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ESTIMATION OF GENETIC AND PHENOTYPIC PARAMETERS OF BODY MEASUREMENTS AND CONFORMATION IN ARABIAN HORSES

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SUMMARY

Data of eleven body measurements and eight body conformation indices on 280 purebred Arabian horses ranging from 1 month to 298 months old. These horses were progeny of 60 stallions and 176 mars.

A multiple trait animal model was used to estimate heritability genetic and phenotypic correlations for the measurements and indices under investigation.

Heritability estimates were 0.35, 0.51, 0.53, 0.33, 0.27, 0.29, 0.28 0.22, 0.14, 0.18 and 0.55 for neck girth, chest girth, fore cannon bone circumference , hind cannon bone circumference , back line length, body length, chest width, croup width, chest depth, wither height and croup height, respectively. For body conformation indices, heritability estimates were 0.11, 0.09, 0.15, 0.23, 0.27, 0.29, 0.16 and 0.25 for format, compactness, rib cage, chest depth, chest girth, boniness, body length and height, respectively.

Genetic correlation coefficients between body measurements were all positive, and ranged from 0.12 to 0.96, except that between the chest depth and body length (-0.03). Genetic correlation coefficients between body conformation indices were low to moderate and some were negative. Phenotypic correlation coefficients for body measurements were all positive and ranged from 0.08 to 0.86. For conformation indices, some of the estimates were positive and some others were negative.

Therefore, body measurements and/or body conformation indices can be efficiently used to accomplish certain breeding program goals that are related to body measurements and conformation of the Arabian horse.

Keywords: Arabian horse, Body measurements, Conformation index, Genetic parameters

INTRODUCTION

Conformation traits play an important role in horse breeding because they are associated with desirable characterization and performance traits of the animals. Several Arabian horse shows for studbook judging and evaluation are arranged yearly in Egypt. Poor soundness related to defects in conformation is an obvious reason for low grade and poor performance of the horses. Good conformation and movements are important factors for horses to fetch high prices (Saastamoinen *et al*., 1991). The body conformation is useful in evaluating and comparing breeds (Lawrence, 2001 and Meadows, 2003). Beauty of horses and their athletic performance are affected by their body conformation. (Evans, 2000; Lawrence, 2001; Parker, 2002 and Meadows, 2003). Iriarte-Diaz (2002) stated that body indices were good scale for body conformation and as selection criteria. Part of the beauty of the Arabian horse depends on its body conformation, body measurements and the relationships between these measurements.

To the author's knowledge, there are no studies on estimating genetic parameters for body measurements and conformation traits of the Arabian horse breed in Egypt. Knowledge of genetic components associated with conformation would allow the design of breeding programs for the breed.

The aim of the present work was to estimate genetic and phenotypic parameters for eleven body measurements and eight body indices for conformation of the pure Arabian horse in Egypt.

MATERIAL AND METHODS

Data were collected on 11 body measurements on 280 pure-bred registered Arabian horses from the Alzahraa stud, the largest stud of registered Arabian horses in Egypt. The stud is a member of the World Arabian Horse Organization (WAHO, 2004). The horses were 95 males (43 stallions and 53 colts) and 185 females (123 mares and 61 fillies). These hoses were the progeny of 60 sires and 176 dams and the age of the horses the time of measurement ranged from 1 to 298 months. Therefore, when age was considered in the statistical analysis, horses were classified into 20 age groups of 6 months interval. One group included horses over 10 years old to avoid disconnectedness in the data.

Horses are raised in a closed herd. They are fed roughage and concentrate supplemented with minerals and vitamins. Roughage is fed ad lib in group feeding and consists of alfalfa hay or Egyptian clover, *Trifolium alexandrinum,* hay. Barley is fed as a concentrate source with mineral and vitamin supplements. The concentrate mixture is offered individually three times a day. Water is available all day. The horses were given regular daily exercise.

