IJCIMR

International Journal of
Clinical Images and Medical Reviews

Original Research

Sexual head profile differences in celoid horses assessed by geometric morphometrics

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Abstract

In the present study, we applied landmark-based geometric morphometrics to explore components of head profile variation (front and face) between sexes among celoid (concave) horses. For this purpose, the heads of 92 celoid adult horses -Pure Arabians and their F1 crosses- were photographed in lateral view. Our results showed that there are significative differences between stallions, mares, and geldings. This is the first attempt to make this evaluation in a geometric way.

Keywords: Celoid; cirtoidism; equine skull; ethnology; nasofacial profile; sexual dimorphism.

Introduction

The use of shape analysis is one approach to understanding the causes of variation and the morphological transformation of animals due to selective breeding. Head shape plays a prominent part in the definition of equine breeds [1]. There is a lack of objective methods to quantify skull profiles. In 1978, Dusek made an attempt to quantify the curve of the nasofacial profile of the Kladrub horse [3]. The Dusek method assumes the skull has a regular curve, something that seems unlikely even in this rather stylised breed. Evans and McGreevy [3] calculated the area created under the curve of the profile. Anyway, due to scale problems with linear measures, these studies do not take into account the morphological complexity of head. Among zoometric methods, one of the most advanced -but scarcely used for animal ethnology- is geometric morphometrics (GM), which is the study of the shape variation and how it covariates with other variables.

GM is a method based upon the Cartesian coordinates of landmarks which preserves the geometry configuration by allowing a statistical representation of real forms. GM relies on the detection of homologous landmarks (x, y coordinate points which are quantified as Cartesian (i.e., x, y, z) coordinates) to explore the morphospace of objects. After standardizing landmark configurations for overall position, scale, and orientation, the resulting shape coordinates represent the shape of the configurations only, whereas the overall size of the configurations is explicitly represented by a single variable: centroid size (CS), a standard measure of the overall size of a landmark configuration. So, GM deconvolutes form, separating the effects on shape that are due to, or independent of size. It is also amenable to visual representation of shape variation. Equine studies have used traditional morphometric studies for [2], sexual dimorphism [7] ontogenetic skull changes [6], postures [9], functionality [5]. However, GM appears to have been never used for the study of skull profile

Considering the analytical advantages of GM, the purposes of this study were:

1. To evaluate quantitatively the nasofacial profile of celoid horses (concave head profile) using geometric morphometric techniques.

2. To assess the strength of the association between craniofacial shape and the head size and to determine the extent to which it might be possible to predict the latter from the former.

3. This is the first attempt to make this evaluation in a geometric way.

Materials and Methods

Sample

AWe used 92 original digital head pictures (15 stallions, 47 mares and 30 geldings) taken in left lateral norm, aged more than 2 years, on celoid horses (Arabian, Anglo-Arabian. Hispano-Arabian, Arabian-appaloosa, Thoroughbred and mixed). The photographs included

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Citation: Parés-Casanova PM. Sexual head profile differences in celoid horses assessed by geometric morphometrics. IJ Clin Img and med Rew. 2022; 1(1): 1019.

Received: Dec 12, 2021 Accepted: Jan 01, 2022 Published: Jan 12, 2022

a metal piece on their cheek to facilitate calibration by the software. Only horses without signs of head alterations were included. The lateral pictures originated from different private owners and breeders. Second author (CC) was responsible of this part.

Geometric morphometrics

The sample collected was studied by geometric morphometrics. A total of landmarks (5) and semi-landmarks (14) were collected on each head (left side) with the software TpsDig version 1.40 [8] (Figure 1). The present study goes further by modelling more precisely and more extensively the head outline of the horse. This structure can be considered as a homologous curve between subjects and can thus be accurately described and studied with points that don't need to be homologous, i.e., semilandmarks. Semilandmarks are points on smooth curves, for which the exact location on the curve cannot be identified and hence is statistically estimated. The principle is to draw a curve with arbitrarily placed semilandmarks and then to optimize the position of each of them by allowing them to slide along the curve. After sliding the semilandmarks, landmark configurations were superimposed by Generalized Procrustes Analysis, a least-squares oriented registration technique, standardizing position, scale, and orientation of all configurations.

Size requires certain evaluation because traits are allometrically related to the organism's size. For this purpose, a multivariate regression assessed the effect of size (CS as independent variable) in shape changes (Procrustes coordinates). To test the null hypothesis of independence of the variables, a non-parametric permutation test of 10,000 rounds was applied. Then, a Canonical Variate Analysis (CVA) was performed to study differences between genders. And finally, to explore general shape variation, a Principal Component Analysis (PCA) was used. For all statistical analyses, we used MorphoJ software version 1.07a [4] with $\alpha = 0.05$.

