Heritability parameters for some body measurements in Turkish Arabian foals

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(Received 27 Aug 2011; revised version 25 Jun 2012; accepted 2 Jul 2012)

Summary

The aim of the present study was to estimate genetic parameters of body measurements in Turkish Arabian foals. Records of wither height, front cannon circumference, heart girth, and body length were used for body measurements at birth, 6 months of age, 1-year-old and 2-year-old. Heritability of body measurements of Turkish Arabian foals was estimated by using records of foals sired by stallions which had at least 5 foals. Body measurement records at birth of 1597 foals sired by 40 stallions were used in heritability calculation of withers height, front cannon circumference, and heart girth. Heritability of all body measurements was estimated by paternal half-sib method. Estimated heritability ranged from 0.05 (heart girth) to 0.58 (wither height). Heritability estimates can be used to improve body measurements of Turkish Arabian horses. These results indicate that mass selection method based on the individual phenotype of the horses at different ages can provide genetic improvement in the herd. Phenotypic correlations between body measurements at consecutive age periods were all positive, ranging from 0.22 to 0.63. Thus, early body measurements of the Turkish Arabian foals can be used for prediction of the size of the adult horse.

Key words: Turkish Arabian horse, Heritability, Body measurements, Phenotypic correlation

Introduction

Characteristics of Arabian horses are beautiful heads, dished face, large round eyes, broad forehead and their tail is always up while running (it holds its tail in the form of "s" while running). Arabian horses have one fewer vertebrae and only 16 ribs instead of 17 ribs (Arpacık, 1994; Lawrence, 2001).

Body measurements of horses could be useful to show their characteristics and general body conformation and can be effectively used for many aims such as, to compare between normal and abnormal growth, to evaluate and compare breeds, and to increase performance in sports. Part of the beauty of the Arabian horse depends on its body conformation, body measurements and the relationships among the body dimensions (Sadek *et al*., 2006). In choice of selection method that will be used to improve body measurements, level of heritability of body measurements should be known. Heritability estimates for body measurement of horse have been reported by many authors and were reported in general between moderate and high heritability (Molina *et al*., 2003; Pretorius *et al*., 2004; Druml *et al*., 2008; Gharahveysi *et al*., 2008; Prado and Mota, 2008; Viklund *et al*., 2008; Bakhtiari and Heshmat, 2009; Kaps *et al*., 2010).

Suontama *et al*. (2011) reported that high heritability for foal traits and high genetic correlations between the foal and studbook traits indicate that an early selection for conformation traits would be efficient in the breeding programs. The aim of the present study was to estimate the heritability of body measurements of Turkish Arabian foals reared in Anadolu State Farm.

Materials and Methods

In this study, four body measurements (wither height, body length, heart girth and front cannon circumference of the front)

were taken. As an anatomical description, wither height is the distance from the highest point of the processus spinali of the second and the sixth thoracic vertebra to the floor. Wither height was measured with measuring stick. Heart girth (circumference of chest) were circumference measured from the base of the wither down to behind the front legs, then under the belly and up the opposite side to where it was started. Circumference of cannon bone-forelimb was smallest circumference of the cannon bone of the forelimb. Circumference of cannon bone-forelimb and heart girth were measured by using plastic measuring tape. Body length was distance from the most cranial point of the sternum to the most caudal point of the pin bone. Body lengths were measured by using measuring stick (Arpacık, 1994; Pretorius *et al*., 2004). For differences between fillies and colts for means of all the measurements, t-test was used in Minitab packet program (1998). Differences between male and female groups were denoted by "a" for groups which had higher mean levels, while groups having lower mean levels were denoted by "b".

Heritability of body measurements of Turkish Arabian foals were estimated from records of foals sired by stallions which had at least 5 foals. At birth, 1597 body measurement records and 40 stallions were used for wither height, front cannon circumference, and heart girth, and 177 records, and 19 stallions were used for body length. At weaning, 257 body measurement records, and 17 stallions were used for wither height, front cannon circumference, and heart girth, and 110 records and 8 stallions were used for body length as shown in Table 3.

At 1-year-old, 386 records and 15 stallions were used for wither height, front cannon circumference, and heart girth, 47 records, and 7 stallions were used for body length. At 2-year-old, 133 records, and 14 stallions were used for wither height, and heart girth, and 38 records, and 6 stallions were used for body length. As the majority of foals are sold at 2 years, and number of data at 3-year-old in this state farm is not enough, the heritability calculation was not done. Heritability of body measurements was estimated by paternal half-sib method (Çilek and Tekin, 2005) for reliable calculations at all necessary conditions such as selection of stallions by chance, coefficient of relationship. Intraclass correlation among paternal half-sibs (t) is shown in the formula below. Heritability of all the measurements was estimated by using variance analysis in Minitab packet program (1998).

