Heritability of jumping ability and height of pony breeds in France

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Abstract

Heritability of jumping ability in competition and height were calculated in three breeds of ponies: Poney Francais de Selle (PFS), Connemara (CO) and New-Forest (NF). Results from 1996 to 1999 were used: 2295867 ranks in 64880 events of which 261077 were in specific pony competitions. A bi-variate analysis was performed for rank and height within each breed separately, i.e. on 2688 (PFS), 2014 (CO) and 671 (NF) ponies. Other results were used as comparison to estimate the level of the event. Ranks were analysed on the relative placing of an underlying performance. Two models were applied: with and without an effect of the height of the pony category. Estimated heritabilities of height were 0.72 (PFS), 0.47 (CO) and 0.34 (NF). Estimated heritabilities of the underlying variable responsible for ranks were 0.05 and 0.06(PFS), 0.10 and 0.13(CO), 0.19 and 0.16 (NF), respectively, for the two models. Effect of height represented a quarter of phenotypic deviation between adjacent categories. Estimated genetic correlations were 0.20 and 0.12 (PFS), 0.16 and 0.13 (CO), 0.11 and 0.07 (NF), respectively, for the two models. This suggests an important effect of size on the overall competitive ability of ponies but not for each breed in a homogeneous height category.

Keywords : horse, pony, heritability, jumping, rank, height

1. Introduction

Jumping competition has been studied in several countries for riding horse breeds. Ponies have been also studied but only to improve their conformation and gait for the standard of the breed. Specific competitions for ponies have been developed in France for many years and the economics of leisure activity for children are important. From an international viewpoint, the market of good ponies is expanding. Performance of horses in jumping competition seems to have a moderate heritability. For event per event criteria based on ranking, earnings or points allocated to ranking, heritability reaches 0.10 - 0.15 in several different countries (Ricard et al, 2000). With annual criteria such as log(annual earnings) or log(annual earning/places) which summarize the results on the year, heritability is higher : for example, 0.21 - 0.33 in France (Tavernier, 1992). In ponies, the variability of phenotypic performance is large because very small ponies (near 1m) and large ponies (maximum 1.48m) participate in competitions. The aims of this study are to calculate the heritability of jumping ability for ponies in France and to define the relationship between this ability and height in order to improve jumping ability in the population.

2. Materials and Methods

2.1 Material

Results of each event in pony competitions are available since 1996. As some ponies also participated to horse competition, the entire data of jumping competitions (horse and ponies) from 1996 to 1999 were used in analysis. These data represented 2295867 results (ranks in each event) performed by 73689 horses and ponies in 64880 different events. The mean number of starters per event is 35.4, the minimum 2 and maximum

304. The specific pony competition represented 261077 starts (11% of the whole), 18580 events, and the mean of number of starters per event is 14.1. Details of jumping competitions are shown in Tables 1 and 2.

The number of ponies which participated in at least one specific jumping competition for ponies was 13725. A large number of these ponies had no known parents (4409, i.e. 32%). In the remainder, the major breeds were: Poney Français de Selle (PFS), Connemara, Welsh, New Forest, and crosses between these breeds and unknown breed (called crossed ponies, CP). This left 16% horses from a lot of different small breeds. The PFS is a crossed breed from known breeds (PFS, pure breed Arabian, Connemara, New Forest, Welsh etc.). Connemara, Welsh and New Forest are pure breed from Great Britain and Ireland.

Height defines the rules of category of competition in which the pony is authorized to participate. Five classes of height are defined: (A) smaller than 107 cm, (B) from 108 to 130 cm, (C) from 131 to 140 cm, (D) from 141 to 148 cm and (E) above 149 cm (with children riders). The pony is authorized to participate in competition of its category of height or of the category above (a “C” pony can compete in a “D” competition). There are also “open” competition for all classes of ponies (B+C+D). So, height has considerable influence on jumping results. The two traits, ranking in competition and height have been studied together. The height of ponies was registered when they participate in competition or for breeding purpose (generally at 3 or 4 years old). This measure was not very accurate because it is declared by the owner of the pony in most cases, except for international or high level competition and for stallions. Elementary statistics on height of major breeds used in jumping competition are shown in Table 3.

