Study of factors affecting the body conformation traits of Iranian Turkoman horses

Hadi GHEZELSOFLOU1, Peiman HAMIDI1 and Shahabodin GHARAHVEYSI1*

1Department of Animal Science, Qaemshahr Branch, Islamic Azad University, Qaemshahr 4849167119, Iran

The Iranian Turkoman horse is considered one of the major categories of Iranian native horses. The aim of this research was to study the genetic and nongenetic factors affecting body conformation traits in Iranian Turkoman horses. For this, measurements were performed on body conformation traits of 121 horses. To study the effect of nongenetic factors, the Lsmeans procedure was used. Variance components and heritability were estimated by restricted maximum likelihood method (REML) and AI-REML convergence algorithm. The standard deviation was estimated to be 7.04 cm for croup depth and 2.08 cm for chest width, and the coefficient of variation was estimated to be 11.27% for croup length and 2.58% for withers height. Sex had a significant effect on head-neck circumference (P<0.05), withers height (P<0.05), chest width (P<0.05), and croup height (P<0.05). Province had a significant effect on withers height (P<0.05) and croup depth (P<0.05). The lowest and highest heritability estimates were for head-neck circumference (0.12 ± 0.06) and neck-body circumference (0.33 ± 0.09), respectively. The lowest and highest additive genetic variance estimates were for head length (0.64) and pelvis width (18.34), respectively. Generally, the medium to high estimated heritability for the traits in this study indicate that genetic improvement would be possible in these traits.

Key words: animal model, circumference, croup, heritability, thorax

One of the main approaches in genetic improvement strategies is to select animals having favorable traits for humans [2]. The main objective of a horse selection program is improvement of traits that are related to body conformation and gait [22]. Horse body conformation has traditionally been an important part of the breeding goal [10]. Horse selection using body conformation is a longstanding tradition in the equine industry [23]. Traditional approaches are based on visual evaluation. Since visual evaluations are subjective and differ between evaluators, it is difficult to obtain a reliable judgment. So today, this method is not effective. If traits are measured and selection of horses is performed using scientific principles, a new method would result in an accuracy of judgment that would certainly be more reliable than the traditional method. Body composition represents the physical appearance of an animal according to the arrangement of muscles, bones, and other body tissues. Thus, body conformation traits are included in the body measures. It has been demonstrated that a reliable and accurate method for evaluation of body conformation could be obtained through measurement of traits [25].

Regarding the relation between body conformation traits and horse performance traits (such as racing traits), genetic analysis of body conformation traits in a horse breeding program is very useful [17]. Before a horse reaches the age of competition, the breeder can do an indirect selection for racing performance traits [4, 6]. This reduces the generation interval and increases the genetic gain for racing performance traits. Body conformation is determined by genetic and nongenetic factors. Genetic factors such as additive genetic effect and nongenetic factors such as sex and age of the horse affect the phenotypic expression of body conformation [8, 26].

There are three horse breeds (Turkoman, Kurdish, and Asil) and one pony breed (Caspian) that are native to Iran [1, 7, 8]. Iranian Turkoman horses are one of oldest breeds in the world [7]. This breed is considered one of the major categories of Iranian native horses and has a history of more
than 2,500 years. In the beginning, they lived in the northern part of the ancient Persian Empire (including present Turkmenistan). The horse breeds mentioned above are warm blooded. Three famous strains of Iranian Turkoman horse are the Akhal-teke, Tchenaran and Yamud (Iomud) [7]. They are bred in two provinces, Golestan and North Khorasan (north of Iran), and are used for riding, competitions, and carrying loads. There are currently no reliable data obtained by scientific principles for the Iranian Turkoman horse. We performed this study to obtain reliable data for the Iranian Turkoman horse using scientific approaches and then compared the obtained data with those of other breeds.

The aim of this research was to study the effect of genetic and nongenetic factors on body composition traits in Iranian Turkoman horses by performing objective measurements of body conformation traits.

Materials and Methods

According to the geographic distribution of the Iranian Turkoman horse, the statistical population in the present study was from two northern provinces of Iran (Golestan and North Khorasan). The studied horses included 33 males and 88 females that ranged in age from 39 to 300 months. Body conformation traits of the 121 horses were measured. The numbers of horse belonging to the Golestan and North Khorasan provinces were 63 and 58, respectively. The studied horses were of the Akhal-teke strain. The pedigree file included 761 horses and 7 generations. In this study, we selected three factors (sex, age, and province) as nongenetic factors. The aim in considering the province’s effect was to find out the probable differences in factors such as management and feeding.

