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Face Shape Differences in Selected Indigenous Peoples' Groups in Mindanao, Philippines

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Abstract

The face shape of individuals belonging to seven different indigenous groups (IG) from Mindanao was studied using geometric morphometric analysis. A total of 496 images of the face (217 males and 279 females) were obtained from the Bagobo, Bilaan, Higaunon, Kalagan, Maranao, Subanen and Talaandig groups. Forty three manually defined landmarks done in triplicates generated relative warp scores which were subjected to different statistical tools in order to compare face shapes and to examine relatedness between IGs. Non-metric multidimensional scaling and discriminant analysis showed significant variation between IGs however, patterns of clustering were different in male and female populations. Procrustes ANOVA showed that sides, individual, and interaction in all IGs of both populations had P-values of <0.000, which is indicative of the presence of asymmetry, distinctness of the face shape each individual, and a significant variation among IGs in both male and female populations. The interaction of sides and individual p-value showed high fluctuating asymmetry (FA) for all IGs regardless of gender. This may be attributed to the intermarriage practices between individuals of same IG which are still applicable to some groups nowadays. In conclusion, each IG possesses distinct face shape but individuals belonging to each group have high degree of variation.

INTRODUCTION

Face analysis had been quite important in studies of distinguishing pure and mixed races[1] and in health-related fields [2]-[6]. The human face can provide demographic information, such as gender and ethnicity[7]. Even though genetic differences among human groups are relatively small, these differences nevertheless can be used to situate many individuals within broad, geographically based groupings[8]. Many argued that each race has different gene pools and different subgroups may exhibit different behaviors, peculiarities, and anthropometric characteristics [9-19] thus, it is important to explore other tools in studying morphological traits that can be used to differentiate human groups especially the face. In the past, facial anthropometry has been successfully utilized for forensic purposes [18, 20-22].

Analysis of the face is important especially for facial recognition, historical research, investigations, telecommunications or even games. Facial data is commonly obtained by direct anthropometric measurements[23]. Landmarks have been used in qualifying cranial variation[23-26] like measuring and comparing linear, angular and surface contours and proportions in people. For many years 47 landmark points were identified to describe the face[23,25-26].

With the advances in computational biology and image analysis, several other methods have evolved to detect faces and find the facial features correctly[27]. Some of these methods include knowledge based [28], invariant feature[29], template matching[32-33] and appearance based[34-37]. The new method of 'geometric morphometrics' (GM), an adaptation of multivariate statistics and graphics to the study of phenotypic variation, has proved to be useful for the detection of form changes and is very useful in understanding shape variations in living organisms thus was used in this study. In this method, the relative locations of a set of individually identified points or "landmarks" are identified as biometric variables, the 'shape coordinates', that can then be regressed one by one on the factors that cause them or the features of the systems they are presumed to affect. The methodological approaches of GM make use of two-dimensional or three-dimensional coordinate data to describe size and shape at the same time[38-42]. The statistical properties of GM have been proven superior to those of distance-based or angle-based methods[43-45] and the supply graphics are far more legible and interpretable to the applied biologist, the tools of GM was therefore used in describing group differences in selected group of indigenous peoples (IP's) groups in the Philippines.

The Philippines is a mountainous archipelago that comprises 7,100 islands grouped into three regions: Luzon, Visayas, and Mindanao. It is a home to a very diverse collection of indigenous ethnic minorities [46] although the Filipino people in general are basically of Malay stock[47]. Approximately 10 to 15 percent of the country's population of 96 million is comprised of different indigenous groups[48]. Indigenous peoples are defined as the descendants of the original inhabitants of the archipelago who retained their own customs, traditions and life ways despite colonization[49.] Of all the Philippine islands, Mindanao has the largest concentration of indigenous peoples, reaching to about 61 percent of the total indigenous peoples population in the country[49]-[50]. The introduction of a different cultural system led to the disintegration of indigenous society[49]. However, the indigenous groups in general still have a rather traditional way of living[51] including endogamous marriages thus are fit to be the subject of anthropometric investigations.