As shown on figures 1, 2 and 3, eleven body measurements (in cm) were taken:

1- The neck girth, i.e. girth of the neck at the area of attachment between the neck and breast;
2- chest girth, i.e. circumference around the chest behind the front legs;
3- fore cannon circumference, i.e. girth of the fore cannon bone at the middle point of its length;
4- hind cannon circumference, i.e. girth of the hind cannon bone at the middle point of its length;
5- back line length, i.e. length from the pin bone to the highest point of the withers;
6- body length, i.e. the distance from the shoulder to the point of the tuber ischium with a sloping line;
7- wither height, i.e. distance from highest point of wither to the ground;
8- croup height, i.e. distance from the highest point of croup, tuber sacral, to ground;
9- chest depth , i.e. distance from the highest dorsal point of chest to the sternum (parallel point at the chest floor);
10- chest width, i.e. distance from the middle point of the front part of chest to the same point on the opposite side;
11- croup width, i.e. the distance from the tuber sacral of hip from one side to same point on the opposite side.

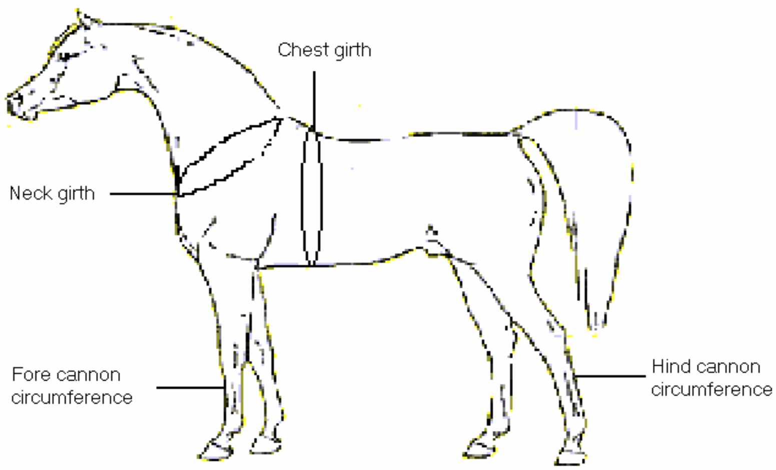

Figure 1. Girth measurements

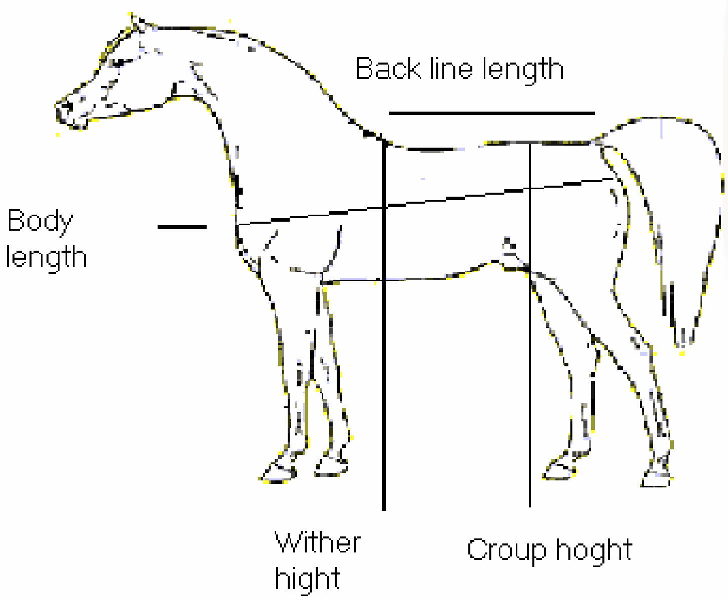

Figure 2. Linear measurements of lengths and heights

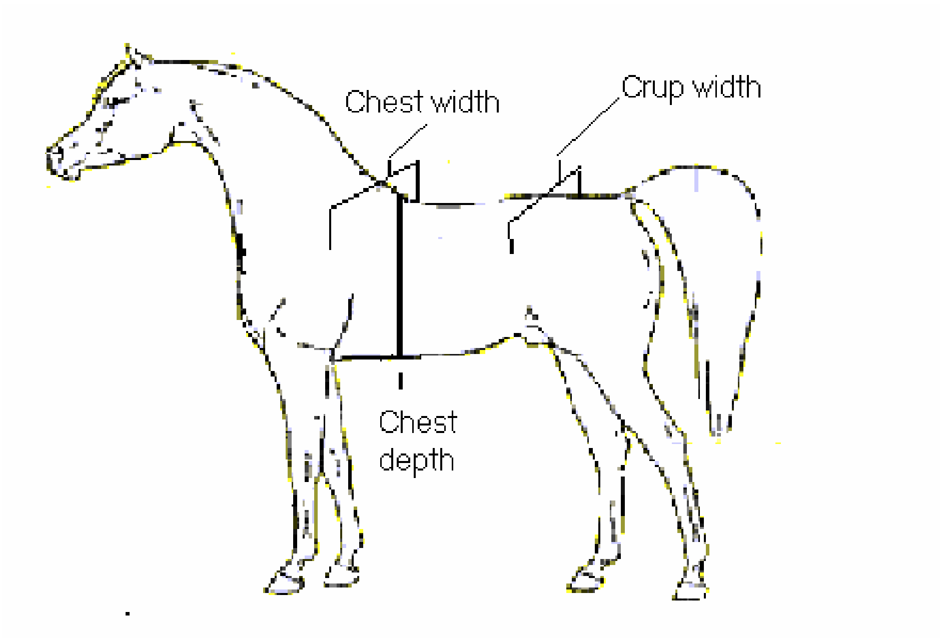

Figure 3. Linear measurements of widths and chest depth

All measurements were taken on the left side of the horse while it was standing on flat ground with all feet on the ground and legs parallel. Circumference measurements were taken using a tape measure while the other measures were taken with a specially designed caliper.

Horses were evaluated for eight body conformation indices according to Pietrazak an Wojciechowski (1992) and Alagic *et al.*, (2002). These indices were:

(1) Format index = (body length /wither height) X 100.

This index can provide a good idea about the coordination among body parts and gives an idea about the general form.

(2) Compactness = (chest girth / body length) X 100.

This index gives information on the degree of compactness of the trunk and the coordination between body girth and length.

(3) Rib cage index = (chest width/chest depth) X 100.

