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Forensic Anthropology Population Data

Quantitative assessment of the facial features of a Mexican population dataset

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ABSTRACT

The present study describes the morphological variation of a large database of facial photographs. The database comprises frontal (386 female, 764 males) and lateral (312 females, 666 males) images of Mexican individuals aged 14–69 years that were obtained under controlled conditions. We used geometric morphometric methods and multivariate statistics to describe the phenotypic variation within the dataset as well as the variation regarding sex and age groups. In addition, we explored the correlation between facial traits in both views. We found a spectrum of variation that encompasses broad and narrow faces. In frontal view, the latter is associated to a longer nose, a thinner upper lip, a shorter lower face and to a longer upper face, than individuals with broader faces. In lateral view, antero-posteriorly shortened faces are associated to a longer profile and to a shortened helix, than individuals with longer faces. Sexual dimorphism is found in all age groups except for individuals above 39 years old in lateral view. Likewise, age-related changes are significant for both sexes, except for females above 29 years old in both views. Finally, we observed that the pattern of covariation between views differs in males and females mainly in the thickness of the upper lip and the angle of the facial profile and the auricle. The results of this study could contribute to the forensic practices as a complement for the construction of biological profiles, for example, to improve facial reconstruction procedures.

1. Introduction

The quantitative analysis of facial morphology is a scientifically useful practice in forensic investigation [1], for example, in cases of identification requiring facial comparisons or when physical evidence, such as the ones gathered from photographs or video surveillance, is available (e.g. [2]; but see [3]). If used with caution, the metric assessment of specific facial regions can also provide information about the biological profile of the individuals [4]. For example, it can be useful for forensic craniofacial reconstruction [5] in order to recreate the appearance of an individual's face at the moment of death, considering a biological template as in Claes et al. [6]. Given the importance of quantitative facial data in legal contexts, it is necessary to assure its reliability, for instance, with the development and analysis of large databases and the improvement of the statistical methods used [7,8].

In the case of database collection, one way of improving the quantitative data for forensic practice is to collect representative samples of contemporaneous populations in which one can assess the frequency of facial traits to understand the normal distribution and recognize those traits with high discrimination power [9,10]. These reference databases can be used for recognition issues of lost individuals or offenders, or for age estimation in investigations related with paedo-pornography [11,12]. In addition, it can be used as an input to model facial reconstruction, in cases of personal identification (e.g. [6]). Thus, facial comparisons based on those reference populations will allow enhancing accuracy and reliability of evidence [8,13], conferring it a probative value; however, several issues could limit the potential contribution of the facial images database in two-dimensions. For instance, given that it is difficult to find in a real context the same facial pose as the one analyzed in a laboratory under controlled conditions (i.e. frontal face variation), disregarding individual morphological variations caused by varying poses could confine the scope of the dataset. Another issue that limits the database potential for facial comparisons is to set aside the variability related to sex, age and ethnicity [8–10], which are important

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sources of variation (e.g. [4,14,15]) to the frequency and distribution of facial traits.

Besides the improvements in database collection, another way of improving quantitative evidence in forensic contexts is incorporating innovative methods for analyzing morphology. Compared with traditional morphometrics which use distances, angles or ratios, the geometric morphometric methods use coordinate data in 2D or 3D for the analysis of shape variation; the latter provides advantages in capturing, analyzing and visualizing shape change [16]. For instance, the variation related with position, orientation and scale of the morphological structures analyzed in geometric morphometrics is mathematically removed after the Procrustes superimposition, leaving only the geometrical arrangement information of the structure of interest [17]. In addition, all this geometric information is considered at the same time throughout the analysis, which enables the graphical representation of shape changes [18,19], rather than solely the examination of changes on individual traits. Finally, while linear distance measurements are highly correlated with size [20], Procrustes coordinates are independent of the size variable used in geometric morphometrics when there is a small isotropic landmark variation [21,22]. Geometric morphometrics methods are widespread in biology, and their application has recently extended to forensic anthropology [13].

In order to contribute to the forensic practice, in this study we provide a detailed description of morphological features of a Mexican individuals sample by exploring facial morphological variations of a photographic database. We have taken into account the aforementioned problems which could limit the potential use of databases by implementing the following considerations. We used geometric morphometric methods to evaluate the facial variation within-group in lateral and frontal photographs on a large sample of Mexican individuals, considering age and sex; in addition, we approached the problem of morphological variation induced by facial position by exploring the degree of independence between traits in both facial views (frontal and lateral).

