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Inbreeding rate and its effect on three body conformation traits in Arab mares

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In a group of purebred Arab mares the level of inbreeding and its effect on three body conformation traits was determined. Moreover, estimated were heritability coefficients of the traits and their phenotypic, genetic and environmental trends. Considered were conformation records of 706 Arab mares born in the years 1936- 1993. The mean inbreeding level of mares was 0.88%. No considerable effect of inbred rate on body conformation traits was found. The obtained partial regression coefficients were close to zero. Heritability coefficients appeared low and amounted to 0.160 (±0.078) for height at withers, 0.052 (±0.067) for chest circumference and 0.050 (±0.054) for circumference of cannon. Negligible positive genetic trend was observed for all the traits studied, whereas the environmental trends were not clear.

KEY WORDS: Arab horse / body conformation / genetic trend / heritability / inbreeding rate

In recent years, a growing interest on the effects of inbreeding on phenotypic and genetic value of livestock can be observed, due to the fact that combination of inbred with other unfavourable conditions often leads to the decrease in performance and functional traits of animals [Analla *et al.* 1999, Sewalem *et al.* 1999, Horn and Meleg 2000, Thompson *et al.* 2000]. On the other hand, controlled inbreeding with a reasonable mating system showed a positive effect on egg production and fertility in chicken [Wilson 1948]. The problem is particularly relevant in small closed populations in which

mating of relatives often leads to the increase of inbreeding level. As the creation of Arab horse was not based on crossbreeding, it is more exposed to inbreeding effects than other horse breeds [Kownacki 1965, Radomska *et al.* 1974, 1981, Budzyński *et al.* 1997]. There are only few studies dealing with inbreeding effects on body conformation traits in Arab horse though the exterior, most objectively described by biometrical measurements, plays a particularly important role in the selection of the breed.

In light of this, the present study was performed to determine the level of inbreeding in a group of purebred Arab mares and its effects on height at withers, chest circumference, and circumference of cannon. Moreover, heritability coefficients of the traits as well as their phenotypic, genetic and environmental trends were estimated.

Material and methods

The results were used of biometrical measurements (height at withers, chest circumference and circumference of fore cannon) and pedigree information kept in the breeding records of 706 Arabian mares maintained in one State Stud. The mares, born in the years 1936 and 1993, formed the active population from 1953 to 2001. The number of mares born was different in particular years, and this tendency together with the mean inbreeding level is presented in Figure 1. The total pedigree included 1027 animals. As there were fewer mares born between 1936 and 1949 their records were pooled in the further analysis. Means for the three traits studied and their standard

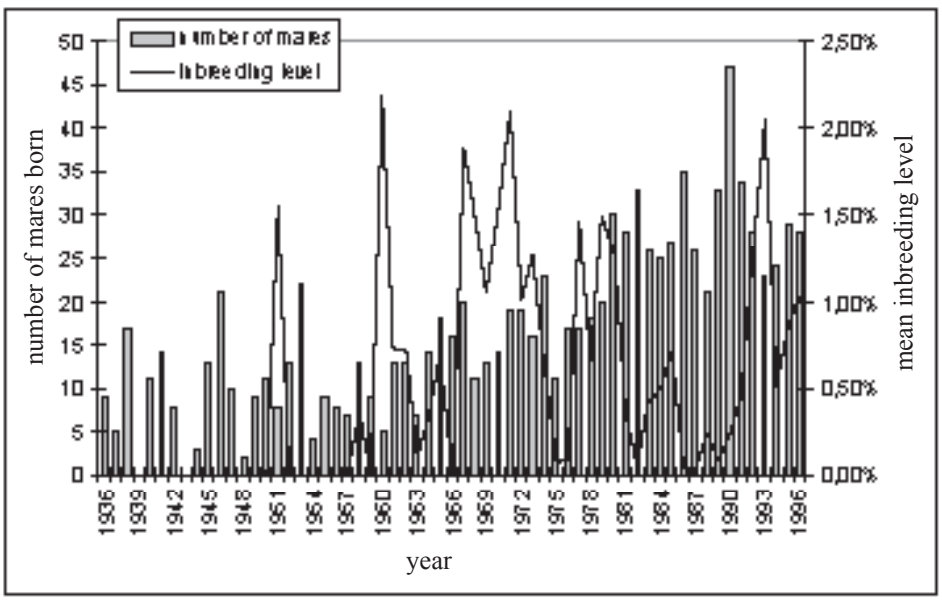

Fig. 1. Number of Arab mares born and their inbreeding levels in particular years.

deviations are given in Table 1. Small standard deviations suggest high consolidation of the population considered. The inbreeding coefficients were obtained from the additive genetic relationship matrix.