Traits that effected horse movement and racing performance were chosen [8, 11, 12, 20, 27]. According to standard convention, all measurements were taken on a flat, solid surface and from the left side of the horse while the horse was standing in a correct position [16, 25]. Circumference measures were taken by tape, while the other measures were taken by caliper (Fig. 1). All measurements were done by the same person.

Body conformation traits of horses

The following body conformation traits of horses were examined: 1) head length, defined as the distance between muzzle and poll; 2) neck length, defined as the distance between atlas vertebra and thoracic vertebra of the horse (distance between poll to withers); 3) head-neck circumference, defined as the circumference of the neck at connection point to head; 4) neck-body circumference, defined as the

Fig. 1. Measurements on the horse body.
circumference of the neck at the connection point to the body; 5) body length, defined as the distance between the most anterior point of humerus (greater tubercle) and most posterior point of ischium (ischiac tuber); 6) withers height, defined as the distance between the highest point of withers to the ground vertically; 7) thorax girth, defined as the circumference of the thorax along the point of withers and olecranon tuber; 8) chest width, defined as the distance between two outer points of the humeral bones from front view; 9) thorax width, defined as the distance between two hypothetical, vertical, parallel lines drawn at the two sides of the thorax and along the withers height line; 10) thorax depth, defined as the distance between the point of withers and sternum along a vertical line; 11) croup height, defined as the distance between the highest point of the croup, i.e., sacral tuber, and ground, vertically; 12) Croup depth, defined as the distance between the coxal tuber of ilium and patella (most dorsal point of the coxal tuber of the ilium and most distal point of the patella); 13) croup length, defined as the distance between the sacral tuber (the highest point of croup) and ischiatic tuber (most posterior point of ischium or point of buttock or seat bone); and 14) pelvis width, defined as the distance between the right and left coxal tuber of ilium (Fig. 1).

The statistical model used in this study was as follows:

$$y_{ijk} = \mu + S_i + R_j + b_1(x_{ijk} - x^-) + b_2(x_{ijk} - x^-)^2 + e_{ijk}, \quad (1)$$

Where $y_{ijk}=$value of each observation, $\mu=$mean effect, $S_i=$sex effect, $R_j=$province effect, $b_1=$coefficient of the linear term, $b_2=$coefficient of the quadratic term, $x_{ijk}=$age (month), $x^-=$mean of ages (month), and $e_{ijk}=$error random effect.

For study of the effect of nongenetic factors on body conformation traits and comparison of means, the Lsmeans procedure in the SAS software (version 9.1, SAS Institute, Cary, NC, U.S.A.) was used. Differences at a significance level of $P<0.05$ were considered statistically significant. Variance components and heritability were estimated by restricted maximum likelihood method (REML) and AI-REML convergence algorithm. All estimates obtained using the MATVEC software (version 1.03, Gordon Smyth, Lincoln, NE, USA). The following single-trait animal model (in matrix notation) was used:

$$y = Xb + Za + e, \quad (2)$$

Where $y=$vector of observations for body conformation traits, $X=$corresponding design matrices associating the fixed effects, $Z_a=$corresponding design matrices associating the additive genetic effect, $b=$vector of fixed effects, $a=$vector of additive genetic effect, and $e=$vector of residual effects. Fixed effects included sex, province, and age. The additive genetic effect was investigated as a random effect in the animal model.

### Results

#### Nongenetic factors

Descriptive statistics of body conformation traits are shown in Table 1. According to Table 1, the standard deviation was estimated to be 2.08 cm for chest width and 7.04 cm for croup depth. The minimum and maximum coefficients of variation were calculated for withers height (2.58%) and croup length (11.27%), respectively.

The study results for fixed effects on body conformation traits are presented in Table 2. Sex had a significant effect on the head-neck circumference, withers height, chest width, and croup height. Although significant effects of province were observed in withers height and croup depth, there were no significant effects on the other 12 body conformation traits.

