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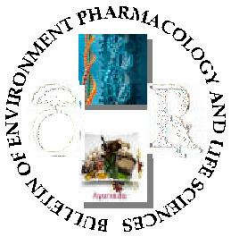

ORIGINAL ARTICLE

Assessment of Body Measurement Characteristics of Iranian Turkmen and Caspian horses

Mohammad Bagher Zandi, Ardeshir Nejati Javaremi, Abbas Pakdel
Department of Animal Science - Faculty of Agricultural Science and Engineering College of Agriculture and Natural Resources - University of Tehran - Karaj – Iran

Email: javaremi@ut.ac.ir

ABSTRACT
Historical and archeological evidences trace some Iranian horse breeds back to about five thousand years ago. These breeds of horses may be useful in investigating the origin of domestic horses and consequent migration pathways. We used phenotypic records of two of the Iranian horse breeds, namely, Turkmen and Caspian to estimate population parameters for different body measurements. Thirty different body measurements were made and the analysis led to a final group of 17 body measurements to be selected as distinctive characters to distinguish between the breeds. Data were analyzed using principal components analysis (PCA) approach using SAS, R and XLSTAT software. Results showed that PC1 and PC2 explained 73% of the total variations. The PC1 showed high correlation with the height at shoulder (HS), circumference of front cannon (CFC) and the circumference of hind cannon (CHC). Therefore, these traits may be helpful in differentiating between the members of the two breeds. Results also demonstrated that these two populations have completely different metric properties for their conformation and body size characteristics. The present results confirm that morphological traits are proper and simple tools for classification and differentiation of the horses of these two breeds. These results may be used as tools for whole genome studies to identify quantitative trait loci that cause the differences between these two breeds.
Key word: *Turkmen and Caspian horse, Principal components analysis, skeletal variation*

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INTRODUCTION

According to the historical and archeological evidences Iranians were engaged in the domestication and breeding of horses since long years ago [1].The history of domestication of horses in Iran returns back to five thousand years ago. Due to wide range of climatic conditions of the Iranian plateau and outbreeding between eastern and western breeds of horses, high variation exists among equine species of this region. Horses were first domesticated in Eurasia about six thousand years ago and were among the first animals that Iranians started to breed them.

The horse generally has an important role in the human cultures around the world. Since domestication, the focus of breeding has been to improve the horses' usefulness to man [2].In the past, the purpose of horse breeding was for their use in agriculture, transportation, wars, race and riding. But nowadays, horses are bred for entertainment, recreation and sport [1].

In Iran there are about 1,727,000 heads of mono-dactyls animals out of which 200,000 are horses, 122,000 are mules and the rest are donkeys.The interest toward conservation and characterization of the horses has increased over the recent years because of their growing importance [3].

Iranian horses are warm-blooded which include famous breeds of horses like Turkmen in the north east, Arab in the south- west and Kurd horses in the west and in the north- west of the country. The Turkmen and Caspian horses are the only forms of the original types of the native horse. The Turkmen horse is primarily bred to be a rideable and talented sport horse with good abilities for the discipline racing, jumping, eventing and driving [4]. These breed of horses are mainly located in the north- east of Iran, generally bred by Turkmen people. Another population of horses exists between the southern shores of the Caspian Sea and the northern skirts of the Elborz mountain ranges. These populations of horses have not been given a specific breed name and instead are called the horses of the northern Iran. Among this breed of horses exist a very small proportion of miniature horses with significantly smaller body size than

their coexistent members of the larger population which have been called the Caspian Horse. It should be noted that the so called Caspian horses have, through the history, been as integrated part of the larger population of the horses of Northern Iran. However, their body measurements significantly differ from the rest of the population. It is obvious that this sub population of horses have strong genetic relationship with the rest of the population as there are no systematic mating systems to separate them from the rest of the population. It is commonly believed that the miniature horses have better capability to adapt to the high mountains and forest areas of the northern skirts of the Elborz region. Severe mountainous conditions have had an influence on their small height and other primitive traits [5]. It is believed that the Caspian breed might have been originated from the crossing of many breeds for centuries [6].

