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A Systematic Review of Inter-ethnic Variability in Facial Dimensions

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Abstract

Background—The earliest recorded facial proportional analysis is in the Greek neoclassical canons (c. 450 B.C.). In contemporary times, there has not yet been a study that describes the relative differences in facial proportions among the world's different ethnic groups. The specific aim of this project is to perform a systematic review of data from the existing literature in order to evaluate the degree of variability in the facial dimensions among various ethnic groups.

Methods—A PubMed database review identified primary articles containing measurements of facial proportions from various ethnic groups. Data extracted from these articles were the actual means and standard deviations of recorded facial measurements. These facial measurements included the heights and widths of the upper, middle, and lower face which are the features originally described by the neoclassical canons. Coefficients of variation (CV) were calculated to derive a unit-free comparison of the degree of variability among different ethnic groups in each of the neoclassically-measured facial dimensions.

Results—Our literature search identified 239 potential articles. After screening for the inclusion and exclusion criteria, seven relevant articles were selected. These articles contained data on 11 linear facial measurements from 2359 male and female individuals from 27 different ethnic groups. 95% confidence intervals of the CVs of the measurements indicated that the features that demonstrated the largest differences between the different ethnic populations are the forehead height, interocular distance, and nasal width. The least amount of variability is found in the ear height and upper, middle, and lower facial widths.

Conclusions—The greatest inter-ethnic variability in facial proportions exists in the height of the forehead. More pronounced difference among the ethnic groups is also present in the measurements of the eyes, nose, and mouth. There is no significant difference between sexes in the neoclassical facial proportions.

Keywords

Systematic Review; inter-ethnic variability; facial dimensions

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The United States is a heterogeneous society comprising multiple ethnic groups, and seeking facial aesthetic surgery has become a cultural norm in our society. Facial proportional analysis is a critical component of the pre-operative assessment in plastic surgery upon the face. For surgical procedures such as rhinoplasty, blepharoplasty, and eyebrow lift, the “ideal” proportion derived from the Greek neoclassical perspective is not applicable for a significant portion of the US population. Several studies have found significant differences between the facial proportions described in the neoclassical canons and the mean values of these proportions in modern non-Caucasian ethnic populations [1–4]. These investigations into the applicability of the neoclassical canons have generated substantial amounts of data on the facial dimensions of numerous ethnic groups. Notably, Farkas et al. has compiled the single most comprehensive anthropometric survey of ethnic groups from multiple regions around the world [5]. Farkas’ data and data from similar studies have never been collated and analyzed to provide an overview of the global range of variation for each facial measurement.

Population studies such as those conducted by Farkas contain a quantitative record of the average facial characteristics that exist for particular ethnic groups. This type of raw data makes possible an analysis of the differences in facial proportions amongst the ethnic groups. The specific aim of this project is to perform a systematic analysis of the available population data in order to quantify the relative degree of inter-ethnic variability that exists in various facial features. We hypothesize that there are certain facial proportion measurements that will have more inter-ethnic variability than others. Understanding the unique facial proportions of various ethnic groups is critical in preserving the ethnic identity of the individual while pursuing the ideal facial proportion.

Materials and Methods

A PubMed database search was performed using the following keywords: “Anthropometry AND Face AND Ethnic,” “Facial AND Proportions AND Ethnic,” and “Facial AND Proportions AND Race.” The initial search was limited to primary articles and English language publications. Full inclusion and exclusion criteria (presented in Table 1) were applied in order to identify citations that were pertinent to our study and to eliminate irrelevant articles. Article review was conducted to clarify the content of studies that had unclear abstracts. The bibliographies of included articles were reviewed to capture additional studies that may have been missed by the original PubMed searches.

Data Extraction for Analysis

From each article in our finalized list, we extracted specific data concerning demographic details of the study population: gender, ethnicity, age range, sample size, anthropometric measurements, and means with standard deviations of anthropometric measurements. Categories for data extraction are listed in Table 2. Overall, the group of articles provided data for 11 of the facial measurements included in the neoclassical canons. Figure 1 provides a visual illustration of the different facial measurements included in the studies of our review.

