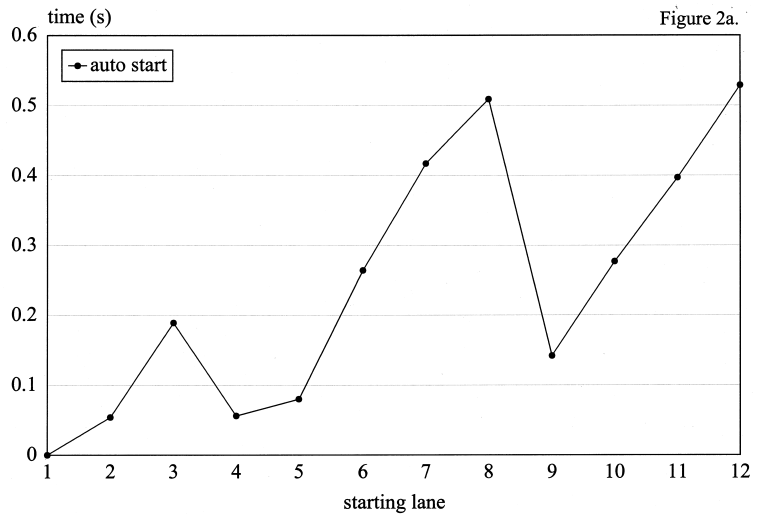
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Fig. 2. The effect of starting method*starting lane on time at finish in auto (2a) and volt starts (2b) for the Finnhorse.

to setting all the horses with zero earnings in a race equal. On the other hand, it indirectly carries information about the records of DNF and disqualified horses. However, annually summarized earnings might be more appropriate, because it follows better normal distribution (after transformation) and makes possible to integrate the results from abroad which is not possible when utilizing individual race results.

The repeated records of a horse are mutually correlated within the career of a horse. However, time interval between the first and last race of a horses's career can be long, and therefore associations between records at the beginning and end of a career are likely to be weaker than associations within a racing year. Therefore, a second permanent environmental effect was fitted to the model to describe the covariance struc-

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Table 5. Estimates of variance components, heritabilities (h^2) and repeatabilities for time at finish, earnings and ranking within a race.

	Trait	Variance components				Genetic parameters		
		animal	pe1	pe2	residual	h^2	r1	r2
Finnhorse	Time at finish	5.88	8.48	3.58	7.46	0.23	0.57	0.71
	Earnings	0.42	0.77	0.60	5.97	0.05	0.15	0.23
	Ranking	1.42	1.60	1.24	7.64	0.12	0.25	0.36
Standardbred trotter	Time at finish	2.05	1.69	0.63	3.08	0.28	0.50	0.59
	Earnings	0.65	0.71	0.37	5.86	0.09	0.18	0.23
	Ranking	1.41	1.56	0.72	8.25	0.12	0.25	0.31

pe1 = permanent environmental effect over whole racing career
pe2 = permanent environmental effect within a year
r1 = repeatability over whole racing career
r2 = repeatability within a year

Table 6. Estimates of variance components for time at finish. In model 1, the non-genetic animal effect is modelled by within racing year and across racing years permanent environment. For model 2 the permanent environmental effect within racing year is excluded.

	Variance			
	Additive	pe1	pe2	Residual
Finnhorse				
model 1	5.88 (23%)	8.48 (33%)	3.58 (14%)	7.46 (29%)
model 2	5.00 (21%)	9.70 (41%)		8.85 (38%)
Standardbred trotter				
model 1	2.05 (28%)	1.69 (23%)	0.63 (8%)	3.08 (41%)
model 2	1.93 (27%)	2.03 (28%)		3.31 (46%)

pe1 = permanent environmental effect over whole racing career
pe2 = permanent environmental effect within a year

ture between records within a year. As expected, estimates of repeatability within a year were distinctly higher than repeatability over the entire career. To validate the assumption of two separate permanent environmental effects a simplified model was fitted without the within racing year animal effect pe2 (Table 6). Two permanent environmental effects accounted for more variation than only one permanent environmental effect, resulting in a smaller residual variance. The influence was more obvious with Finnhorse data which is probably due to evaluation of data collected over a longer period of time and the longer racing career of Finnhorse trotters. Pösö (1993) reported an average racing career length of 3.5 years for Finnhorses and 2.6 years for Standardbred trotters.

In earlier studies concerning individual race records, trait definitions and statistical models have differed from those in this study. Katona and Osterkorn (1977) ascertained that racing time is influenced by race track, track condition and starting method, and reported a heritability of adjusted racing time for 2–10 year-old horses of 0.20, while Katona and Distl (1989) found a heritability estimate for average racing time of 0.35. For Finnhorse trotters, Ojala and Van Vleck (1981) calculated repeatabilities at specific ages

from single records of a horse. Repeatability estimates varied for time at finish from 0.61 to 0.74, for prize money 0.18–0.28 and for rank at finish 0.14–0.42. Klemetsdal (1989) utilized precorrected results from single races; his heritability estimates for average racing time were similar in magnitude to time at finish in this study, varying from 0.17 to 0.19 for the Norwegian trotter (a so-called cold-blooded breed type as is the Finnhorse). However, heritability estimates for Standardbred trotters were close to zero (0.01–0.04). Compared to summarized records, our heritability estimates were somewhat lower than those reported for best racing time and earnings calculated from repeated annual records (Tavernier 1989, Pösö and Ojala 1997). Part of this difference comes from the statistical nature of the traits defined. The best annual time and the annual earnings clearly summarise the information of the individual race records, and are therefore expected to have higher heritabilities than the original observations. The best racing time is equal to the individual race record if the horse has only raced once, but will diverge to a biologically different trait when more records in a year are accumulated. Also, one must bear in mind that when analyzing total time at finish and having a fixed race effect in the model, in fact, observations become deviations from the winning time. This results in the trait resembling a general ranking than a time based trait.