The number of Caspian horses in the world is about 700 heads out of which 500 heads are available in Iran. They are used for riding by teenagers, show jumping and circus shows [3].

Conformation evaluation and accurate biometric measurements may be used to determine the breed characteristic indexes. These have not been reported for the two Iranian breeds of Turkmen and Caspian horses.

Analysis of metric traits is an ongoing research trend in the field of horse breeding as well as in investigations of their origin [8, 9].The horse, like other domestic animals, is comprised of many inbred and highly selected breed populations. Like all domestic mammals, the horse has experienced intense selection for certain traits and therefore the horse body size varies greatly due to intense selection within each breed [10].

Quantitative measurements from morphological traits of the horses have been reported in several studies [8, 9, 7 11]. In each case only one or several foreign horse breeds had been studied, but the similar research has not been done for Iranian native horse breeds.

The main purpose of this research was to study the morphological variation between the Caspian and Turkmen horse breeds. We used principal component analysis (PCA) of 17 characters measured on head, neck, abdomen and limbs. PCA is a statistical procedure that uses orthogonal transformation to convert a set of observations of possible correlated variables into a set of values of linearly uncorrelated variables, namely, "principal components" [12]. This kind of research will be useful in surveying the signature of selection between these two populations.

MATERIALS AND METHODS

In this study, 17 different body measurements from 30 Caspian and 45 Turkmen horses were used as described in Table 1 and Figure 1.

Samples:

The samples were collected from living animals, and the measurements were taken from the left side of the animals. All the horses were evaluated on a level, hard surface and the horses were held by the staff of the stud or by the horse owners.

The study was performed on horses from different breeding systems (pasture, closed, horse championship and etc.), and different environmental conditions (Tehran, Alborz , Guilan and Mazandaran provinces for the Caspian; and North Khorasan , Tehran , Alborz , Golestan, Mazandaran and Isfahan provinces for Turkmen)(Figure 2). All the horses were adult in terms of physical growth and had reached to skeletal maturity with the ages 4 to 30 years.

Traits:

The Brooks et al. [8] protocol for body measurement of live horses (Figure 1) was modified in this study. Thirty parameters were measured on each horse (29 characters in the Figure 1 plus body condition score). Not of the thirty characters were measured for all of the horses because some horses were not calm and could not be comfortably constrained. Therefore, only 17 of the characters that have been measured on all horses have been used in the analysis.

Table 1 shows the list of the 17 characters that have been used in our analysis. Quantitative measurements were made by standard equipments including standard measuring sticks, nonelastic measuring tape, and caliper dedicated to biometric measurements. Other information such as age of the horse, registration number and microchip number, photo, name of the breeder/owner, geographic information, names of parents with biometric measurements were taken.

Table1. The list of 17 characters used in the analysis with description

Traits	Abbreviation	**Variables Number in the Figure1**	Description of the variables
Length of head	LH	1	Starting between the top corners of the two nostrils, measure straight to the

			front of the poll(poll to muzzle)
Throat latch circumference	TL	4	Settle the tape where the throat latch of the bridle goes.
Length of neck	LN	6	Measure from the poll to the withers, with horses head level with the withers
Heart girth circumference	HGC	9	Settle the measuring tape where the girth of the saddle fits, directly behind the forelegs.
High shoulder	HS	8	Measure from the ground to the highest point of the withers. Keep the tape taut and straight.
Length of underline	LU	14-1	Measure from the point of the elbow to the stifle joint.
Length of stifle from the sideview	LS	14-2	Measure from the end of underline joint to the back point of stifle.
Length of front cannon	LFC	11-1	Measure from the back of the knee cap to the ergot
Circumference of front cannon	CFC	11-2	Measure around the cannon bone halfway between the knee and the ergot.
Length of hind cannon	LHC	22-1	Measure from the point of the hock to the ergot
Circumference of hind cannon	CHC	22-2	Measure around the cannon bone halfway between the hocks to the ergot.
Length of front pastern	LFP	12-1	Measure from the bottom of the fetlock joint to the top of the coronet.
Circumference of front pastern	CFP	12-2	Measure around the front pastern.
Length of hind pastern	LHP	23-1	Measure from the bottom of the fetlock joint to the top of the coronet.
Circumference of hind pastern	CHP	23-2	Measure around the hind pastern.
Length of forearm	LF	10	Measure from the point of the elbow to the back of the kneecap.
Length of gaskin	LG	21	Measure from the stifle joint to the point of the hock.