### Table 1. Descriptive statistics of the body conformation traits

| Traits                  | Max (cm) | Min (cm) | Mean (cm) | SD (cm) | CV (%) |
|-------------------------|----------|----------|-----------|---------|--------|
| Head length             | 65.21    | 59.19    | 62.20     | 2.09    | 3.36   |
| Neck length             | 67.31    | 53.29    | 60.13     | 3.92    | 6.52   |
| Head neck circumference | 97.16    | 83.87    | 89.95     | 4.05    | 2.58   |
| Neck body circumference | 144.14   | 120.73   | 137.04    | 5.63    | 4.11   |
| Body length             | 177.19   | 160.42   | 171.67    | 5.54    | 3.23   |
| Withers height          | 162.39   | 151.91   | 157.09    | 4.05    | 2.58   |
| Thorax girth            | 194.33   | 177.94   | 188.04    | 6.01    | 3.20   |
| Chest width             | 41.21    | 35.79    | 38.93     | 2.08    | 5.34   |
| Thorax width            | 69.93    | 53.51    | 60.03     | 5.17    | 8.61   |
| Thorax depth            | 87.35    | 69.77    | 80.83     | 6.11    | 7.56   |
| Croup height            | 162.12   | 147.49   | 156.13    | 5.21    | 3.33   |
| Croup depth             | 74.33    | 51.95    | 66.84     | 7.04    | 10.53  |
| Croup length            | 68.92    | 51.69    | 60.23     | 6.79    | 11.27  |
| Pelvis width            | 57.14    | 45.38    | 51.04     | 3.98    | 7.80   |

SD, standard deviation; CV, coefficient of variation.
traits (Table 2). The effects of the coefficients of the linear term of each observation of head length, neck length, neck-body circumference, body length, thorax girth, and pelvis width on age were significant. The effects of the coefficients of the quadratic term of each observation of head length, neck length, neck-body circumference, body length, thorax girth, and pelvis width on age were significant.

**Genetic factors**

Variance components and heritability estimates are presented in Tables 3 and 4. The lowest and highest heritability estimates were for head-neck circumference (0.12 ± 0.06) and neck-body circumference (0.33 ± 0.09), respectively. The minimum and maximum of additive genetic variance estimates were for head length (0.64) and pelvis width (18.34), respectively. The environmental variance ranged from 3.24 for chest width to 39.15 for croup depth. Finally, the minimum and maximum of phenotypic variance estimates were for chest width (4.33) and pelvis width (60.84), respectively.

### Table 2. Mean comparisons of the body conformation traits

| Traits                      | Factors                      | Sex Male (cm) | Female (cm) | Province Golestan (cm) | North Khorasan (cm) |
|-----------------------------|------------------------------|---------------|-------------|------------------------|---------------------|
| Head length                 |                              | 62.19a        | 61.89a      | 61.41a                 | 62.09a              |
| Neck length                 |                              | 61.46a        | 61.16a      | 62.18a                 | 61.99a              |
| Head neck circumference     |                              | 90.14a        | 86.05b      | 89.23a                 | 88.89a              |
| Neck body circumference     |                              | 136.78a       | 136.06a     | 137.81a                | 137.19a             |
| Body length                 |                              | 172.10a       | 171.91a     | 172.54a                | 172.39a             |
| Withers heights            |                              | 159.08a       | 154.11b     | 158.93a                | 153.82a             |
| Thorax girth                |                              | 188.09a       | 188.34a     | 188.54a                | 188.33a             |
| Chest width                 |                              | 39.10a        | 35.06b      | 38.25a                 | 38.45a              |
| Thorax width                |                              | 60.29a        | 59.90b      | 60.91a                 | 60.05a              |
| Thorax depth                |                              | 80.16a        | 80.23a      | 80.41a                 | 80.89a              |
| Croup height                |                              | 159.03a       | 153.94b     | 157.12a                | 156.83a             |
| Croup depth                 |                              | 66.90a        | 66.61a      | 69.89a                 | 64.70b              |
| Croup length                |                              | 60.97a        | 60.12a      | 60.10a                 | 60.43a              |
| Pelvis width                |                              | 51.81a        | 51.45b      | 51.90a                 | 51.41b              |

Means within a row with different superscripts differ significantly ($P<0.05$).

### Table 3. Variance component and heritability of the head, neck, and croup traits

|                | HL  | HNC | NBC | NL  | CH  | CD  | CL  |
|----------------|-----|-----|-----|-----|-----|-----|-----|
| $\sigma^2_A$  | 0.64| 2.82| 10.52| 2.86| 6.35|10.41| 11.70|
| $\sigma^2_E$  | 3.73|20.41|21.18|12.51|20.79|39.15|34.40|
| $\sigma^2_P$  | 4.37|23.23|31.70|15.37|27.14|49.56|46.10|
| $h^2 \pm SE$  | 0.15±0.07| 0.12±0.06| 0.33±0.09| 0.19±0.07| 0.23±0.08| 0.21±0.08| 0.25±0.07|

$\sigma^2_A$, additive genetic variance; $\sigma^2_E$, environmental variance; $\sigma^2_P$, phenotypic variance; $h^2$, heritability; SE, standard error; HL, head length; HNC, head-neck circumference; NBC, neck-body circumference; NL, neck length; CH, croup height; CD, croup depth; CL, croup length.