It is a scale indicating the chest volume and it could reflect the respiratory capacity of the chest.

(4) Chest depth index = (chest depth / wither height) X 100.

It can measure the height of chest, height of legs and the degree of chest depth in comparison to the height of horse. The length of the legs, in general should preferably not be the same as the chest depth (Evans, 2000, Parker, 2002 and Meadows, 2003).

(5) Chest girth index = (chest girth / wither height) X 100.

This index expresses the volume of the chest in comparison with the general height of the horse.

(6) Boniness index = (fore cannon circumference / wither height) 100.

This relates the thickness of the horse′s bones compared with its height and can reflect the capacity of the horse in all gaits, jumping and in carrying a rider while remaining well balanced.

(7) Body length index = (body length / back line length) X 100.

Loch *et al.* (2000), Parker (2002) and Meadows (2003) reported that the back line length should be shorter than underline length. It increases the height and length of stride and leads to a good athletic ability.

(8) Height index = (wither height /croup height) X 100.

The ratio between wither height and croup heights could give an idea about the balance between these two heights. Evans (2000) and Meadows (2003) reported that a properly balanced horse will be higher at the wither than at the croup. When wither height is higher than croup height, the hindquarters are positioned more under the body, which enhances the athletic ability of the horse.

Data for the eleven body measurements and eight indices were analyzed separately using the following animal model by utilizing the multiple-trait derivative free restricted maximum likelihood (DFREML) programs (Meyer, 1998):

$$y = Xb + Za + e$$

where:

y is a vector of observations of the eleven body measurements or the eight indices;

b is a vector of fixed effects (sex, 2 levels, and age in months, 21 levels);

a is a vector of random additive direct genetic effects;

e is a vector of random residual effects; and

X and Z are known incidence matrices relating observations to the respective fixed and random effects with Z augmented with columns of zeros for animals without records.