Statistics and data edition:

The descriptive statistics of studied traits are given in Table 2.Principal components analysis (PCA)[20] was applied in this study. This method was used to decrease the dimension of analysis and clustering the animals into two groups of Caspian and Turkmen horses. By using the PCA analysis it was possible to assess the morphological differences between animals of both populations on a 2-dimensional diagram. Data were analyzed using SAS, R13-2 and XLSTAT software.

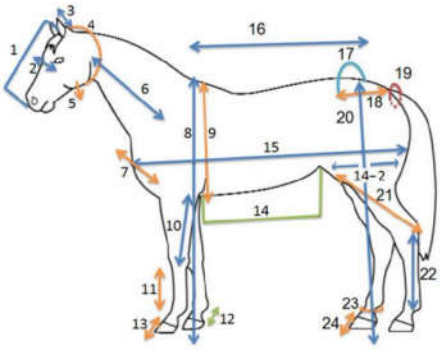

Fig 1 **Fig 2**

Figure 1.Measurements of biometric parameters recorded for Caspian and Turkmen:1-Head length, 2-Eye to eye width, 3- Ear length, 4- Throat latch circumference, 5-Jaw width, 6- Length of neck, 7-Chest width, 8- High shoulder, 9- Heart girth circumference, 10-Length of forearm, 11- Length and circumference of front cannon, 12-Length and circumference of front pastern, 13-For Hoof length, 14-

Length of underline, 14-2-Length of stifle from the side view, 15- total body length, 16-Withers to croup length, 17- Hip to hip length, 18, Hip to basal tail length, 19- Circumference the basal tail, 20-High at croup, 21 -Length of gaskin, 22- Length and circumference of hind cannon, 23- Length and circumference of hind pastern, 24- Hind Hoof length.

Figure 2. Geographical location of sampling record for two Iranian horse populations. Green color is Turkmen and violet color is Caspian.

RESULT

The descriptive statistics for the traits in the two horse populations are shown in Table 2.For all the measurements, the means for Caspian's were lower than Turkmens and the results showed moderate to low coefficient of variation, which in Caspian horses, the obtained the highest coefficient of variation(11.61) and the LF the lowest (1.23), whereas in Turkmen horses the HGC obtained the highest standard deviations(18.62) and the LFP the lowest (2.45).

Table 2. Descriptive statistics for the traits in two horse populations (Caspian and Turkmen)

Population		Caspian			Turkmen		
Variable(CM)	Abbr	Num	Mean(cm)	CV(%)	Num	Mean(cm)	CV(%)
Length of head	LH	30	47.06	2.04	45	55.45	5.33
Throat latch circumference	TL	30	59.17	3.21	45	73.00	7.63
Length of neck	LN	30	47.56	5.14	45	59.79	10.85
Heart girth circumference	HGC	30	139.83	9.55	45	171.00	18.62
High shoulder	HS	30	123.72	11.61	45	152.62	13.11
Length of underline	LU	30	65.50	2.96	45	84.64	10.13
Length of stifle from the sideview	LS	30	28.67	2.87	45	36.85	15.23
Length of front cannon	LFC	30	21.78	7.30	45	27.79	8.99
Circumference of front cannon	CFC	30	14.72	2.88	45	18.79	4.66
Length of hind cannon	LHC	30	30.83	6.05	45	40.76	6.83
Circumference of hind cannon	CHC	30	16.33	4.85	45	20.88	5.71
Length of front pastern	LFP	30	9.06	2.67	45	12.15	2.45
Circumference of front pastern	CFP	30	14.78	7.48	45	18.38	9.44
Length of hind pastern	LHP	30	8.78	10.78	45	13.30	12.28
Circumference of hind pastern	CHP	30	15.56	5.16	45	19.52	9.92
Length of forearm	LF	30	36.06	1.23	45	48.61	5.90
Length of gaskin	LG	30	43.33	5.20	45	52.79	8.22