Genetic parameters were estimated in each breed separately. Only breeds used in jumping with stud-book were analysed: PFS, Connemara, Welsh and New Forest. As an animal model is not suitable for discrete variable and, in our case, for ranking, a sire model was applied and then only sires with five offspring or more with ranking were kept in the analysis. All progeny with height from these sires were included. Number of ponies used in each analysis is shown in Table 4.

2.2 Method

In competition for ponies (and children), there are no winnings for the owner of the pony. The only result is the rank of the pony in the event. No points or metric measures were allocated to the ranks. An underlying physical performance was assumed and ranks were the relative placings of each horse in the event. The model used for the underlying performance was:

$$\boldsymbol{y} = \boldsymbol{Xb} + \boldsymbol{Zs} + \boldsymbol{Zc} + \boldsymbol{e}$$

where $\boldsymbol{y}$ was the vector of underlying performance responsible for ranks, $\boldsymbol{b}$ was the vector of fixed effects, $\boldsymbol{s}$ was the vector of sire effects, $\boldsymbol{c}$ was the vector of effects common to the different performances of the same horse, $\boldsymbol{e}$ was the vector of residuals, $\boldsymbol{X}$ and $\boldsymbol{Z}$ were design matrices.

The fixed effects were the followings:

-Age effect from 4 to 15 years and more in steps of 1 year (different effects for ponies and horses)

-Sex effect (two classes : males and geldings combined, females)

-Month of birth (January and February, March, April, May, June, July to December, Unknown)

-Height of the pony in 4 classes (A : ≤107 cm, B : 108-130cm, C : 131-140 cm, D : 141-148 cm). This effect is not the effect of the category of competition. This effect is estimable only in competition with ponies of different height (for example in a "D" competition with ponies D and C who want to perform in a high level or in open competition with ponies D, C and B)

The latter effect has been included or not according to the definition of the underlying trait: ability for jumping within ponies of the same height or absolute ability for jumping. The effect of the event (or category of competition) was not necessary because the likelihood compares all the ponies in the event and then uses differences between the values of the ponies. With that likelihood, level of the event was measured by the differences in the ability of each pony in the event ; heterogeneities of variances according to the rank of the pony and the number of starters in each event were also taken into account.

The model for height was the following.

$$\boldsymbol{\psi} = \boldsymbol{X\beta} + \boldsymbol{Z\theta} + \boldsymbol{Z\omega} + \boldsymbol{\varepsilon}$$

with $\boldsymbol{\psi}$ the vector of heights of ponies, $\boldsymbol{\beta}$ the vector of fixed effects, $\boldsymbol{\theta}$ the vector of sires effects for height, $\boldsymbol{\omega}$ the vector of residuals correlated to the effects common to the different performances in jumping of the same horse and $\boldsymbol{\varepsilon}$ the uncorrelated residuals. Actually, to estimate covariance between the two traits, the residual of height must be divided in two parts: one that explains correlation with every ranking of the pony, one that is not correlated to ranking.

Fixed effects were:

-Region of birth (19 levels)

-Month of birth (January to March, April, May, June, July to December)

-Sex (male, female, geldings)

-Age of the mother (unknown, 3 years, 4 and 5 years, 6 years and more)

-Parity (unknown, from1 to 8 and more in steps of 1)

-Year of birth (from 1980 and before to 1996)

-Breed of the mother for analysis of crossed breed only. For the study of PFS there were mares with known height with three levels :B, C, D and mares of unknown height with level according to the breed: Connemara, PFS, Landais and Welsh cob, New forest, Pottok and Welsh A, Welsh B, crossed ponies, unknown parents ponies, group of Haflinger, highland, Merens, Welsh cob, foreign ponies, other breeds. For the study of Welsh there were five levels according to the sections of the studbook: WA, WB, WTC, WD, W. This effect tried to take into account maternal influence which can’t be estimated directly due to the low number of progeny per mares.