The study aims to compare face shape among and within the seven selected indigenous groups in Mindanao and to examine the extent of variation exhibited among these populations using geometric morphometric analysis. It is hoped that the comparison of face shape among and within the seven indigenous groups will provide information as to the degree of relatedness and differences among these groups. The study focuses only in examining the extent of difference and similarities of face shape of individuals belonging to the seven selected indigenous groups in Mindanao, Philippines. The groups included in this study are the Bagobo, Bilaan, Higaunon, Kalagan, Maranao, Subanen, and Talaandig.

METHODOLOGY

IMAGE ACQUISITION AND PROCESSING

We recruited a total of 496 male and female members of the different indigenous peoples' groups to participate in this study. Front view images of the face with neutral expression, closed mouth and without deformations were captured using a digital camera. These images were particularly sampled from both male and female individuals belonging to the seven selected indigenous groups, namely the Bagobo, Bilaan, Higaunon, Kalagan, Maranao, Subanen, and Talaandig. Table 1 summarizes the number of samples gathered from each group and specifies the exact sampling regions within the island of Mindanao.

Figure 1

Table 1. Number of image samples acquired from the seven indigenous groups and their respective sampling sites

GROUP	SITE	NUMBER OF IMAGES		
		Male	Female	Total
Bagobo	Bukidnon, Philippines	43	45	88
Bilaan	Cotabato and Southeastern Davao, Philippines	29	43	72
Higaunon	North-Central Mindanao, Philippines	19	28	47
Kalagan	Western Davao, Philippines	17	39	56
Maranao	Lanao del Sur, Philippines	26	27	27
Subanen	Zamboanga, Philippines	70	72	142
Talaandig	Bukidnon, Philippines	13	25	38
TOTAL		217	279	496

Forty three (43) anatomical landmarks were defined in each image in regions that characterize the morphological difference in the human face structure. The manual input of landmarks was done in triplicates and the Cartesian coordinate scores of these landmarks were recorded using the tpsDig 2.10 program[43]. The landmark locations in the face are illustrated in Figure 1 below and the details are summarized in Table 3. Each landmark was classified into type I landmark, a point that occurs at joins of tissues or bones, or type II landmark, a point defined by local properties such as maximal curvatures.

Figure 2

Figure 1. Location of anatomical landmarks of the face.