Abbr: The abbreviation of variables , Num: Number of samples, CV: Coefficient of Variation

In the current study the correlation matrix was used, rather than the covariance matrix, for PCA analysis because of the large variation in scale between different measures (from 1.71 meters in high at wither to 10 cm in Length of front pastern).

The Pearson correlation coefficients of variables are shown in Table 3. The estimated correlations among variables were positive and ranged from 0.20 for HGC and LHC to 0.91 for CFC and CHC. These high estimates were expected because variables are correlated with each other. The body size of horse is a function of many characters, and the use of Pearson correlation is a suitable statistical tool for the analysis. PCA produced linear combinations of the 17 variables to generate the axes, also known as PC1 to PC17 (Table 4).The PCA analysis revealed 2 principal components (PC1 and PC2) with eigenvalues greater than 1.0. These two components jointly explain about 73% of the total variation. PC1 explained 66.58% of the variance and PC2 explained 6.58 %(Table 4). The next stage of the analysis consisted of selection of characters that are related to a given component to the greatest degree. After performing the varimax rotation, each variable was given a load, which is a correlation coefficient reflecting the correlation of a variable with a given component (Table 4). Values of principal components 1 and 2are plotted in Fig. 3. The Turkmen obtained the large median for PC1 values, while the Caspian showed the low PC1 values (Figure 3).

The powerful component, PC1, was surely linked with 3 out of 17 characters, namely, HS, CFC and CHC. Whereas, PC2 was correlated with HGC, LU and LS (Table 5).

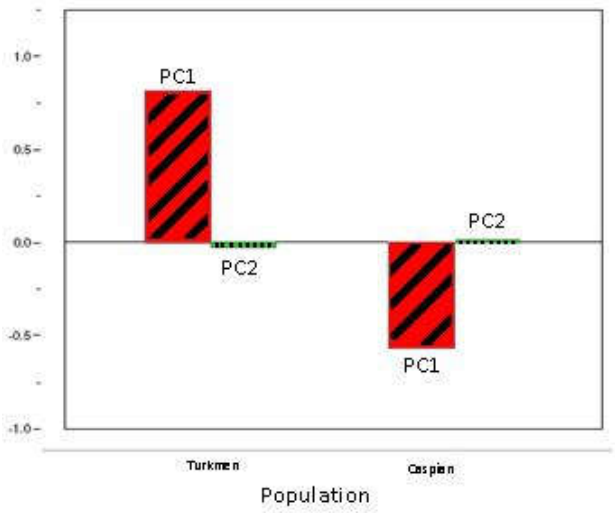

Figure 3- Principal component analysis factor loadings of the populations (Turkmen and Caspian) onto principal component 1 and principal component 2 for the all measured horses

Table 3. The Pearson correlation matrix (Pearson (n))of variables:

Variables	LH	TL	LN	HGC	HS	LU	LS	LFC	CFC	LHC	CHC	LFP	CFP	LHP	CHP	LF	LG
LH	1.00																
TL	0.67	1.00															
LN	0.55	0.67	1.00														
HGC	0.62	0.69	0.57	1.00													
HS	0.73	0.83	0.57	0.73	1.00												
LU	0.50	0.57	0.45	0.59	0.71	1.00											
LS	0.25	0.47	0.33	0.59	0.57	0.48	1.00										
LFC	0.77	0.80	0.65	0.71	0.76	0.54	0.36	1.00									
CFC	0.74	0.81	0.71	0.75	0.80	0.55	0.35	0.86	1.00								
LHC	0.38	0.50	0.34	0.20	0.42	0.29	0.24	0.50	0.45	1.00							
CHC	0.72	0.85	0.60	0.75	0.84	0.57	0.41	0.82	0.91	0.44	1.00						
LFP	0.71	0.80	0.61	0.68	0.78	0.51	0.29	0.75	0.88	0.44	0.84	1.00					
CFP	0.66	0.72	0.57	0.68	0.74	0.48	0.27	0.78	0.88	0.34	0.87	0.76	1.00				
LHP	0.52	0.69	0.51	0.55	0.70	0.49	0.33	0.62	0.68	0.40	0.66	0.70	0.66	1.00			
CHP	0.67	0.71	0.58	0.64	0.76	0.57	0.29	0.67	0.81	0.44	0.84	0.78	0.79	0.65	1.00		
LF	0.69	0.73	0.62	0.73	0.77	0.55	0.35	0.73	0.83	0.41	0.80	0.76	0.76	0.71	0.78	1.00	
LG	0.64	0.80	0.65	0.74	0.78	0.55	0.39	0.80	0.82	0.37	0.80	0.76	0.79	0.62	0.62	0.71	1.00

Table 4: Eigenvalues, percent variability and cumulative percent with their plot for each PC(Fi).

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	sum
Eigenvalue	11.32	1.12	0.86	0.61	0.53	0.49	0.39	0.36	0.28	0.24	0.19	0.17	0.15	0.10	0.07	0.07	0.05	17
Variability (%)	66.58	6.58	5.07	3.60	3.10	2.87	2.27	2.14	1.67	1.41	1.10	0.99	0.88	0.59	0.44	0.42	0.29	100
Cumulative %	66.58	73.16	78.23	81.82	84.92	87.79	90.06	92.20	93.88	95.29	96.39	97.38	98.26	98.85	99.29	99.71	100	100

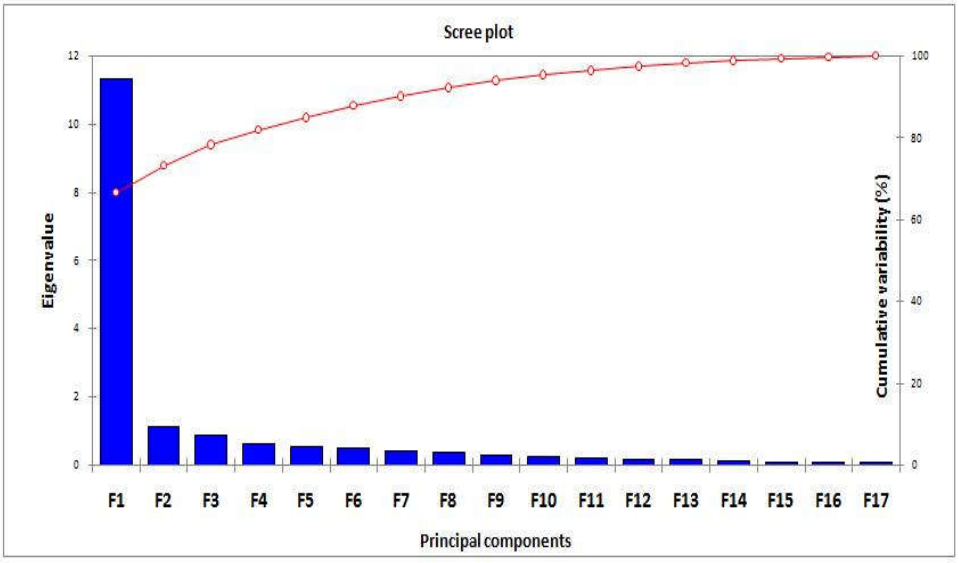

Table 5: The variables Contribution and Correlations between variables and PC

Variables	Contribution of the variables (%)		Correlations between variables and PC	
	PC1	PC2	PC1	PC2
LH	0.632	0.021	0.795	-0.146
TL	0.806	0.001	0.898	0.030
LN	0.527	0.000	0.726	-0.020
HGC	0.668	0.096	0.817	0.310
HS	0.827	0.037	0.909	0.191
LU	0.454	0.161	0.674	0.401
LS	0.232	0.618	0.481	0.786
LFC	0.786	0.010	0.887	-0.102
CFC	0.887	0.024	0.942	-0.153
LHC	0.252	0.035	0.502	-0.188
CHC	0.875	0.005	0.936	-0.068
LFP	0.785	0.037	0.886	-0.191
CFP	0.756	0.039	0.869	-0.198
LHP	0.583	0.004	0.764	-0.062
CHP	0.724	0.025	0.851	-0.159
LF	0.766	0.006	0.875	-0.075
LG	0.758	0.000	0.871	0.012