The two traits were studied in a binary trait model. Likelihood of ranking with the underlying model is the following:

$$P(y_{(1)} > y_{(2)} > \ldots > y_{(t)} > \ldots > y_{(n)}) = \int_{-\infty}^{+\infty} \int_{y_{(n)}}^{+\infty} \cdots \int_{y_{(t+1)}}^{+\infty} \cdots \int_{y_{(2)}}^{+\infty} \prod_{i=1}^{n} \varphi(y_{(i)} - \mu_{(i)}) dy_{(i)}$$

with (1)..(n) the ranks of ponies in the event, $y_{(t)}$ the underlying performance of the horses ranked *t*, φ the normal density, $\mu_{(i)}$ the location parameter of the horse ranked *(i)* (equal to fixed effects and random effects). Further explanations are in Tavernier (1991). Likelihood for height is a normal one. The joint posterior distribution is the product of likelihood and prior normal distributions.

Variance covariance matrices were the following:

$$V\begin{bmatrix} \boldsymbol{s} \\ \boldsymbol{c} \\ \boldsymbol{e} \\ \boldsymbol{\theta} \\ \boldsymbol{\omega} \\ \boldsymbol{\varepsilon} \end{bmatrix} = \begin{bmatrix} I\sigma_s^2 & 0 & 0 & I\sigma_{s\theta} & 0 & 0 \\ 0 & I\sigma_c^2 & 0 & 0 & I\sigma_{c\omega} & 0 \\ 0 & 0 & I\sigma_e^2 & 0 & 0 & 0 \\ I\sigma_{s\theta} & 0 & 0 & I\sigma_\theta^2 & 0 & 0 \\ 0 & I\sigma_{c\omega} & 0 & 0 & I\sigma_\omega^2 & 0 \\ 0 & 0 & 0 & 0 & 0 & I\sigma_\varepsilon^2 \end{bmatrix}$$

For underlying variable responsible for ranks, no physical measure is available and residual variance was fixed to 1. So heritability was defined as:

$$h_y^2 = \frac{4\sigma_s^2}{\sigma_s^2 + \sigma_c^2 + 1} \quad h_\psi^2 = \frac{4\sigma_\theta^2}{\sigma_\theta^2 + \sigma_\omega^2 + \sigma_\varepsilon^2}$$

Genetic correlation was :

$$r_{y,\psi}^a = \frac{\sigma_{s\theta}}{\sigma_s \sigma_\theta}$$

Phenotypic correlation was:

$$r_{y,\psi}^p = \frac{\sigma_{s\theta} + \sigma_{c\omega}}{\sqrt{\sigma_s^2 + \sigma_c^2 + 1}\sqrt{\sigma_\theta^2 + \sigma_\omega^2 + \sigma_\varepsilon^2}}$$

To estimate variance components, an iterative scheme similar to REML for normal variables was used. This scheme estimated the mode of the marginal posterior distribution of the variances (Gianola et al, 1986, Foulley et al, 1987). Details of calculations are given in Tavernier (1990, 1991).

The objective was to estimate heritability in only one breed at a time. However, it is not possible to take into account only results of ponies from each breed separately because estimation of each pony depends on the value of ponies in the same competition, and in competition all breeds are mixed. So the horse/pony effect (*s* + *c*) was estimated for all horses and ponies with the complete file (ponies and horses) and a given repeatability (correlation between two performances, $\frac{\sigma_s^2 + \sigma_c^2}{\sigma_s^2 + \sigma_c^2 + 1}$). Then, the estimations of the horses and ponies, which were not in the sample of the breed studied, were used as fixed parameters. They are used to calculate first and second derivatives of the likelihood for ponies in the sample. An E-M scheme is used to estimate variance-covariance matrices on the ponies in the sample. Then new variance-covariances were estimated. These new parameters gave new repeatability, which is re-used to estimate all horses and ponies. This scheme is used until the parameters converge. Computer programs were used for the calculations.

3. Results

3.1 Environmental effects

For the underlying variable responsible for ranking, the most important effects are age and height category. The month of birth effect has negligible influence and sex effect has moderate influence in favour of females (+0.7 point with a phenotypic standard deviation of 20). The age effect increases to a maximum around 8-14 years old and then there is a small negative influence of ageing (Figure 1). At 5 years old, a pony has a negative effect of a quarter of phenotypic standard deviation on performance and a 60% chance of being beaten by an older pony (all others parameters being equal). The effect of height is not well estimated for the first category: pony A (≤107cm) because these ponies did not participate in other levels of competition; neither "open" nor higher category competition. For the other categories, there was a sufficient number of ponies in open competition and in two different categories to allow relative estimation. Difference between ponies B and C represents six points with a phenotypic standard deviation of 20 and between C and D 4 points (Figure 2). A pony in category B has a 67% chance of being beaten by a D pony and a C pony had 57% chance of being beaten by a D pony (all other parameters being equal).