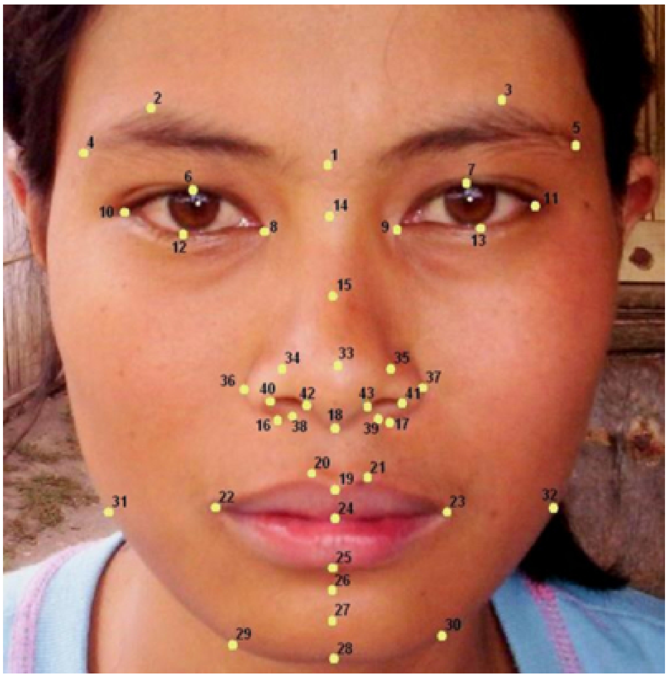


Figure 3

Table 2. Anatomical landmarks of the face

Landmark	Description of Landmark	Type
1	Midpoint of the nasofrontal suture	II
2	Highest point on the upper margin of the midline portion of the eyebrow (left)	II
3	Highest point on the upper margin of the midline portion of the eyebrow (right)	II
4	Most lateral point of the eyebrow (left)	II
5	Most lateral point of the eyebrow (right)	II
6	Highest point of the eyelid (left)	II
7	Highest point of the eyelid (right)	II
8	Medial hinge of the eyelid (left)	I
9	Medial hinge of the eyelid (rigt)	I
10	Lateral hinge of the eyelid (left)	I
11	Lateral hinge of the eyelid (right)	I
12	Lowest point in the middle of the margin of the lower eyelid (left)	II
13	Lowest point in the middle of the margin of the lower eyelid (right)	II
14	The deepest point of the nasofrontal angle	II
15	Nose bridge	II
16	Most lateral point of the nose (left)	I
17	Most lateral point of the nose (right)	I
18	Most inner point between the nose tip and the upper lip	I
19	The midpoint of the vermilion border of the upper lip	I
20	Highest point of the upper lip (left)	I
21	Highest point of the upper lip (right)	I
22	Most lateral point where the upper and lower lip meet (left)	I
23	Most lateral point where the upper and lower lip meet (right)	I
24	Midline point where the upper and lower lip meet	II
25	Midpoint of the lower margin of the lower lip	I
26	Midpoint of the pogonion and lower lip	II
27	Most anterior point of the chin	II
28	Lowest point in the midline on the lower border of the chin	II
29	Protrusion of the mental tubercle (left)	II
30	Protrusion of the mental tubercle (right)	II
31	Most lateral point at the angle of the mandible (left)	II
32	Most lateral point at the angle of the mandible (right)	II
33	Most protruded point of the nasal tip	II
34	Medial point of the nasal ala outer margin (left)	II
35	Medial point of the nasal ala outer margin (right)	II
36	Most lateral point on the nasal ala (left)	II
37	Most lateral point on the nasal ala (right)	II
38	Lowest lateral point of the nasal ala inner margin (left)	II
39	Lowest lateral point of the nasal ala inner margin (right)	II
40	Highest point of the nasal ala inner margin (left)	II
41	Highest point of the nasal ala inner margin(right)	II
42	Medial point of the nasal ala inner margin (left)	II
43	Medial point of the nasal ala inner margin (right)	II

GEOMETRIC MORPHOMETRIC ANALYSIS

In order to compare face shape, standard procedures of geometric morphometrics were applied to the samples. These include Procrustes superimposition and thin-plate spline interpolation which eliminate scale, position and orientation biases and create maximal fit of homologous landmarks.

Variables describing shape variation in the datasets based on 2D coordinates were calculated and relative warp scores were then obtained using tpsRelw 1.45[44]. The scores were used to generate the XY plot of the relative warps in a Procrustes coordinate using the paleontological statistics software (PAST)[52]. This process gives picture to the distribution of the individuals of the entire population, which was further visualized in the deformation grid in order to explain shape patterns as we move along axes.

A consensus configuration of the face shape was also generated using tpsSpline[45]. The same program was used to produce the mean shapes of each indigenous group which were warped consorting to the consensus configuration. This aids in the visualization of variation of each group relative to the entire population.

STATISTICAL ANALYSES

The relative warp scores generated were subjected to various statistical tools in order to further analyze the face shape of the indigenous groups. But first, scores of the images were symmetrized by getting the average shape of the left and right sides of each image using the superimposition method. SPSS 13.0[53] was the software used for this procedure.

The process of symmetrization eliminates asymmetry biases, thus eliminating environmental factor as variable that determines face shape other than the developmental or genetic component. In this way, indigenous groups can be compared to each other without having to face the problem in difference of environmental factors.