One problem with the analysis of individual race records is that of results of horses that are either disqualified or do not finish. The propor-

tion of the results of such horses was 15% and 10% in Finnhorse and Standardbred trotter data, respectively. Disqualifications and not finishing a race may be caused by conformation faults or a horse's character and temperament. Neglecting these records may lead to an overestimation of breeding values for those horses that are often disqualified but that do well when they finish a race. Therefore, when analysing time at finish and ranking within a race, we tested an approach where missing observations were replaced by pseudo records created by adding one second to the time of the last horse and one rank to the last placing in corresponding race. However, because the majority of disqualified and DNF observations occurred in the first volting group, this resulted in a situation where starting lane solutions in later volting groups became better than those in the first volting group. A more appropriate way to deal with this kind of selection bias would be the use of both time at finish and earnings in breeding value estimation, or to develop a multitrait evaluation where the time at finish is evaluated simultaneously with DNF status.

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SELOSTUS

Ravikilpailumenestysmittojen periytymisasteet ja toistumiskertoimet kilpailukohtaisten tulosten perusteella

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Vuonna 1996 käynnistyneen projektin tarkoituksena oli kehittää eläinmalli-BLUP -menetelmään perustuva ravihevosten jalostusarvostelusysteemi. Lähtökohtana oli kilpailukohtaisten tulosten tarjoama mahdollisuus määritellä entistä tarkempi tuloksia kuvaava tilastollinen malli, jonka avulla hevosia pystytään vertaamaan kilpailukohtaisesti. Ensisijaisena vertailuryhmänä olisivat kaikki samaan lähtöön osallistuvat hevoset, eli ne, joita vastaan hevonen kilpailee.

Tutkimuksessa määritettiin tilastollinen malli ja perinnölliset tunnusluvut kilpailukohtaisille tuloksille. Tarkastelun kohteena oli kolme ravikilpailumenestystä mittaavaa tekijää: kokonaisaika, sijoitus ja voittosumma. Analyyseissä olivat mukana tulokset Vermon keskusradalta ja Etelä-Suomen maakuntaradoilta. Suomenhevosten osalta aineisto (SH) käsitti vuodet 1991–1995 ja sisälsi 81 643 kilpailukohtaista tulosta 4808 eläimeltä. Lämminveristen hevosten aineisto (LV) jouduttiin laskentateknisistä syistä rajaamaan vuosiin 1993–1995, käsittäen 74 855 tulosta 5869 eläimeltä. Sukulaisuudet otettiin huomioon kolmen sukupolven ajalta.

Käyttökelpoisen tilastollisen mallin todettiin sisältävän seuraavat kiinteät ympäristötekijät: sukupuoli, ikä, ohjastaja, lähetystapa-lähtörata ja lähtö. Ohjastajan vaikutus oletettiin kiinteäksi, ajokokemuksen mukaan luokitelluksi tekijäksi. Ohjastajaa testattiin myös satunnaistekijänä; tällöin mallin avulla oli kuitenkin vaikea erottaa ohjastajan ja pysyvän ympäristötekijän vaikutukset toisistaan. Lähetystapa ja lähtörata yhdistettiin yhdeksi tekijäksi, koska auto- ja tasoituslähdöittäin lähtöratojen ratkaisut olivat erilai-

set. Kiinteä lähtötekijä, joka koostui päivämäärästä, raviradasta ja lähdön numerosta, johtaa eläinten vertailuun kunkin lähdön sisällä, jolloin erillistä juostavan matkan pituutta kuvaavaa tekijää ei tarvittu. Lisäksi tilastollinen malli sisälsi eläimen jalostusarvoa kuvaavan termin sekä eläimen ei-perinnöllistä vaikutusta kuvaavan tekijän. Tämä ns. pysyvä ympäristötekijä jaettiin kahteen osaan: ensimmäinen kuvaa kilpailutulosten toistuvuutta hevosen koko uran ajalta, toinen kunkin kilpailuvuoden sisällä. Kun pysyvä ympäristötekijä jaettiin kahteen eri osaan, mallin selitysaste parani.

Molemmilla roduilla kokonaisajan (SH h^2=0,23 LV h^2=0,28), sijoituksen (SH ja LV h^2=0,12) ja voittosumman (SH h^2=0,05 ja LV h^2=0,09) periytymisasteet vaihtelivat alhaisesta kohtalaiseen. Kokonaisaikaa voidaan pitää monipuolisimpana kilpailumenestyksen mittana, koska se kertoo sekä hevosten järjestyksen että niiden väliset erot. Sijoitus kertoo ainoastaan hevosten järjestyksen, kun taas voittosumma asettaa samanarvoisiksi kaikki ne hevoset, jotka eivät ole saaneet rahapalkintoja. Toisaalta hylättyjen ja keskeyttäneiden hevosten huomioiminen jalostusarvostelussa on tärkeää, sillä niiden huomiotta jättäminen vääristää jalostusarvoja. Eräs ratkaisuvaihtoehto olisi kokonaisajan ja voittosumman käyttäminen samanaikaisesti jalostusarvostelussa.