On height at withers, the most important environmental effect is the breed of the mother ; other effects have often a less than 1cm and maximum 2cm effect. For example, for the study of Welsh ponies, the effect of a mare in the D category is +7.9 cm and the effect of a mare in the category A section is –3.4 cm for a phenotypic standard deviation of 4.8. For PFS, Connemara and measured D mares have a favourable effect (+2.3 and +2.7cm, respectively) versus negative effect of measured C mares and Welsh B ponies (-0.8 and –3.2cm, respectively). The effect of month of birth is unfavourable for ponies born from July to December (about –2cm). Effect of sex is negative for females compared to male and geldings (-0.8 cm for PFS and Connemara, -2.4 cm for New Forest). The effect of the age of the mother seems to tend negatively for young mares (3 years) but it depended of the breed (-2.5 cm for Connemara, -0.6cm for PFS, -0.4cm for New Forest). Effect of parity increases with the number of foals, with perhaps a maximum before the sixth (about –1 cm for the first foal compared to the third one). Year of birth has low variations (≤1 cm) but with no trends (increasing or decreasing) in the opposite to positive phenotypic evolution in some breeds. In PFS, regression coefficient of year effect was 0.01 cm/year (r^2=0.02) and regression coefficient of height during the same period (from 1981 to 1996) was 0.07 cm/year (r^2=0.39) ; in Connemara respective regressions were 0.01 (r^2=0.00) and 0.03 cm/year (r^2=0.11) and in New Forest they were -0.06 (r^2=0.15) and 0.04 cm/year (r^2=0.14).

3.2 Heritability and correlations

In order to distinguish absolute and relative jumping ability in the corresponding height category, the results for the two analyses (with and without the category of pony) are reported in Table 5. Heritabilities have high variations according to the breed. Heritability of height in Welsh breed was higher than 1, even when the effect of height of the mares is included, so results are not presented in the table. Heritability of underlying variable responsible for ranks ranged from 0.05 to 0.19, heritability for height from 0.34 to 0.72. Genetic correlations between height and ranking ranged from 0.11 to 0.20 in the model with no correction for category and 0.07-0.13 in the model with correction. Phenotypic correlations are around 0.

No standard errors of estimates of variances and covariances were computed from the bi-variate model. In order to have a range of possible standard errors, standard errors of the heritability estimates of heigh were computed on a single-trait model. They were 0.07 for PFS, 0.06 for Connemara, and 0.11 for New-Forest.

4. Discussion

Heritability of height at withers has been studied in different breeds, but only the most recent studies with up-to-date methods are referenced here. A general review was performed by Saastamonein and Barrey (2000). Very different results are obtained which suggest that heritability of this trait depends strongly of the breed. Moderate heritability (around 0.30) was obtained in Bavarian warmblood horse (Von Butler, 1986), in another German warmblood horse (Von Butler and Krollikowsky, 1986), in Trakehner (Kaiser et al., 1991), and in Lipizzaner horses (Baban et al., 1998) ; medium heritability (0.50-0.60) was found in young thoroughbred (Hintz et al, 1978), Icelandic Toelter horses (Arnason, 1984), Bavarian heavy horse (Von Butler, 1987), Brasileira pony breed (Costa et al, 1998), Swedish warmblood horse (Gerber et al., 1997), and Andalusian horse (Molina et al, 1999) ; while high heritability (more than 0.70) are found in Shetland ponies (Van Bergen and Van Arendonk, 1993), Haflinger horse (Miglior et al, 1998), Finnhorse trotter (Saastamoinen et al, 1998), a German riding horse (Hartmann ret al, 1994), and in Norwegian trotter (Klemetsdal and Wallin, 1986). No systematic relation of the level of heritability with the mean height at withers of the population was found, but heritability was medium to high in breeds of ponies (or small horses). This is because there is a high variation in heritability for the different breeds in our analysis. Phenotypic variability of height in the populations of this study were higher than those in the literature. Mean standard deviation varied from 3 to 4cm in the literature compared to 4.1-8.7cm in this study. Major problems arise when breeds covers large interval of height as for Welsh ponies (four categories according to the type in the studbook) or for crossed ponies. This explains the difficulty in estimation of heritability, especially heritability higher than 1 with a sire model. In these breeds, two phenomena may occur. First, a large positive assortative mating occurs in these kind of breeds: 60% of matings between Welsh ponies concern Welsh of the same category (the 4 categories have following mean of height at withers: 120.6, 130.3, 135.0, 144.5). Even with the introduction of an effect for the category of the mare, the lack of a precise value for their height biases estimation of heritability. Second, as heritability varies from breed to breed, a different mechanism of genetic regulation of height may occur. So when analysing heritability of crossed breeds, the model is too simple to provide a good estimation of heritability. Obviously the purpose of the study is not to calculate heritability of height in all breeds of ponies in France but to understand the relationship between jumping results and height. Heritability of height at withers obtained for the three breeds (more or less pure breeds) is medium for Connemara and New Forest and high for PFS. Height at withers does not seem to be a breeding objective of Connemara which is a high pony with the majority in category D and with a mean height only 4.6 cm less than the maximum level authorized in international pony competitions (148 cm). In PFS, which is a rival breed of Connemara, the mean height is smaller (2cm less than Connemara) and so height may be a breeding objective and a phenotypic increase was observed during the period 1981 to 1988 (+0.25cm/year) followed by a levelling-off (-0.04cm/year). With high heritability it is easy to introduce or suppress height as the objective. There is no phenotypic evolution of height in New Forest which is a breed equally divided between C and D categories.