The effects of inbreeding rate (inbreeding coefficient) on conformation traits were

Table 1. Means and their standard deviations of three body conformation traits in Arab mares

Trait	Mean	Standard deviation
Height at withers (cm)	149.5	2.92
Chest circumference (cm)	174.8	5.37
Cannon circumference (cm)	18.2	0.54

described based on partial regression coefficients. The analyses were performed using the Derivative Free Restricted Maximum Likelihood (DFREML) algorithm described by Graser *et al*. [1987]. Two linear animal models were applied:

$$y_{ijk} = \mu + r_i + b x_{ijk} + a_{ijk} + e_{ijk} \quad (1)$$

where:

y_{ijk} – body conformation (exterior) trait of *ijk*-th mare;
μ – overall mean;
r_i – fixed effect of *i*-th year of birth;
b – partial regression coefficient;
x_{ijk} – inbreeding coefficient of *ijk*-th individual;
a_{ijk} – random additive genetic effect of *ijk*-th individual;
e_{ijk} – random error connected with *ijk*-th observation.

As the effect of inbreeding is not necessarily linear [Analla *et al.* 1999] the quadratic regression was also computed for:

$$y_{ijk} = \mu + r_i + b_1 x_{ijk} + b_2 x^2_{ijk} + a_{ijk} + e_{ijk} \quad (2)$$

where:

b_1, b_2 – linear and quadratic partial regression coefficients, respectively.
y_{ijk}, μ, r_i, x_{ijk}, a_{ijk} and e_{ijk} – listed for model (1).

The adequacy of the models was examined by the following criteria: error variance estimate and Akaike's Information Criterion (AIC), the latter defined as:

AIC= -2log (maximum likelihood)+2(number of independently adjusted parametres).

The model with the minimum of AIC is considered as the best one [Wada and Kashiwagi, 1990]. Inbreeding depression (for the mean inbreeding level in the population) was estimated based on these models. The DFREML package programme was applied [Meyer 2000].

Phenotypic trends were obtained as the population means for mares born in particular years, whereas environmental and genetic trends were estimated based on the breeding value estimates and solutions for the year effect, respectively.

Results and discussion

The estimated mean inbreeding coefficient was 0.88% for the overall population and 2.84% for 233 inbred animals. Only in nine mares inbreeding coefficient exceeded 12%. In Poland, the research on inbreeding in horses was initiated by Kownacki [1965], who estimated its level in Arab horses as 1.82% for mares and 1.04% for stallions. Investigation was continued by Radomska *et al.* [1974, 1981]. The most recent results were submitted by Budzyński *et al.* [1997] who reported the mean inbreeding of 3.2% in Arab horses born between 1976 and 1993. A low mean inbreeding rate found in this study as compared to the earlier data can be explained by a higher number of individuals taken into account in the population analysed.

The changes in inbreeding show noticeable regularities over time (Fig. 1). An increase in the mean level of inbreeding appeared in 1971 and 1993 due to a relatively higher proportion of inbred mares, and in 1960 because of a small number of individuals. The mares born in 1950, 1952-1957 and 1966 were non-inbred, which could result from the fact that breeders try to avoid mating of close relatives. However, due to a restricted population size, an increase in the inbreeding level can be observed every 10 years probably due to the intensive use of particularly valuable stallions. In the first reproduction seasons the inbreeding level of the population decreased as the stallions were not related to the mares, but when their progeny reached sexual maturity the inbreeding level increased because related animals – due to their high breeding values – were intermated. It was shown by Nomura *et al.* [2001] that reduction in population size and the intensive use of particular males might lead to a considerable increase in the level of inbreeding. Periodical changes in the inbreeding level can also result from culling of animals.

Table 2. Partial regression coefficients and inbreeding depression estimated by models with linear and quadratic regression on the inbreeding rate in Arab mares

Trait	Partial linear regression	Mean inbreeding depression	Partial quadratic regression	Mean inbreeding depression
Height at withers	-0.0934x	-0.0059	$-0.1428x + 0.0061x^2$	-0.1216
Chest circumference	-0.0488x	-0.0432	$-0.3079x + 0.0321x^2$	-0.2473
Cannon circumference	-0.0067x	-0.0826	$-0.0337x + 0.0037x^2$	-0.0287

The estimates of partial regression coefficients and inbreeding depression values are given in Table 2. All partial regression coefficients were close to zero. This and the corresponding low inbreeding depression suggest that the level of inbreeding was not critical. Chmiel *et al.* [2001] suggested a positive effect of inbreeding on the performance traits of Arab horses. In a group of 685 horses the highest marks were given to those with the highest inbreeding level (more than 10%). Twenty years earlier Radomska *et al.* [1983] came to the opposite conclusion. In their study the inbreeding level higher than 5% showed a negative impact on reproduction, body weight and some conformation traits. The negative inbreeding effect was also recorded for other horse breeds [Klemetsdal 1998]. The results obtained in the present study confirm the absence of a negative effect of low inbreeding level on body conformation traits in Arab mares.