The first and the second moments of the model were assumed to be:

E(y) = Xb, E(a) = E(e) = 0;

$$V\begin{bmatrix} a_i \\ e_i \end{bmatrix} = \begin{bmatrix} A \otimes Ja_i & 0 \\ 0 & I_n \otimes \sigma^2_{e_i} \end{bmatrix}$$

A is the additive numerator relationship matrix for horses. The full pedigree of all horses were available. *J* is a matrix of 1′s of order 11x11 or 8x8. I_n is an identity matrix of order equal the number of horses (n). Symbol $\otimes$ means the direct product of two matrices. Subscript i refers to the eleven measurements or the eight indices.

RESULTS AND DISCUSSIONS

Means, minimum, maximum, standard error and coefficient of variation for each of the eleven body measurements and the eight conformation indices are presented in tables 1 and 2, respectively. The results showed that there were high variation in the data for chest width, croup width, neck girth, chest depth, chest girth and back line length. However, there was low variation in the other measurements. The rib cage index showed higher variation than other indices.

Table 1. Descriptive statistics of the eleven studied measurements (cm, N = 280)

Measure	Minimum	Maximum	Mean	SE	CV%
Age (months)	1	298	83.5	4.33	86.8
Neck girth	62	130	104.6	0.71	11.4
Chest girth	102	193	166.6	1.00	10.7
Cannon bone circumference (fore leg)	14	22	19.3	0.07	6.9
Cannon bone circumference (hind leg)	14	22	18.3	0.07	6.4
Back line length	62	115	99.7	0.57	9.6
Body length	90	158	139.9	0.74	8.9
Chest width	23	58	42.1	0.36	14.6
Croup width	26	57	47.8	0.34	12.2
Chest depth	39	74	64.9	0.43	11.1
Wither height	110	157	144.6	0.53	6.2
Croup height	111	157	145.0	0.50	5.8

Table 2. Descriptive statistics of the eight studied indices (in percent, N = 280)

Index	Minimum	Maximum	Mean	SE	CV%
Format index	80.0	105.0	96.6	0.27	4.7
Compactness index	80.7	135.6	119.0	0.32	4.6
Rib cage index	50.0	90.2	64.9	0.36	9.5
Chest depth index	35.1	50.4	44.8	0.17	6.4
Chest girth index	81.3	132.9	114.9	0.42	6.2
Boniness index	10.7	14.1	12.4	0.03	4.5
Body length index	120.0	161.3	140.8	0.34	4.1
Height index	95.3	104.9	99.8	0.08	1.4

Heritability

It is well known that the estimates of heritability vary according to the size of data, model and method of analysis. In addition, the available reports in the literature deal with different horse breeds. Therefore, it was impractical to compare the results of the present work with that reported in the literature. However, this comparison could be legitimate from the standpoint of showing trends of the estimates.

Tables 3 shows heritability estimates for the eleven studied body measurements. These estimates ranged from low, less than 0.2 or medium, more than 0.2 to less than 0.3, to high, over 0.3. For body measurements, the lowest heritability was for the chest depth, 0.14, while the highest estimate was for croup height, 0.55. Costa *et al.*(1997) reported heritability of 0.52 in the Brasileira pony breed. In the thoroughbred horse, Fedorski and Pikuta (1987) reported heritability of 0.28, 0.44 and 0.12 for wither height, chest girth and fore cannon circumference, respectively. In the present study, these estimates were 0.18, 0.51 and 0.53 for the same measurements, respectively. Miserani *et al.* (2002) investigating the pantaneiro horse, and Sasstamoinen *et al.* (1991), investigating the Finn horse, reported higher heritability estimates for all measurements than those recorded in the present work. Molina *et al.* (1999) reported moderate to high (0.35 to 0.95) heritability estimates for body measurements in the Andalusian horse. In the Haflinger horse, Samore *et al.* (1997) reported heritability estimates from 0.02 to 0.53 for body measurements. These were somewhat higher than those reported by Koenen *et al.* (1995) in the Dutch warm-blood riding horse. It can be noticed that the tendency in most cases is towards medium to high heritability while individual values within breeds vary greatly due to different selection criteria and management systems.