The influence of the mare on the height of the horse is often reported but in all literature cited, there is no introduction of maternal effect. In our study, the addition of a maternal effect, for example, a maternal grand sire effect, was too complicated and perhaps not easy to estimate with the few number of grand-offsprings by maternal grand sire. For example, in the larger breed PFS, there were 771 different maternal grand sires ; a mean of 3.4 grand sons by grand sires. By comparison, there were 144 sires to estimate heritability with 18.1 offsprings by sire. So, in order to take into account particularities of the mother, effects which are supposed to have the larger influence were added: parity and age of the mother.

Heritability of jumping ability in competition is measured either by cumulated measure (over year or all life) or measured in each competition for horses. In the first case, heritability is near 0.20 and 0.30. In France, heritability was 0.27 for the logarithm of annual earnings (Tavernier, 1992), in Ireland 0.32 for the logarithm of points allocated to rank and level of competition, and 0.18 for the logarithm of points divided per starts (

Foran et al., 1994), in Italy 0.15 for the logarithm of annual earnings (Silvestrelli et al, 1995), in Netherlands 0.19 for maximum level reached transformed into points (Koenen et al., 1995) and 0.23 for the same criterion for horses aged more than 7 years (van Veldhuizen, 1997). Obviously, for measurement in each competition heritability was smaller (0.10-0.15) but the trait showed a lot of repetition in the life of the horse. In France, for the underlying trait responsible for rank in horse jumping, heritability was 0.16 (Tavernier, 1994). In Germany, heritability of logarithm of earning in each placing is about 0.10 (Bruns and Schade, 1998, Reinhardt and Schmutz, 1997). In Ireland, heritability of normal score was 0.07-0.10 according to low or high level competition (Aldrigdge et al., 2000). In Belgium, heritability of normal scores was 0.11-0.19 without or with a rider effect (Janssens et al., 1997). Therefore, results on ponies are in agreement with these results for horses. Note, however, that heritability is lower for crossed breeds, perhaps because other genetic phenomena are involved. Even if heritability is rather low, selection could occur because in only one year, reliability (R^2_{TI}) of genetic estimation of a pony will be about 0.17 (PFS) to 0.41 (NF) according to heritability, repeatability, and a number of 10 starts per year per pony.

The relationship between height and jumping ability seems to be confused. There is a rather large effect of categories of height on jumping ability, i.e. half a phenotypic standard deviation between “B” and “D” category ponies, and there is a small genetic correlation between results in jumping competition and height (no more than 0.20). The effect of height category is estimated with accuracy as expected with the large number of ponies of different height categories in the same category of competition (Table 2). However correlation is obtained for each breed separately and in one breed there is not a large number of different categories. For example, in Connemara, 73% of ponies are D ponies and only 1% B ponies. So in each breed there is a small relationship between ability and height, even if the average height of the breed is important in the overall competition against other breeds. Height is important when large variability occurred but not in a homogenous category. So it is important to take this effect into account in estimating the level of the performance of the horse, especially in open and D competitions but it is not an important objective for a particular breed which must develop jumping ability within a small variability of height.