DISCUSSION

The body size and conformation characters are important traits in the horses and are presumably under strong selection. Body conformation varies widely among different breeds and even between different subpopulations and lines of the same breed [13]. Differences between the body characters of the two breeds may be related to the preferences of the breeders of the two breeds for different types of the horse during the centuries as well as the impact of geographic and climatic differences the two breeds have been raised.

The correct skeletal conformation is a key determinant of body type. Morphological traits in the horse are interesting because they are associated with desirable characterization and performance traits [14]. Standard metrics of Caspian horses have less variation around the average values, but the Turkmen horse showed more variation than Caspian horse when we compared the coefficients of variation of all 17 parameters (Table, 2). It can be concluded that the Turkmen horses are mixed population while the horses we sampled were not separated into subpopulations., In the literature the Turkmen horses are classified into two major subpopulations, namely, Yamud, with their lower height at shoulder (HS), and Akhal-Teke which are characterized by their higher HS and strong build [15, 6].

Turkmen horses were often used for riding and transporting in both mountainous and plain areas; therefore, their body conformation became typical for this kind of activities. In addition, the body size of Turkmen horses is another trait that is usually considered as a race horse.

Caspian horses are similar, in appearance, to the other breeds of horses like Turkmen, Arab, Kurd, etc. However, from the body size point of view they are smaller than the other breeds and for that reason they are known as miniature horses. Their environment such as severe mountainous and forest conditions might have had an influence on their small height and other primitive traits.

Two-dimensional plot summarized the patterns of variation of the populations measured for all parameters by using two main factors identified by the principal component analysis. PC 1 clearly differentiates between the Turkmen and Caspian horses. Turkmen horses are grouped together with high PC1 scores; whereas the Caspian horses have low PC1 scores (Figure, 3). The PC1 showed high correlation with the HS, CFC and CHC.PC1 is a single value for each horse that incorporates measurement data from all characters of each horse. This may be used for signature of selection and QTL mapping studies.

In horses the conformation traits are correlated with their performance. For example, height at withers of mature horses is positively correlated with racing performance [17] and stride length [16]. Yearling measurements can be used to predict mature dimensions with reasonable accuracy [18], conformation measurements of yearling Thoroughbreds have predictive value for their future racing performances [19]. Moreover, well balanced animals achieve better market prices. Therefore, these traits are important and can be used in the evaluation and selection of Iranian native horses.

Here, we have described skeletal variation in the two horse breeds as two key axes of variation, PC1 and PC2. This information provide a solid foundation for future mapping studies that will define the genetic control of body size and shape in the Turkmen and Caspian horses.

CONCLUSION

It can be concluded that the Turkmen and Caspian horses are characterized by significantly different standard metrics. In terms of body metric traits, Caspian horse is more uniform than Turkmen horse. However, this may be due to the fact that Caspian horses are chosen from their larger population based on stricter body measurements. Considering that samples selection was based on morphological characters such as height at wither and body size in the two populations, we have described skeletal variation in these two populations as two key axes of variation, PC1 and PC2.

PC1 is a single value for each horse that integrates measurement data from all over that horses morphological traits; it can be easily applied to sweep signature studies. Furthermore, PC1 clearly separates horse breeds based on the more traditional description of body size. Turkmen horses are grouped with high PC1 scores (Fig. 3) and the Caspian have low PC1 scores.

The PC1 showed high correlation with the HS, CFC and CHC. These traits may be affected by artificial selection and at the first step this trait must be considered in genomic survey to determine the signature of selection.

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