$$t = \frac{\sigma^2 a}{\sigma^2 a + \sigma^2 i}$$

The heritability is multiplied by 4 the value of intraclass correlation ($h^2 = 4\ t$). The standard error of the correlation coefficient within stallions (St) was shown in the formula below. These values were multiplied by 4 and the standard error of heritability (Sh^2) was estimated ($Sh^2 = 4\ St$) (Arıtürk and Yalçın, 1966; Çilek, 2002).

$$S_t = \frac{(1-t)[1+(k-1)t]}{\sqrt{1/2(k)(k-1)(N-1)}}$$

k: average foal number for each stallion
N: number of stallions

Using Minitab packet programme (1998), Pearson's phenotypic correlations between four body measurements were calculated at consecutive age periods.

Results

Heritability estimates for body measurement of horse have been reported by many authors and are shown in Table 1. Means of all body measurements of Turkish Arabian horses at different ages were shown in Table 2. Generally, it can be said that body measurements of fillies were smaller than colts ($P<0.05$). Also, variance is small at birth, and variance between foals increased with increasing of foal age. While there is only maternal environment at birth, there are other factors such as sex, stallion line, care, feeding, climate, and season in age difference periods. This large variation in the following ages can be utilized in order to increase body measurements.

Variance components and heritability of body measurements were presented in Table 3. For example, in heritability estimation of wither height at birth, the average foal number for each stallion (k) was 39.074.

Total phenotypic variance (σ^2total) and variance between stallions were estimated by using means of squares between stallions and within stallions. Total phenotypic variance (σ^2total) was 11.333 and variance between stallions (σ^2a) was 1.333. Then the correlation coefficient within stallions (t) was calculated by dividing σ^2a/σ^2total and was found to be 0.118. Heritability was found as 0.47 from the equation $h^2 = 4$ t. The standard error of the correlation coefficient within stallions (St) was estimated as 0.00028. These values were multiplied by 4 and the standard error of heritability for wither height at birth (Sh^2) was found to be 0.001. Heritability of other body measurements was presented in Table 3. Phenotypic correlations between some body measurements at consecutive age periods were presented in Table 4 for Turkish Arabian foals. Phenotypic correlations between some body measurements at consecutive age periods were estimated at moderate level, positive and between 0.22 and 0.63. Specifically, phenotypic correlations between wither height measurements at consecutive age periods were statistically important and high level.

Discussion

Gharahveysi *et al*. (2008) reported that body length, wither height and front cannon circumferences in mature Arabian horse were 148.54, 149.17 and 18.34 cm, respectively. These values were similar to body measurements of 3-year-old horse in this study. However, in this study, heart girth value found as 175.50 cm for mares and 174.91 cm for stallions was higher than 169.45, reported in Iran (Gharahveysi *et al*., 2008).

Heritability of wither height at birth, 6 months age, 1-year-old, and 2-year-old were 0.47, 0.58, 0.14 and 0.26, respectively. These values were in agreement with the estimates of previous studies which were between 0.24 and 0.63 for wither height (Molina *et al*., 2003; Pretorius *et al*., 2004; Dario *et al*., 2006; Druml *et al*., 2008; Gharahveysi *et al*., 2008; Prado and Mota, 2008; Viklund *et al*., 2008; Bakhtiari and Heshmat, 2009). In contrast, the values reported for 1-year-old in previous studies (Hintz *et al*., 1978; Kaps *et al*., 2010) were remarkably higher than the 0.14 value reported for this trait. As heritability of

Table 1: Heritability estimates for some body measurements in horses

Traits	Heritability	Breed	Reference
Withers height	0.58	Andalusian horse	Molina *et al*., 2003
	0.30	Friesian horse	Pretorius *et al*., 2004
	0.24	Murgese horse breed	Dario *et al*., 2006
	0.63	Mangalarga horse	Prado and Mota, 2008
	0.67	Austrian Noriker draught horse	Druml *et al*., 2008
	0.84	Swedish Warmblood horses	Viklund *et al*., 2008
	0.38	Iranian thoroughbred horse	Bakhtiari and Heshmat, 2009
	0.57	Iranian Arabian horses	Gharahveysi *et al*., 2008
Heart girth (circumference of chest)	0.48	Andalusian horse	Molina *et al*., 2003
	0.39	Murgese horse breed	Dario *et al*., 2006
	0.35	Austrian Noriker draught horse	Druml *et al*., 2008
	0.26	Iranian Arab horses	Gharahveysi *et al*., 2008
	0.66	Mangalarga horse	Prado and Mota, 2008
	0.49	Iranian thoroughbred horse	Bakhtiari and Heshmat, 2009
Cannon bone circumference	0.35	Andalusian horse	Molina *et al*., 2003
	0.57	Friesian horse	Pretorius *et al*., 2004
	0.44	Murgese horse breed	Dario *et al*., 2006
	0.39	Austrian Noriker draught horse	Druml *et al*., 2008
	0.055	Arabian	Gharahveysi *et al*., 2008
	0.41	Mangalarga horse	Prado and Mota, 2008
	0.30	Iranian thoroughbred horse	Bakhtiari and Heshmat, 2009
Body length	0.72	Andalusian horse	Molina *et al*., 2003
	0.48	Friesian horse	Pretorius *et al*., 2004
	0.52	Austrian Noriker draught horse	Druml *et al*., 2008
	0.27	Iranian Arabian horses	Gharahveysi *et al*., 2008