The symmetrized data were subjected to non-metric multidimensional scaling (NMDS), a method for visualizing dissimilarity in data. It measures similarity or dissimilarity of each data instead looking at its characteristic[54]. The distances were computed in Euclidean similarity measure and the stress value which determines the significance of variation between groups was obtained using the Shepard plot. This technique determines if the variation in each indigenous group is significant, particularly a stress value below 0.05.

The data also underwent cluster analysis in order to further sort the groups into clusters that could explain which indigenous groups are most closely related to each other. A Bootstrap value of 50 or greater denotes significant grouping. Cluster analysis specifically, is just an exploratory data analysis that sorts different objects into groups in a way that the degree of association is maximal[55], that is why NMDS was applied first to determine the presence of significant variation between the pre-determined before sorting them out into the most related indigenous groups.

PROCRUSTES ANOVA

Procrustes ANOVA was used to study left-right variation in the face shape. The deviations of the configurations from the consensus are broken down according to the main effects of individuals, sides (for object symmetry), and individuals-by-side interaction.

The main effect of individuals represents the inter-individual variation, that is, variation present within an indigenous group. Sides on the other hand, represent the asymmetric variation called directional asymmetry (DA), that is, one side is systematically different from the other one. The individuals-by-side interaction quantifies the asymmetric variation within individuals called fluctuating asymmetry (FA), small random differences between the left and right sides in bilateral traits[56].

DISCRIMINANT ANALYSIS

This technique was used to determine which variables discriminate between the indigenous groups in male and female populations[57]. The purpose of employing discriminant analysis is to see the relatedness among indigenous groups by basing the percentage of original group cases which are correctly classified. If a significant number of individuals are correctly classified to a group, the classification table will yield a high percentage of correct estimate which is 70 percent or higher[58].

RESULTS AND DISCUSSION

Canonical variate analysis showed significant differences between the indigenous Peoples' groups (Fig. 2). The Procrustes ANOVA results show extremely significant asymmetric variation within each group although not all individuals exhibit face asymmetry (Table 3). While variability existed within each group as revealed by procrustes ANOVA, minimal overlapping of scores among indigenous groups was observed, indicating differences in face shapes between groups.

Figure 4

Figure 2. Distribution of the indigenous peoples groups (A) female and (B) male along the first two canonical variate axes.