Table 3. Heritability estimates (diagonal and underlined), genetic correlations (below diagonal), phenotypic correlations (above diagonal) among the eleven body measurements

Measure	Neck girth	Chest girth	Fore cannon cerc.	Hind cannon cerc.	Back line length	Body length	Chest width	Croup width	Chest depth	Wither height	Croup height
Neck girth	0.35	0.69	0.48	0.53	0.30	0.26	0.33	0.49	0.62	0.54	0.39
Chest girth	0.89	0.51	0.49	0.51	0.34	0.25	0.35	0.52	0.64	0.59	0.59
Fore cannon cerc.	0.82	0.73	0.53	0.86	0.37	0.29	0.48	0.54	0.24	0.49	0.61
Hind cannon cerc.	0.89	0.85	0.93	0.33	0.31	0.28	0.47	0.53	0.29	0.51	0.53
Back line length	0.31	0.16	0.57	0.28	0.27	0.64	0.37	0.39	0.26	0.41	0.35
Body length	0.22	0.06	0.65	0.32	0.77	0.29	0.33	0.33	0.18	0.29	0.25
Chest width	0.66	0.72	0.67	0.64	0.12	0.44	0.28	0.53	0.08	0.36	0.42
Croup width	0.87	0.95	0.88	0.94	0.32	0.26	0.67	0.22	0.35	0.61	0.54
Chest depth	0.96	0.87	0.67	0.82	0.19	-0.03	0.47	0.81	0.14	0.58	0.28
Wither height	0.89	0.77	0.77	0.81	0.53	0.20	0.31	0.82	0.91	0.18	0.51
Croup height	0.69	0.83	0.84	0.77	0.45	0.50	0.81	0.89	0.54	0.59	0.55

Table 4. shows heritability estimates for the eight body conformation indices. These estimates ranged from 0.09 to 0.29 for compactness and boniness, respectively. Most of the heritability estimates of body conformation indices that were suggested to be related to the athletic ability of a horse such as boniness, chest girth and height indices were medium (0.29, 0.27 and 0.25, respectively).

Table 4. Heritability estimates (diagonal and uderlined), genetic correlations (below diagonal), phenotypic correlations (above diagonal) among the eight conformation indices

Index	Format	Compactness	Rib cage	Chest depth	Chest girth	Boniness	Body length	Height
Format	0.11	-0.15	0.14	0.35	0.37	0.18	0.51	-0.18
Compactness	0.63	0.09	0.29	0.15	0.66	0.07	-0.25	-0.07
Rib cage	0.34	0.43	0.15	-0.21	0.42	0.17	0.23	-0.12
Chest depth	0.61	0.52	-0.35	0.23	0.44	0.09	0.14	-0.03
Chest girth	0.89	0.92	0.43	0.62	0.27	0.22	0.18	-0.21
Boniness	-0.21	-0.54	-0.22	-0.16	-0.43	0.29	-0.07	-0.10
Body length	0.41	0.07	0.40	0.17	0.24	-0.32	0.16	0.02
Height	-0.28	-0.11	-0.23	0.29	-0.23	0.37	0.17	0.25

Genetic and phenotypic correlations

Table 3 presents estimates of genetic and phenotypic correlations between different body measurements. For body measurements, genetic correlations were all positive except the genetic correlation between chest depth and body length with a value of -0.03. Other genetic correlations ranged from 0.12 to 0.96 between chest width and back line length and between chest depth and neck girth, respectively. Most of the genetic correlations between body measurements were found to be high. In the Brazilian Pony breed, genetic correlation varied between 0.32 to 1.0 (Costa *et al.,* 1997), the lowest between back line length and chest width while the highest was between neck width and body length. Molina *et al.* (1999) reported that the genetic correlations between body measurements within the Andalusian horse were all positive and ranged between 0.11 and 0.94. These high correlations may be due to the same genes acting on these measurements but more likely are due to the low coefficient of variation for these measures (table 1). All phenotypic correlations among body measurements were positive with less magnitude than the genetic correlation.