5. Conclusion

In conclusion, a practical breeding evaluation method must be chosen. According to the low genetic correlation, it would be easier to perform two different evaluations, one for height within each breed and one for ranking. So the different heritabilities and genetic models (crossed ponies) may be used for genetic evaluation on height. However, for ranking the problem is more complex. The use of all ponies is needed to measure jumping performances, whatever their breed and height, because the measure compares the ranking of ponies in each event. However according to the different genetic parameters, separate genetic evaluations may be preferable. Further investigation must be performed to choose between a single genetic evaluation with mean parameters or different genetic evaluation with equivalent performances obtained from the whole analysis. According to the low genetic correlation, it would be easier to perform two different evaluations, one for height within each breed and one for ranking with all breeds using average genetic parameters.

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Table 1

Elementary statistics on jumping competition for ponies from 1996 to 1999

	Number of starts	Number of events	Number of different horses	Starts/ Total (%)	Ponies/ Total (%)
Total jumping competition	2295867	64880	73689		
Specific ponies competition					
Young ponies	8762	1635	859	3	6
A	24852	1684	1548	10	11
B	35244	3872	2146	13	16
C	54702	4180	3366	21	25
D	88959	4771	5221	34	38
E	8417	955	1233	3	9
“Grand Prix”	1447	53	220	1	2
International	7726	272	192	3	1
Open (any ponies)	30968	1158	5634	12	41
Total	261077	18580	13725	100	149*
Ponies which participate in horse and pony competition	83706		2108		15

* One horse may participate in different categories: open categories for all ponies and categories of higher height.

Table 2

Separation of ponies according to category of competition and height

Height of ponies	Category of competition				
	A	B	C	D	Open
A (≤107cm)	1541	48	1	1	4
B (108-130 cm)	7*	2077	224	8	362
C (131-140 cm)	0	21*	3080	604	1990
D (141-148 cm)	0	0	61*	4587	2841
E (≥149 cm)	0	0	0	21*	437

*These horses competed in a category which were not allowed for the height

Table 3

Elementary statistics on height of the major breeds used in jumping competition.

	PFS*	Connemara	Welsh	New Forest
Number of ponies registered with height	3933	2790	1569	1382
Mean	141.4	143.4	133.3	139.8
Standard deviation	5.6	4.1	8.7	5.1
Minimum	100	124	107	120
Maximum	160	160	155	154
Skewness	-0.9801	-0.8639	-0.0171	-0.5101
Kurtosis	1.4779	1.3697	-0.7880	0.2243

* PFS=Poney Français de Selle

Table 4

Number of ponies in the data and used for estimation of variance components.

	Breeds			
	PFS*	Connemara	Welsh	New Forest
Number of ponies in the data :				
with ranking in jumping	2482	1433	685	548
with height	3933	2790	1569	1382
Number ponies in sample for variance components :	2688	2014	820	671
with ranking in jumping	1816	1159	467	366
with height	2611	1990	817	667
mean height of the sample	141.8	143.4	135.7	140.4
standard deviation. of height of the sample	5.1	4.1	7.9	4.8
Number of sires of ponies in sample	144	106	46	36

* PFS = Poney Français de Selle

Table 5

Heritability of underlying performance responsible for rank and height, and genetic correlations.