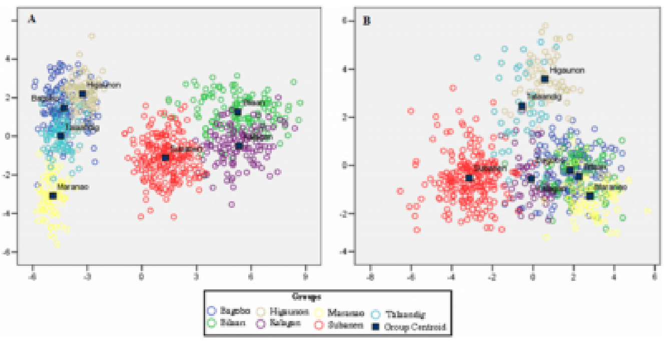


Figure 5

Table 3. Procrustes ANOVA results

SEX	GROUP	SOURCE	SS	d.f.	MS	F	P-VALUE
Female	Bagobo	Side	0.0424	41	0.001	12.3664	<0.000
		Individual	0.7308	1804	0.0004	4.8397	<0.000
		Interaction	0.151	1804	0.0001	6.0702	<0.000
		Error	0.1018	7380	0.0000	--	--
	Bilaan	Side	0.0191	41	0.0005	5.6018	<0.000
		Individual	0.9173	1722	0.0005	6.4219	<0.000
		Interaction	0.1428	1722	0.0001	6.1909	<0.000
		Error	0.0945	7052	0.0000	--	--
	Higaunon	Side	0.0356	41	0.0009	7.6238	<0.000
		Individual	0.6139	1107	0.0006	4.8621	<0.000
		Interaction	0.1263	1107	0.0001	10.9382	<0.000
		Error	0.0479	4592	0.0000	--	--
	Kalagan	Side	0.0332	41	0.0008	9.9723	<0.000
		Individual	0.8481	1558	0.0005	6.7099	<0.000
		Interaction	0.1264	1558	0.0001	5.5283	<0.000
		Error	0.0939	6396	0.0000	--	--
	Maranao	Side	0.0197	41	0.0005	4.3371	<0.000
		Individual	0.5059	1066	0.0005	4.2875	<0.000
		Interaction	0.118	1066	0.0001	7.9168	<0.000
		Error	0.0619	4428	0.0000	--	--
	Subanen	Side	0.0398	41	0.0001	7.5345	<0.000
		Individual	1.3972	2911	0.0005	3.7257	<0.000
		Interaction	0.375	2911	0.0001	9.3436	<0.000
		Error	0.1628	11808	0.0000	--	--
	Talaandig	Side	0.0191	41	0.0005	3.3232	<0.000
		Individual	0.6171	984	0.0006	4.4843	<0.000
		Interaction	0.1376	984	0.0001	10.5002	<0.000
		Error	0.0546	4100	0.0000	--	--
Male	Bagobo	Side	0.0312	41	0.0008	8.533	<0.000
		Individual	0.8473	1722	0.0005	5.519	<0.000
		Interaction	0.1535	1722	0.0001	7.6213	<0.000
		Error	0.0825	7052	0.0000	--	--
	Bilaan	Side	0.0173	41	0.0004	4.4731	<0.000
		Individual	0.5755	1148	0.0005	5.3198	<0.000
		Interaction	0.1082	1148	0.0001	8.0908	<0.000
		Error	0.0554	4756	0.0000	--	--
	Higaunon	Side	0.0254	41	0.0006	5.5459	<0.000
		Individual	0.3022	738	0.0004	3.661	<0.000
		Interaction	0.0825	738	0.0001	9.303	<0.000
		Error	0.0375	3116	0.0000	--	--
	Kalagan	Side	0.0227	41	0.0006	7.6982	<0.000
		Individual	0.3533	656	0.0005	7.4912	<0.000
		Interaction	0.0472	656	0.0001	5.6893	<0.000
		Error	0.0352	2788	0.0000	--	--
	Maranao	Side	0.0189	41	0.0005	2.6782	<0.000
	Maranao	Individual	0.7379	1025	0.0007	4.1737	<0.000
		Interaction	0.1768	1025	0.0002	12.7949	<0.000
		Error	0.0575	4264	0.0000	--	--
	Subanen	Side	0.0485	41	0.0012	12.0003	<0.000
		Individual	1.6269	2829	0.0006	5.835	<0.000
		Interaction	0.2788	2829	0.0001	7.8436	<0.000
		Error	0.1442	11480	0.0000	--	--
	Talaandig	Side	0.0136	41	0.0003	2.4798	<0.000
		Individual	0.2365	492	0.0005	3.5986	<0.000
		Interaction	0.0657	492	0.0001	11.1907	<0.000
		Error	0.0255	2132	0.0000	--	--

The 43 manually defined landmarks in the 496 images from the Bagobo, Bilaan, Higaunon, Kalagan, Maranao, Subanen and Talaandig groups generated relative warps scores presented as scatter plot (Figure 3). RW1 shows a shift of face shape from a more pronounced forehead to a more pronounced jaw moving from left to right. Likewise, RW2 shows a shift of an elongated to a broader face shape going from top to bottom of the diagram.