Genetic and phenotypic correlations between body conformation indices are shown in table 4. Some correlations coefficients were positive while some others were negative. The highest positive correlation (0.92) was between chest girt index and compactness index while the lowest positive correlation (0.07) was between body length index and compactness index. The lowest negative correlation (-0.43) was between chest girth index and boniness index. Molina *et al.,* reported that the genetic correlations among body conformation scores within the Andalusian horse were all positive and ranged between 0.12 and 0.91. Some phenotypic correlations between indices were positive while some others were negative but with less magnitude than the genetic correlations.

CONCLUSION

In Arabian horses, heritability estimates found in this investigation for body measurements were moderate to high, varying from 0.22 to 0.55 for most measurements except chest depth and wither height, meaning that these measurements may respond to a mass selection of varying degrees. For body conformation indices, estimates were low to medium. Most of the genetic correlations among body measurements were positively high. For body conformation indices, some genetic correlations estimates were positive while others were negative. Selection for certain body measures or conformation depends on the objectives of selection.

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تقدير المعالم الوراثية والمظهرية لمقاييس الجسم وتكوينه في الخيول العربية

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حللت بيانات 11 مقاسا جسميا و 8 أدلة تكوين الجسم لعدد 280 حصان عربي أصيل، أبناء 60 طلوقة و 170 أم، تراوحت أعمارها بين شهر واحد 298 شهر، تابعة لمحطة الزهراء للخيول العربية الأصيلة.

استخدم نموذج الحيوان متعدد الصفات لتقدير المكافئ الوراثي ومعاملات الارتباط الوراثي والمظهري للمقاييس والأدلة محل الدراسة.

كانت تقديرات المكافئ الوراثي 0.35، 0.51، 0.53، 0.33، 0.27، 0.29، 0.28، 0.22، 0.14، 0.18، 0.55 وذلك لمقاييس: محيط الرقبة، محيط الصدر، عظمة المدفع الأمامية، عظمة المدفع الخلفية، طول خط الظهر، طول الجسم، عرض الصدر، عرض الكفل، عمق الصدر، ارتفاع الغارب، ارتفاع الكفل، علي الترتيب. وكانت تقديرات المكافئ الوراثي لأدلة تكوين الجسم 0.11، 0.09، 0.15، 0.23، 0.27، 0.29، 0.16، 0.25 للأدلة: الشكل، الاندماج، القفص الصدري، عمق الصدر، محيط الصدر، النحافة، الطول، الارتفاع، علي الترتيب.

كانت تقديرات معاملات الارتباط الوراثي جميعها موجبة وتراوحت بين 0.12 إلي 0.96 باستثناء معامل الارتباط الوراثي بين عمق الصدر وطول الصدر الذي كان (-0.12) . معاملات الارتباط الوراثي بين أدلة تكوين الجسم تراوحت ما بين المنخفضة والمتوسطة وكان بعضها موجباً والبعض الأخر سالباً.

تقديرات معاملات الارتباط المظهري بين مقاييس الجسم كانت جميعها موجبة 0.08 إلي 0.86 أما تقديرات معاملات الارتباط المظهري للأدلة تكوين الجسم فكان بعضها موجبا والبعض الأخر سالبا.

ومن ثم، فأن مقاييس الجسم وأدلة تكوينه يمكن استخدامها بكفاءة لتحقيق أهداف تربوية معينة مرتبطة بشكل ومقاييس الحصان العربي.