Statistical Analysis

We verified that the primary data from each of the articles in our review were collected in a uniform and standardized fashion by the original authors. Given the numerous different facial features in this set of data, it was necessary to create a unit-free index of variability in order to eliminate the confounding effect of comparing different facial dimensions. For example, when comparing ear measurements to eye measurements, the differences between these two organs make a unit-dependent comparison of the dimensions of these two organs

totally meaningless. Thus, we decided that a calculation of coefficients of variation (CVs) would be the optimal method for establishing a unit-free index of variability. Such an index allows us to compare the relative degree of difference in inter-ethnic variability in a unit-free manner among the 11 facial measurements that had been extracted from the included publications [6].

To derive this index, we compiled the standard deviation and mean of each of the 11 facial measurements for each of the 27 ethnic groups. The quotient (standard deviation/mean) for each facial feature was calculated to yield the CV for each ethnic group. This CV represents “variability” and is defined as the dimension-less range of difference present within the different ethnic groups for a particular facial measurement. Higher values of CV represent greater measured variability [6]. The mean values and standard deviations for the 26 CVs for a particular facial feature were then calculated to determine of the range of inter-ethnic variability for each of the 11 facial measurements. The 95% confidence intervals were then derived from these values. Comparison of the confidence intervals amongst the 27 different ethnic groups shows the relative inter-ethnic degree of variability for each of the neoclassical facial proportions. For ease of interpretation, these confidence intervals are documented in graphic representation (Figures 3 and 4). Any two facial measurements that have confidence intervals that do not overlap are interpreted to have significant differences in the degree of inter-ethnic variability.

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Results

Literature Search

Search of the PubMed database identified 239 citations; 211 citations remained after this group was filtered for human subjects, English language, and primary articles. This group was further narrowed to 151 citations by exclusion of cephalometric studies. The cephalometric articles were excluded because they did not report any of the neoclassical proportional measurements. Of the remaining group, all articles except seven were eliminated because they did not report actual values for facial measurements. These seven remaining articles were all classified as cross-sectional anthropometric surveys [5,7–12]. The flow chart in Figure 2 provides a step-by-step visualization of the literature search and inclusion/exclusion process.

Population Groups

Our group of articles includes data from 27 total ethnic groups comprising 5 principal racial groups (European, African, East Asian, South Asian, Native American) that span all inhabited continents except for Australia and South America [13]. The data for each ethnic group include measurements for both male and female populations except for Tonga (male data only) and Korea (female data only). To eliminate confounding by the variable of age, all studies included in this review are restricted to an age range between 18 to 35 years, as Farkas et al. have shown age related variation in measurements, particularly in younger individuals outside of this age range [2]. Furthermore, all patients in these studies are reportedly healthy, non-syndromic individuals without history of facial injuries or surgeries.

Study Findings

After tabulating the mean and standard deviation values of each facial feature from each ethnic group (except North American black female and Korean female populations for

which the gonion-gonion [go-go] and exocanthion-exocanthion [ex-ex] measurements were not available), we compared the levels of variability in each facial feature relative to other facial features. We used the unit-free index that was obtained by calculating coefficients of variation (CV) for the facial measurements of each ethnicity as described earlier. A normal distribution of values was observed for these calculations. From these 26 CVs, a mean and standard deviation value were calculated; this was performed for each of the 11 facial measurements. These values are listed in Tables 3 and 4. 95% confidence intervals of the CVs were then plotted to compare the variability of each particular facial measurement relative to the variability of the other facial measurements. Overlap of the 95% confidence intervals was interpreted as non-significant difference in variability. (Figures 3 and 4)