### Table 4. Variance component and heritability of the thorax traits, body length, withers height, and pelvis width

|                | TG  | TW  | TD  | CW  | BL  | WH  | PW  |
|----------------|-----|-----|-----|-----|-----|-----|-----|
| $\sigma^2_A$  | 6.50| 4.94| 5.97| 1.09| 7.49| 4.23| 18.34|
| $\sigma^2_E$  | 29.62| 21.79| 31.36| 3.24|23.20|12.17|42.50|
| $\sigma^2_P$  | 36.12|26.73|37.33|4.33|30.69|16.40|60.84|
| $h^2 \pm SE$  | 0.18±0.05| 0.18±0.05| 0.16±0.09| 0.25±0.08| 0.24±0.08| 0.26±0.08| 0.30±0.08|

$\sigma^2_A$, additive genetic variance; $\sigma^2_E$, environmental variance; $\sigma^2_P$, phenotypic variance; $h^2$, heritability; SE, standard error; TG, thorax girth; TW, thorax width; TD, thorax depth; CW, chest width; BL, body length; WH, withers height; PW, pelvis width.
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Discussion

Nongenetic factors

In this study, we evaluated factors affecting body conformation traits by measuring objective parameters. It was reported that the coefficients of variation were 2–8% in the Brazil Pantaneiro horse [13] and 2.1–6.7% in Hungarian Thoroughbred broodmares [3]. It was also reported that the coefficients of variation for croup height and croup width in the Pura Raza Espanola horse were 2.3 and 9.3%, respectively [17]. Although the coefficients of variation obtained in the present study (2.58–11.27%) were slightly larger than those in previous reports, most parameters showed similar values within an acceptable range.

The findings of the present study indicate that Iranian Turkoman horses are larger than other Iranian horse breeds [7, 8]. They also have large bodies compared with Polish Arab horses [18], Polish warmblood stallions [5], and Spanish purebred horses [9]. Since it was demonstrated that body conformation measurements were influenced by nongenetic factors such as sex, age, and horse management [4], these factors should be considered when body conformation data are used in horse selection and genetic analysis. In a study on the Arab horse in Egypt, sex had a significant effect on most of the traits [15]. In another study on Finnhorse trotters with a minimum age of 48 months and mean age of 78 months, the year-sex effect had an influence on body measures [21]. Moreover, age had an important influence on all traits with the exception of height at the withers and body conformation. The results of the abovementioned study are in agreement with findings of the present study in terms of age and sex. According to the results of a study on Posavje horses that were 30 to 60 months of age, age did not have a significant effect on any trait with the exception of body length [19]. This finding was confirmed by the results for effects of the coefficients of the quadratic term of each observation of body length on age. Meanwhile, we observed a significant effect of province for some reason. In our study, although significant effects of province were observed in withers height and croup depth, the reason is uncertain. Since the two provinces studied in this research are neighbors and located in northern of Iran, the reasons why significant effects of province were not observed in most body conformation traits likely included the similarity in factors such as weather conditions, vegetation, feeding, and breeding in both provinces.

Genetic factors

The heritability estimates for body conformation traits obtained in the present study ranged from 0.12 to 0.33. These values were similar to the results reported for Arabian horses (0.14–0.55) [16], Polish warmblood horses (0.14–0.87) [5], old Kladruber breed (0.04 to 0.65) [24], Iranian Arab horses (0.05–0.61) [8], Iranian Thoroughbred horses (0.22–0.49) [1], Andalusian horses (0.35–0.95) [14], Brazil’s Pantaneiro horse (0.27–0.83) [13], German purebred Arab horses (0.05–0.16) [18], and Finnhorse trotter (0.53–0.78) [21]. It is considered that genetic parameters such as heritability are influenced by gene frequency, estimation method, statistical model, and trait nature [6]. Since there may have been differences in the factors used in each study, slight differences in values between the present study and previous studies might be attributable to those differences.

The medium to high estimated heritability for the traits in the current study indicate that genetic improvement would be possible in these traits [6]. Horses for any activity should have the appropriate body conformation. Body conformation traits can be used for horse evaluation.

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