Table 3. Heritability estimates and their standard deviations (SD) for conformation traits in Arab mares

Trait	Linear regression on inbreeding		Quadratic regression on inbreeding	
	heritability	SD	heritability	SD
Height at withers	0.160	0.078	0.158	0.078
Chest circumference	0.032	0.067	0.067	0.068
Cannon circumference	0.030	0.054	0.054	0.057

Table 4. Error variance estimates and Akaike's Information Criterion (AIC) values for models with linear (model 1) and quadratic (model 2) regression on the inbreeding rate

Trait	Error variance estimate		AIC	
	model 1	model 2	model 1	model 2
Height at withers	5.517	5.531	2149.64	2142.14
Chest circumference	24.152	23.754	3019.6	3008.14
Cannon circumference	0.219	0.217	52.22	44.1

Heritability estimates with their standard deviations for conformation traits are presented in Table 3. Literature provides various estimates of heritability of body dimensions in horses [Dolvik and Klemetsdal 1999, Molina *et al.* 1999]. Low heritability estimates found in the present study in Polish Arabs indicate a marked environmental variation of the traits analysed. This observation is supported by considerable year effects (Fig. 3), but it also suggests a high genetic consolidation within the Stud considered, resulting from permanent selection which leads to the decrease of genetic variability.

Two criteria were employed of the adequacy of the models used. The results are shown in Table 4. There was a relatively small difference between the goodness of fit of the models. Therefore, only linear relationship between the inbreeding level and taits analysed was assumed. From this point of view, it seems that in further studies on a population with a related inbreeding level a simplier model can be used.

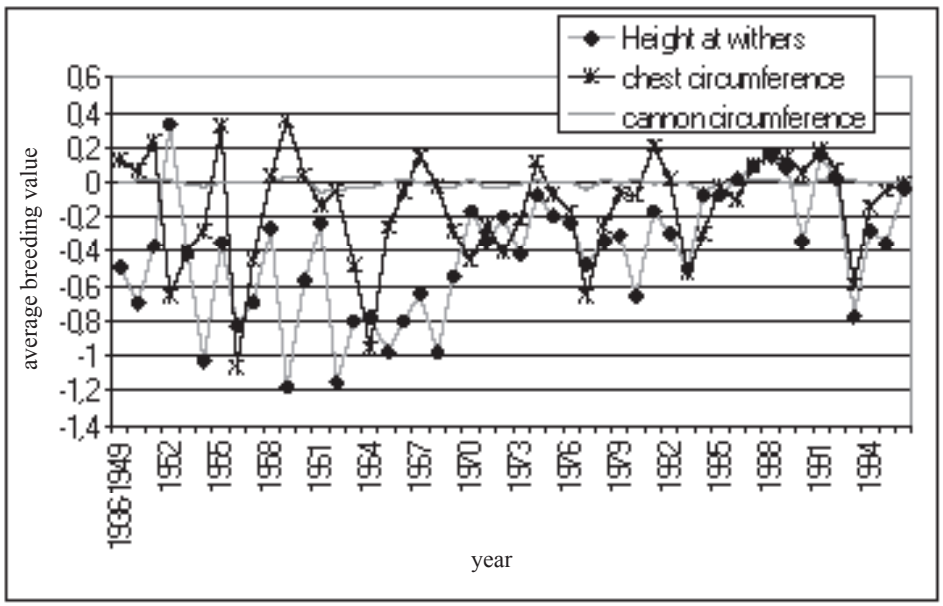

Fig. 2. Genetic trends for conformation traits in Arab mares.