For both male and female populations within each ethnic group, the level of variability for each facial measurement matched closely between genders. This observation was expected because the unit-dependent differences in facial measurements due to sexual dimorphism were eliminated by our method. Amongst the ethnic groups surveyed, the midface widths zygion-zygion (zy-zy) and exocanthion-exocanthion (ex-ex) along with the lower face width gonion-gonion (go-go) showed the lowest level of variation. The forehead height (tr-n) had the greatest degree of variation, being significantly more variable than every measurement except endocanthion-endocanthion (en-en). The remaining facial measurements can be organized into three groups of intermediate levels of variability. The less variable intermediate group includes the supraurale-subaurale (sa-sba) and endocanthion-exocanthion (en-ex) measurements. The level of intermediate variability includes the subnasale-gnathion (sn-gn), nasale-subnasale (n-sn), cheilion-cheilion (ch-ch), and alare-are (al-al) measurements. The more variable intermediate group contains the endocanthion-endocanthion (en-en) measurement. In summary, five levels of variability are classified—least variable, less variable intermediate, intermediate, more variable intermediate, and most variable (Table 5). Significant difference (with 95% confidence) exists between any two non-adjacent groups (e.g. least variable compared to middle intermediate or less variable intermediate compared to more variable intermediate).

Discussion

The first recorded set of facial proportional tenets was introduced by the Greeks. Polycleitus (450-420 B.C.) was among the first to use artwork to portray the “ideal” facial proportions. Aristotle (384-322 B.C.) later recorded his subjective impressions of what specific measurements represented the “ideal” facial proportions. Marcus Vitruvius Pollio (31 B.C.-14 A.D.) later wrote about the exact dimensions that were deemed the aesthetic ideal by the ancient Greeks. The European Renaissance artists, most notably Leonardo da Vinci (1452-1519 A.D.), would later take the concepts of the Greeks and develop them into a system known as the “neoclassical canons” [14–20]. Currently, most plastic surgeons use standards for the “ideal” proportions that are based upon these neoclassical canons.

The aim of this systematic review was to show the relative amounts of inter-ethnic variability in each of the standard neoclassical canon measurements of facial proportional analysis. In examining the data compilations of L.G. Farkas and other authors, we had initially suspected that certain facial measurements are less variable whereas others are more variable across ethnic lines. With our systematic review, we confirmed this hypothesis and quantified the relative inter-ethnic variability of 11 neoclassically measured facial dimensions. Our analysis found statistical significance in the inter-ethnic variability of the neoclassical facial measurements with a 95% confidence level, allowing classification of the facial measurements into five distinct levels of variability. This provides a new and useful tool for plastic surgeons practicing in today’s increasingly multicultural society. Our review of the existing data provides plastic surgeons with the range of possible facial variations.

This enables the plastic surgeon to approach the face in a manner that is similar to the method that the general surgeon uses in acknowledging the degree of variability present in the biliary system or that the vascular surgeon uses in heeding the potential different paths of the left renal vein. Furthermore, our data reference the specific ethnic differences of each facial feature. This provides the information to specifically tailor a patient's surgery based upon compiled data for his or her ethnic group. By understanding these ethnic variations of the face, the plastic surgeon will be equipped to decide the degree to which certain features may be altered in either reconstructive or aesthetic efforts and still achieve a desirable outcome.

Our study controls for the potential inaccuracy of calculation caused by dimensional differences between facial features by establishing a "unit-free" index for comparison, the coefficient of variation (CV). By this method, two dimensionally distinct values (e.g. eyes versus whole face width) are converted to dimension-less values that can subsequently be compared in a meaningful manner. The validity of these results is supported by the good correlation between the male and female data. The least variable facial measurement (zy-zy) and the most highly variable facial measurement (tr-n) are concordant between sexes. Furthermore, the variability of the intermediate measurements (e.g. ex-ex, go-go, en-en, ch-ch) also matches well between male and female data [6].