Breed	PFS		Connemara		New Forest	
	1	2	1	2	1	2
Heritability of ranking	0.05	0.06	0.10	0.13	0.19	0.16
Heritability of height	0.72	0.72	0.47	0.47	0.34	0.34
Repeatability of ranking	0.25	0.27	0.27	0.29	0.30	0.32
Genetic correlation	0.20	0.12	0.16	0.13	0.11	0.07
Phenotypic correlation	0.03	-0.01	0.02	-0.02	0.03	-0.01

1 : Model with no correction for the category of competition defined by the height of the pony for the trait ranking

2 : Model with correction for the category of competition defined by the height of the pony for the trait ranking

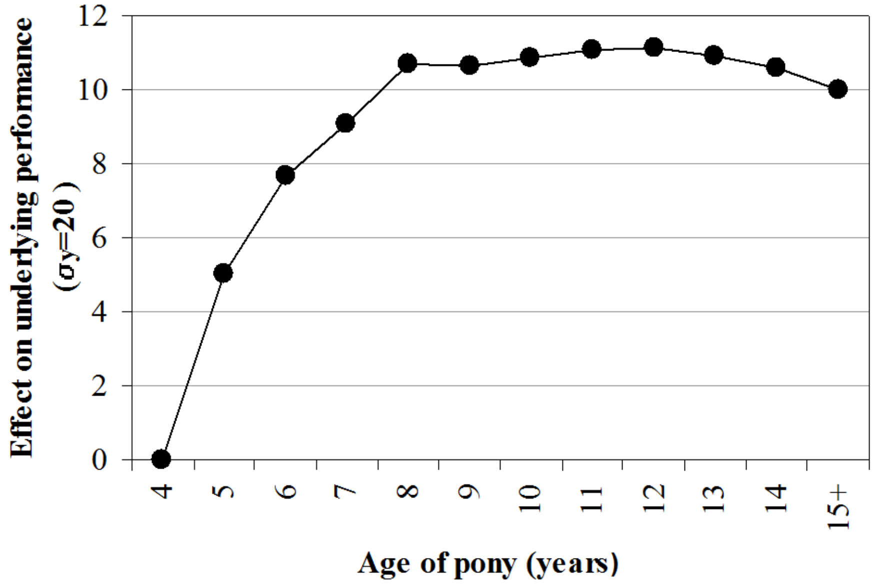
Captions of illustrations.

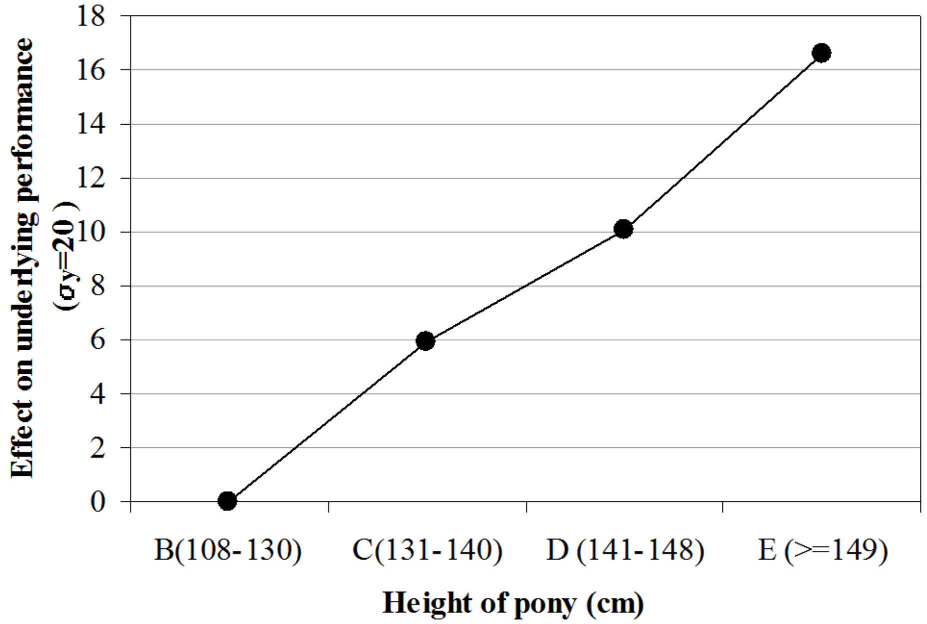
Fig. 1

Effect of age of pony on underlying performance responsible for ranks.

Fig 2.

Effect of the height of pony (in four classes) on underlying performance responsible for ranks.


Effect on underlying performance
(σy=20)
12
10
8
6
4
2
0
4
5
6
7
8
9
10
11
12
13
14
15+
Age of pony (years)



18
16
14
12
10
8
6
4
2
0
Effect on underlying performance
(σy=20)
B(108-130)
C(131-140)
D (141-148)
E (>=149)
Height of pony (cm)