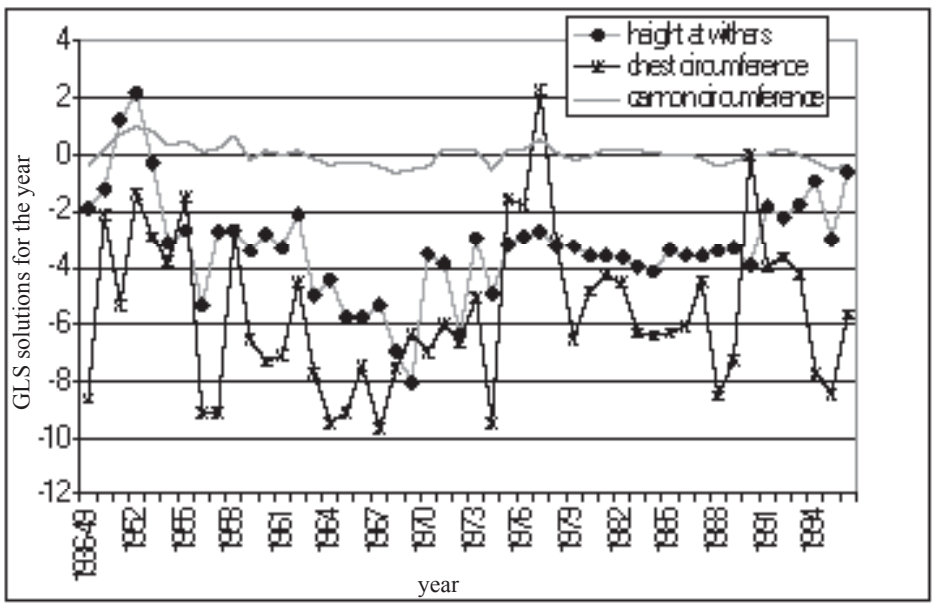

Fig. 3. Environmental trends for conformation traits in Arab mares.

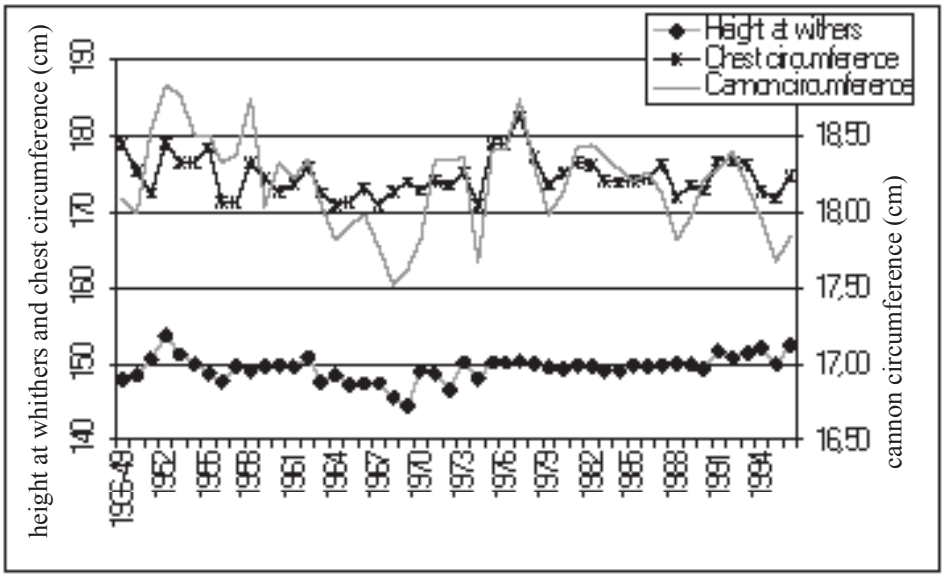

Fig. 4. Phenotypic trends for conformation traits in Arab mares.

The genetic, environmental and phenotypic trends are presented in Figures 2, 3 and 4, respectively. The annual mean genetic values increased over the period analysed (Fig 2). There was negligible variation of the mean breeding values except for the circumference of cannon. Some regularities can be observed in height at withers: there was a negative trend in the sixties with an increase thereafter. However, for chest circumference no clear genetic trend was observed. It should be noticed that from the foundation of the Stud until the early 1970s the genetic trends were negative, probably due to difficulties in obtaining valuable breeding material in the formation of the base population. The situation began to change in 1970 when a breeding programme and valuable stallions were introduced. Both annual environmental effects and phenotypic means changed over time.

The present study was based on multigenerational information, and showed a relatively low level of inbreeding in a small population (single state stood) of Arab horses. Negligible inbreeding depression on three body conformation traits was found. The heritability estimates of traits studied were low. Hence, means for annual genetic effect changed slowly, whereas year (environmental) effect estimates and annual phenotypic means showed wider variation.

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Poziom inbredu i jego wpływ na trzy cechy pokrojowe klaczy arabskich

S t r e s z c z e n i e

Celem podjętych badań było określenie poziomu inbredu i jego wpływu na cechy pokroju w populacji klaczy arabskich, a także ocena wskaźników odziedziczalności oraz trendów fenotypowych, genetycznych i środowiskowych tych cech. Analizowano dane pokrojowe 706 klaczy. Średni poziom inbredu badanych osobników wynosił 0,88%. Nie zaobserwowano znaczącego wpływu inbredu na cechy exterieru, a stwierdzone współczynniki regresji cząstkowej były bliskie zeru. Oszacowane wskaźniki odziedziczalności były niskie i wynosiły odpowiednio 0,160 (± 0,078) dla wysokości w kłębie, 0,052 (± 0,067) dla obwodu klatki piersiowej oraz 0,050 (± 0,054) dla obwodu nadpęcia. Zaobserwowano nieznaczny pozytywny trend genetyczny dla wszystkich analizowanych cech, podczas gdy trendy środowiskowe były nieukierunkowane.