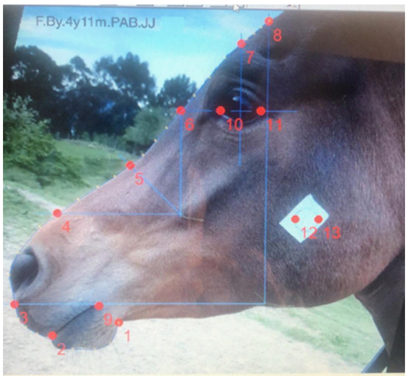

Figure 1: A total of 5 landmarks (big dots, numbered 4 to 8) and 14 semi-landmarks (small dots) were collected on each head (left side). Landmarjs 12 and 13 represents a ruler (e.g. a pattern of known distance).

Results

Allometry

Multivariate regression showed that a 6.30% of the shape variation was explained by size variation (p=0.0057), so for ulterior analysis, regression residuals were used.

Canonical Variate Analysis

CVA reflected statistical differences between genders (p<0.04 for Mahalanobis distances among groups). On the plot, first axis explained a 70.96% of the variance and second one, a 29.03% **(Figure 2)**.

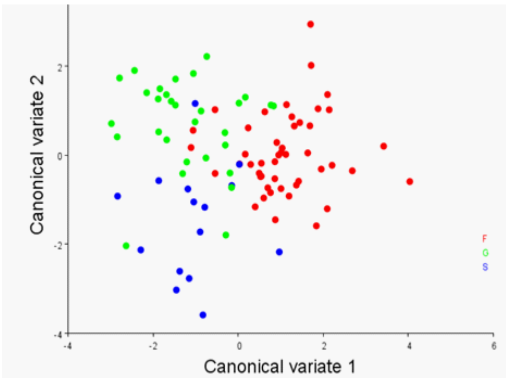

Figure 2: Canonical Variate Analysis. It reflected statistical differences between genders (15 stallions S, 47 mares F and 30 geldings G). On the plot, first axis explained a 70.96% of the variance and second one, a 29.03%.

Principal Component Analysis

First two components for PCA explained 84.88% of the total observed variance (PC1+PC2=72.95%+11.93%) (**Table 1**).

Table 1: Results for the Principal Component Analysis. First two principal components (PC) explained 84.88% of the total observed variance (PC1+PC2=72.95%+11.93%). Most discriminative values (>[0.3]) appear in bold.

	PC1	PC2
x1	0.0335	-0.0783
y1	0.2535	-0.1623
x2	-0.0086	0.0466
y2	-0.1875	0.1707
x3	-0.0386	0.0519
y3	-0.1717	0.2281
x4	-0.0277	-0.0359
y4	-0.2330	**-0.4541**
x5	0.0605	-0.0176
y5	**0.4026**	0.2137
x6	0.0061	-0.1098
y6	**0.3360**	**-0.3765**
x7	0.0388	-0.0314
y7	0.1666	-0.0218
x8	0.0311	-0.0030
y8	0.0333	0.0570
x9	0.0106	0.0304
y9	-0.0875	0.1216
x10	-0.0086	0.0540
y10	-0.1828	0.2163
x11	-0.0165	0.0454
y11	-0.1838	0.2282
x12	-0.0273	0.0433
y12	-0.1771	0.2371
x13	-0.0388	0.0588
y13	-0.2041	0.1126
x14	-0.0415	0.0507
y14	-0.2161	-0.1297

x15	-0.0421	0.0101
y15	-0.2146	-0.3351
x16	-0.0187	-0.0296
y16	-0.0937	-0.2772
x17	-0.0011	-0.0353
y17	0.0869	-0.1093
x18	0.0280	-0.0328
y18	0.2706	0.0621
x19	0.0610	-0.0177
y19	**0.4025**	0.2185

Discussion

There is no muscle tissue covering the frontal and nasal bones, only skin, superficial fascia and deep fascia. Therefore, the proposed digital method can be close and consistent approximations of the underlying bony structures, the head profile in the studied case so we propose geometric morphometric techniques as a good tool to assess head profile. Head profile appears different between genders, being differences mainly on front profile while face profile shows less differences.

Conflicts of Interests: The authors declare no conflicts of interest.

Acknowledgements: We thank owners for their kind support in allowing us the access to their animals. We are also grateful to anonymous reviewers for their insightful recommendations.

Authors' Contribution: PMPC designed the study and directed implementation and tissue collection. CC spanned pictures and obtained landmarks from them. Both authors analysed the data.

Supporting Information: The contents of all supporting data are the sole responsibility of the authors.

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