2. Materials and methods

2.1. Sample

To explore the facial variation within-group, we analyzed frontal and lateral images obtained from the large database of facial photographs of the "La cara del mexicano" (The Mexican's face) project. The sample in both views was divided into four age groups (Table 1), with a larger interval used for adults groups (G2–G4) than for the younger group (G1) given the sample size within each group. Even though individuals in the G1 group have not finished their growth, we decided to include them in order to account for their variation, that is interesting in itself.

The photography protocol was conducted using a portable studio using a Pentax K1000 camera mounted on a tripod, with a 135 mm AF Pentax lens. The studio included two flash strobes and reflective umbrellas and a white background with the individual ID and a scale in centimeters. The distance between subject and the camera was set at 2 m, aligning the subjects' heads on a Frankfurt horizontal plane. It is important to mention that, although the procedure tried to keep constant the Frankfurt horizontal plane in all individuals, differences in the anterio-posterior dimension of the face could distort the 2D image obtained in frontal view given the loss of depth information in this type of database. This and other limitations of the database along with advantages of the study are further considered in Section 4. Finally, the resulting 35 mm films were digitized using a ScanMaker 35 scanner (for further details about the project and the procedure see [24,25]). Only the digital images of faces with neutral expressions, hair removed from the face and without earrings or any other esthetic intervention were selected.

For the morphological variation induced by facial position analysis we used a subsample of individuals whose photograph in both views was available, which led to a sample (Table 1) of 292 individuals.

We used the software TPSDIG 2.16 [26], to place twenty-six landmarks in frontal view and twenty landmarks in lateral view. A detailed description and spatial location of landmarks is presented in Table 2 and Fig. 1. In order to estimate the magnitude of measurement error in the study, repeated measurements of 50 faces in each view were taken and analyzed by a hierarchical Procrustes ANOVA. This method was originally proposed by Klingenberg and McIntyre [27] to quantify the different components of asymmetry in landmark-based shape analysis. It is also currently used (e.g. [28,29]) to quantify the variance between replicate measurements relative to the inter-individual variation. In this analysis, the total variance is decomposed into the one corresponding to the individual variation and the replicated measurements, in a way that the sum of squares of each effect is adjusted for the previously entered effects [30].

Table 1
Age distribution of the database. Decimal age was calculated to two decimal points as in Eveleth and Tanner [23].

Age range	Age group	Frontal view		Lateral view		Subsample	
		Female	Male	Female	Male	Female	Male
14–18.9	G1	150	266	147	277	27	57
19–28.9	G2	186	406	131	337	49	95
29–38.9	G3	32	53	24	25	13	12
>39	G4	18	39	10	27	14	25
Total		386	764	312	666	103	189

2.2. Data analysis

The Shape information was extracted from the digitized coordinates by a generalized Procrustes analysis, which centers the configurations of landmarks on the origin and then scales them to unit centroid size and iteratively rotates them to minimize the sum of squared distances between the corresponding landmarks. The size information of the landmarks configuration is retained as the square root of the summed squared distances of all landmarks from their centroid [17,21,22]. This Procrustes registration was performed separately for the frontal and lateral views, although in the frontal view an additional step was considered regarding the bilateral symmetry of the face. In the frontal view, the Procrustes superimposition was performed with the original and the mirrored configurations of each set of landmarks in order to symmetrize the configurations and to discard the morphological variation related to asymmetry. This asymmetric variation is of no interest in this study [30] and has been studied elsewhere [25]. The resulting Procrustes coordinates were used for the following analysis. GPA and the multivariate analyses were performed using the software MorphoJ [31].

1. Facial variation within group in lateral and frontal photographs, analyzed by sex and age.We computed a principal component analysis (PCA) in order to explore the main facial patterns of covariation that contribute to the variation within the sample, taking into account only those components that explained more than 10% of the total variance. The assessment of the morphological variation related to sex and age was performed in two steps. We carried out a discriminant function analysis (DFA) to explore the shape differences between groups. In the first step, we used DFA to explore the mean morphological differences between sexes within each age group (Table 1). In