Table 2: Descriptive statistics for some body measurements (cm)

Variable	Sex of foals	N	Mean	SE Mean	P-value
Body measurements at birth					
Wither height	Female	794	96.36[b]	0.12	0.005
	Male	803	96.84[a]	0.12	
Heart girth	Female	794	79.65[b]	0.10	0.018
	Male	803	79.99[a]	0.10	
Front cannon circumference	Female	794	10.71	0.02	0.260
	Male	803	10.74	0.02	
Body length	Female	89	68.46	0.29	0.190
	Male	88	69.07	0.35	
Body measurements at 6 months age					
Wither height	Female	116	132.04[b]	0.60	0.020
	Male	141	134.39[a]	0.76	
Heart girth	Female	116	143.88[b]	0.66	0.009
	Male	141	147.29[a]	0.66	
Front cannon circumference	Female	116	16.53[b]	0.09	0.024
	Male	141	16.89[a]	0.12	
Body length	Female	73	122.26	0.45	0.740
	Male	83	122.47	0.43	
Body measurements at 1-year-old					
Wither height	Female	197	141.81[b]	0.32	0.012
	Male	189	143.07[a]	0.39	
Heart girth	Female	197	156.75	0.57	0.270
	Male	189	155.79	0.65	
Front cannon circumference	Female	197	17.78[b]	0.05	0.001
	Male	189	18.05[a]	0.06	
Body length	Female	40	133.95	0.67	0.990
	Male	45	133.96	0.53	
Body measurements at 2-year-old					
Wither height	Female	38	148.47[b]	0.56	0.007
	Male	95	150.15[a]	0.31	
Heart girth	Female	38	169.11[b]	0.79	0.032
	Male	95	171.03[a]	0.47	
Front cannon circumference	Female	34	18.56[b]	0.11	0.001
	Male	74	19.31[a]	0.08	
Body length	Female	25	142.60	0.92	0.690
	Male	46	142.22	0.51	
Body measurements at 3-year-old					
Wither height	Female	10	150.50	0.93	0.130
	Male	22	152.18	0.60	
Heart girth	Female	10	175.50	1.26	0.680
	Male	22	174.91	0.76	
Front cannon circumference	Female	10	18.90[b]	0.23	0.003
	Male	22	19.68[a]	0.12	
Body length	Female	10	147.60	0.12	0.170
	Male	17	146.18	0.76	

[a]: High mean and [b]: Low mean to show as statistically importance differences in between sex groups

wither height at birth and 6 months age was at high level, selection of foals according to wither height measurements may provide genetic improvement in wither height.

Heritability of heart girth at birth, 6 months age, 1-year-old, and 2-year-old were 0.05, 0.33, 0.24 and 0.40, respectively. Except for birth, these values were in agreement with the estimates of previous studies which were between 0.26 and 0.66 for heart girth (Molina *et al*., 2003; Dario *et al*., 2006; Druml *et al*., 2008; Gharahveysi *et al*., 2008; Prado and Mota, 2008; Bakhtiari and Heshmat, 2009). Heritability estimate for heart girth at birth was 0.05. Phenotypic and genetic variance among heart girth of

Table 3: Variance components and heritability of body measurements

Traits	Record number	Stallion number	Additive genetic variance	Residual variance	Phenotypic variance	Heritability + SE
Birth						
Wither height	1597	40	1.333	10.0	11.333	0.47 ± 0.001
Heart girth	1597	40	0.096	8.16	8.256	0.05 ± 0.001
Front cannon circumference	1597	40	0.014	0.19	0.208	0.28 ± 0.08
Body length	177	19	0.609	8.79	9.399	0.26 ± 0.02
6 months age (weaning)						
Wither height	257	17	9.539	56.2	65.739	0.58 ± 0.03
Heart girth	257	17	9.159	101	110.16	0.33 ± 0.02
Front cannon circumference	257	17	0.092	1.54	1.632	0.23 ± 0.17
Body length	110	8	0.480	11.8	12.280	0.16 ± 0.02
1-year-old						
Wither height	386	15	0.912	23.6	24.512	0.14 ± 0.11
Heart girth	386	15	4.313	67.5	71.813	0.24 ± 0.15
Front cannon circumference	386	15	0.041	0.61	0.651	0.25 ± 0.14
Body length	47	7	0.423	3.22	3.643	0.46 ± 0.22
2-year-old						
Wither height	133	14	0.694	10	10.694	0.26 ± 0.26
Heart girth	133	14	2.254	20	22.254	0.40 ± 0.29
Front cannon circumference	108	11	0.010	0.465	0.475	0.08 ± 0.07
Body length	38	6	0.30	9.86	10.16	0.12 ± 0.11