One of the potential pitfalls of our analysis is that the data are limited to the two-dimensional measurements of facial features from population anthropometric studies. Therefore, the primary shortcoming of current anthropometric population data is in the analysis of areas of the face such as the nose where the three-dimensional geometry makes a two-dimensional construct less accurate. For instance, two well studied structures in plastic surgery are the eyes and nose [21–31]. These facial components are often cited as exhibiting the highest degree of inter-ethnic variability. The inter-ethnic differences of these organs lie mainly in the three-dimensional architectural structure rather than simple two-dimensional measures [28,29]. This is confirmed by our results that underestimate the differences by showing only moderate degrees of inter-ethnic variability in the two-dimensional quantification of each structure.

Future work in the area of facial dimensional analysis of inter-ethnic differences will likely involve compiling data upon the countless analytical planes and angles that have been described for aesthetic analysis of the face [32–36]. There has not yet been a collective effort to compile most of the non-neoclassical canon measurements that exist in the vast ethnic spectrum (in the style of L.G. Farkas). Also, a substantial amount of cephalometric data exists [37–45] and can potentially be analyzed in the same manner as we have done with the two dimensional anthropometric data.

Our analysis highlights the differences in phenotypic variability that are present within the features of the face. The increased variability that is present in a particular measured facial feature seems to suggest either an expression of a larger number of alleles or perhaps an increased susceptibility to environmental shaping. For instance, the large range of forehead heights (tr-n) may be the product of many different genetic alleles. These alleles may control the amount of bone formation of the skull or perhaps only control the depth of the hairline. On the other hand, the forehead height may also simply be largely determined by sleeping positions during early age in the setting of a highly environmentally malleable structure (the skull). Identifying which facial dimensions are more or less variable across ethnic lines opens the door to further exploration by evolutionary biologists upon the concepts of natural selection, mutation, and genetic drift in the human population [46].

As plastic surgery patient population continues to become increasingly multicultural, previously defined tenets of facial proportion based upon the stereotypical Caucasian features are no longer adequate. Furthermore, surgical technique has evolved to such a degree that manipulation of ethnically characteristic features is now routinely performed. More than ever before, there is a need to synthesize information that defines the areas of relative difference in the human countenance. The systematic review is the ideal tool to achieve this task of combining multiple individual investigations and producing a single coherent statement that summarizes the available data [47]. The future direction of this area of study will be to continue to define and clarify the ethnically characteristic features that exist and to determine the inter-ethnic variability of each facial feature so that the plastic surgeon may consider these variables to arrive at predictable outcomes.

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Figure 1.

These measurements are derived from the neoclassical canons, and populational data of these measurements are reviewed in our study. A color gradient is used to illustrate the degree of inter-ethnic variability in each region of the face. **Tr**=tragion--notch on upper margin of the tragus, **n**=nasion--point in the midline of both the nasal root and nasofrontal suture, **sn**=subnasale--midpoint of the angle at the columella base where the lower border of the nasal septum and the surface of the upper lip meet, **gn**=gnathion--lowest median landmark on the lower border of the mandible, **sa**=superaurale--highest point on the free margin of the auricle, **sba**=subaurale--lowest point on the free margin of the ear lobe, **ex**=exocanthion--point at the outer commissure of the eye fissure, **en**=endocanthion--point at the inner commissure of the eye fissure, **zy**=zygion--most lateral point of each zygomatic arch, **al**=alare--most lateral point of each alar contour, **ch**=cheilion--point located at each labial commissure, **go**=gonion--most lateral point on the mandibular angle [1,2].

Figure 2.

Diagram of the systematic literature search performed to identify population studies addressing inter-ethnic facial proportional differences. The vast majority of articles were eliminated because they were reviews, cephalometric studies, and without raw data.

Figure 3. 95% confidence intervals of female data were calculated from the coefficients of variation (CV= standard deviation/mean) listed in Table 3. Intervals that do not overlap may be interpreted as significant differences in inter-ethnic variability.

Confidence Interval Plot of Male CV's

Figure 4. 95% confidence intervals of male data were calculated from the coefficients of variation (CV= standard deviation/mean) listed in Table 4. Intervals that do not overlap may be interpreted as significant differences in inter-ethnic variability.

Table 1**Inclusion and Exclusion Criteria for Systematic Literature Search**

Inclusion criteria
Primary data
Human subjects
English language
Linear anthropometric data
Neoclassical Canon Measurements: (al-al, ch-ch, en-en, en-ex, ex-ex, go-go, n-sn, sa-sba, sn-gn, tr-n, zy-zy).
Actual means and standard deviations reported
Sample size ≥ 30
Gender discriminate study
Exclusion criteria
Review article
Non-human subjects
Non-English language
Non-linear anthropometric data
Cephalometric and non-neoclassical canon measurements
Analysis without actual means and standard deviations reported
Sample size < 30
Grouped gender study (male and female data processed together)

Table 2**Extracted Data**

Mean and standard deviation from 11 facial measurements tabulated from 27 ethnic groups, male and female—with the exception of Korean females (no males), and Tonga males (no females)

11 facial measurements (Figure 1)

27 ethnic groups:

African American male/female

White North American male/female

Korean female (only)

Azerbaijan male/female

Bulgarian male/female

Czech male/female

Croatian male/female

German male/female

Greek male/female

Hungarian male/female

Italian male/female

Polish male/female

Portuguese male/female

Russian male/female

Slovak male/female

Slovenian male/female

Iranian male/female

Turkish male/female

Egyptian male/female

Indian male/female

Singaporean Chinese male/female

Vietnamese male/female

Thai male/female

Japanese male/female

Angola male/female

Zulu male/female

Tonga male (only)

Age range all between 18 and 35 years

Table 3

95% confidence intervals of female data were calculated from the coefficients of variation (CV= standard deviation/mean). For ex-ex, data from Korean and African American women is not available. For go-go, data from Korean women is not available.

95% Confidence Intervals for Female Coefficients of Variation (CV)					
Measurement	n	Mean (CV)	Std.Err. (CV)	Min (CV)	Max (CV)
al-al	26	0.078	0.0040	0.070	0.086
ch-ch	26	0.076	0.0037	0.068	0.083
en-en	26	0.087	0.0036	0.079	0.094
en-ex	26	0.069	0.0043	0.060	0.078
ex-ex	24	0.051	0.0023	0.046	0.056
go-go	25	0.051	0.0025	0.046	0.056
n-sn	26	0.076	0.0046	0.066	0.085
sa-sba	26	0.062	0.0021	0.058	0.067
sn-gn	26	0.078	0.0029	0.072	0.083
tr-n	26	0.098	0.0044	0.089	0.11
zy-zy	26	0.046	0.0038	0.038	0.054

Table 4

95% confidence intervals of male data were calculated from the coefficients of variation (CV = standard deviation/mean).

95% Confidence Intervals for Male Coefficients of Variation (CV)						
Measurement	n	Mean (CV)	Std.Err. (CV)	Min (CV)	Max (CV)	
al-al	26	0.072	0.0029	0.066	0.078	
ch-ch	26	0.079	0.0062	0.066	0.091	
en-en	26	0.088	0.0037	0.080	0.095	
en-ex	26	0.065	0.0036	0.058	0.072	
ex-ex	26	0.049	0.0029	0.043	0.055	
go-go	26	0.056	0.0027	0.050	0.062	
n-sn	26	0.070	0.0052	0.059	0.080	
sa-sba	26	0.062	0.0021	0.058	0.066	
sn-gn	26	0.080	0.0033	0.073	0.086	
tr-n	26	0.110	0.0051	0.096	0.120	
zy-zy	26	0.042	0.0028	0.036	0.047	

Table 5

The 11 facial measurements can be categorized into 5 general levels of variabilities based upon their ranges of coefficients of variation (CV).

5 Groups of Variability in CV	Facial Measurement
Least Variable	zy-zy ex-ex
Less Variable Intermediate	go-go sa-sba en-ex
Intermediate	n-sn ch-ch sn-gn al-al
More Variable Intermediate	en-en
Most Variable	tr-n