Table 4: Phenotypic correlations between some body measurements at consecutive age periods phenotypic correlations

	Between birth and 6 months	Between 6 months and 1 year	Between 1- and 2-year-old	Between 2- and 3-year-old
WH	0.22^{*}	0.59^{***}	0.29^{*}	0.52^{**}
HG	NS	0.50^{***}	0.43^{**}	NS
FCC	NS	0.27^{**}	0.53^{***}	NS
BL	NS	NS	NS	0.63^{**}
n	85	125	42	31

WH: Wither height, HG: Heart girth, FCC: Front cannon circumference, BL: Body length at birth, n= record number, *: P<0.05, **: P<0.01, ***: P<0.001, and NS: Non-significant

foals at birth is small because of slow development of heart girth of fetus in uterus of mare. However, high heritability estimation for wither height may be associated with high variance as a result of fast development of wither height and development of skeleton system in uterus.

Heritability of front cannon circumference at birth, 6 months age, 1-year-old, and 2-year-old were estimated as 0.28, 0.23, 0.25 and 0.08, respectively. These values were lower than the estimates of previous studies which were between 0.30 to 0.57 (Molina *et al*., 2003; Pretorius *et al*., 2004; Dario *et al*., 2006; Druml *et al*., 2008; Prado and Mota, 2008; Bakhtiari and Heshmat, 2009). For front cannon circumference, heritability estimate of 0.08 was similar to the report of Gharahveysi *et al*. (2008) of 0.055 in Arabian horse. Heritability of front cannon circumference at 2-year-old was estimated as low value (0.08).

Heritability of body length at birth, 6 months age, 1-year-old, and 2-year-old were 0.26, 0.16, 0.46 and 0.12, respectively. These values were in agreement with the estimates of previous studies which were between 0.27 and 0.52 for body length (Pretorius *et al*., 2004; Druml *et al*., 2008; Gharahveysi *et al*., 2008) and lower than 0.72 in one study (Molina *et al*., 2003).

In horse breeding, current selection has been directed towards obtaining horses that have bigger body measurements and better racing performance, and family selection (mother and father) has been used for centuries. According to the moderate heritability estimates of this study, mass or individual selection method is suggested for the improvement of body measurements. Thus, mass selection can provide a slow increase in some body measurements over a long period of time in Turkish Arabian horses.

Heritability was estimated at moderate

level in this study and mass selection is suggested to increase body measurements of horse. In mass selection, some stallions with high body measurements are commonly used for mating of mares. Thus, the inbreeding level in horse population will increase. When mass selection is done, inbreeding and mating between relatives must be avoided.

There was risk of inbreeding associated with large book sizes and small numbers of popular stallions, shuttle stallions and artificial insemination in the thoroughbred. Mare owners should pay attention to this information at mating to decrease inbreeding coefficient.

As shown in Table 4, although correlations between birth and 6 months of age were generally non-significant, the phenotypic correlations at other consecutive age periods were generally at moderate level and significant ($P<0.001$-$P<0.05$). Thus, the measurements taken during the growth of the Turkish Arabian foals can be used in prediction of the next size of the mature horse. Generally, it can be said that correlations between three measurements (wither height, heart girth and front cannon circumference) at consecutive age periods were positive and statistically significant ($P<0.05$). Phenotypic correlations between some body measurements at consecutive age periods were lower than values reported by Baban *et al*. (2003). According to moderate phenotypic correlations estimated in this study, the measurements taken during the growth of the Turkish Arabian foals can be used for prediction of the size of the adult horse.

Although heritability of some body measurements decreased with increasing age in this study, it can be generally said that there was a trend for heritability of body measurements to increase with increasing age, in agreement with previously mentioned work (Hintz *et al*., 1978). In agreement with Suontama *et al*. (2011), it can be said that heritability for body measurements increased with the increase in foal age, and generally moderate level correlations were found between measurements at any age and measurements at next age. These results show that early selection for body measurements can be efficient in the breeding programs for horses. Whereas using some stallions for more mating in mass selection may be the reason for the increase in inbreeding in Arabian horse herds, both mass selection and family selection according to body measurements can be accurately done to increase body measurements of horses in Arabian horse breeding.

Acknowledgements

The author would like to thank the staff of Anadolu State Farm and Sinan Çilek for help during this study.

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