Grids generated from the relative warp scores, showed the conformation of face shape of each group with respect to a consensus configuration (Fig. 3A, B, 4A, 5A). In the female population (Fig. 3A, 4A), the Bagobo females exhibit slimmer nasal area compared consensus shape. The Bilaan females show a wider jaw line, thinner lips and a horizontally compressed nose. The Higaunon females show a rounder face and wider set of eyes. The Kalagan females exhibit a more elongated face shape with prominent cheekbones. The Maranao females has broader face than when compared to the rest of the females. The Subanen females has the closest face configuration that of the consensus. The Talaandig females generally has broader forehead than their jaw line.

It is important to note here that the grids only show differences in traits which are visibly warped from the consensus. Thus, the application of non-metric multidimensional scaling and cluster analysis is important to provide a statistical basis in describing the degree of similarities and differences exhibited by the indigenous peoples' groups. Fig 4B shows the minimum spanning tree of female groups generated in Euclidean distance by means of non-metric dimensional scaling. The stress value of 0.03476 indicates a significant level of variation among these groups. Cluster analysis (Fig. 4C) showed five significant groupings in the female population which are indicated by Bootstrap values greater than 50. Subanen, Bilaan, Kalagan, and Maranao groups are significantly different from the rest of the female population. The Higaunon, Bagobo, and Talaandig females have certain degree of similarities as shown by a low bootstrap value..

Figure 6

Figure 3. Relative warps of (A) female and (B) male populations obtained from the seven different indigenous groups

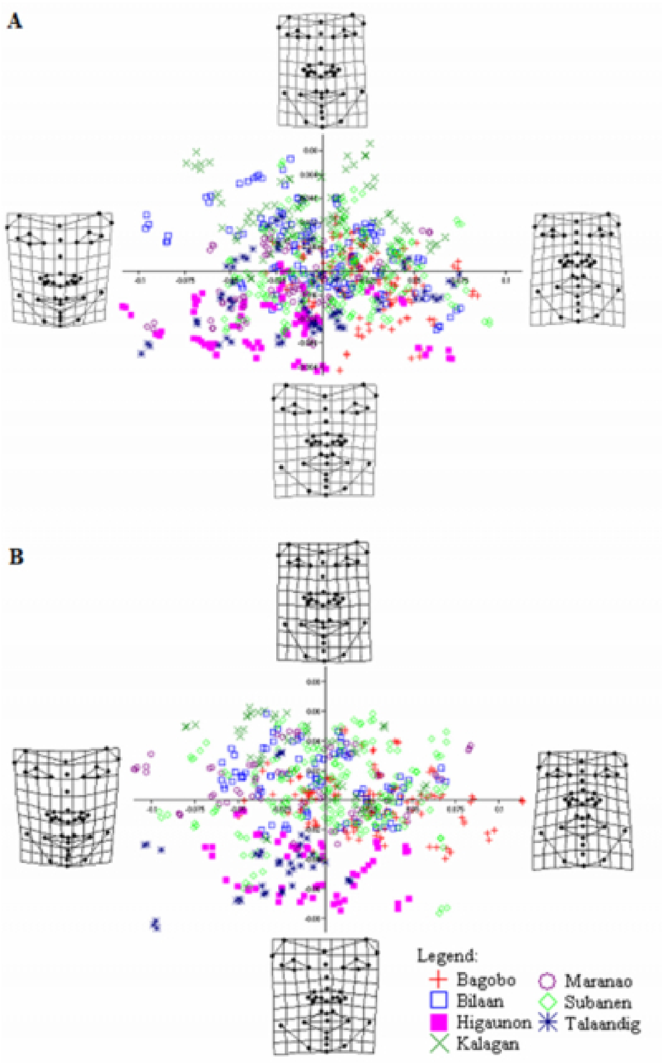


Figure 7

Figure 4. Comparison of face shape of the female population: (A) Mean shapes of the face of the different indigenous peoples groups derived from relative warp analysis; (B) Non-metric multidimensional scaling with stress value of 0.03476; (C) Dendogram based on Euclidian distances computed from relative warp scores.

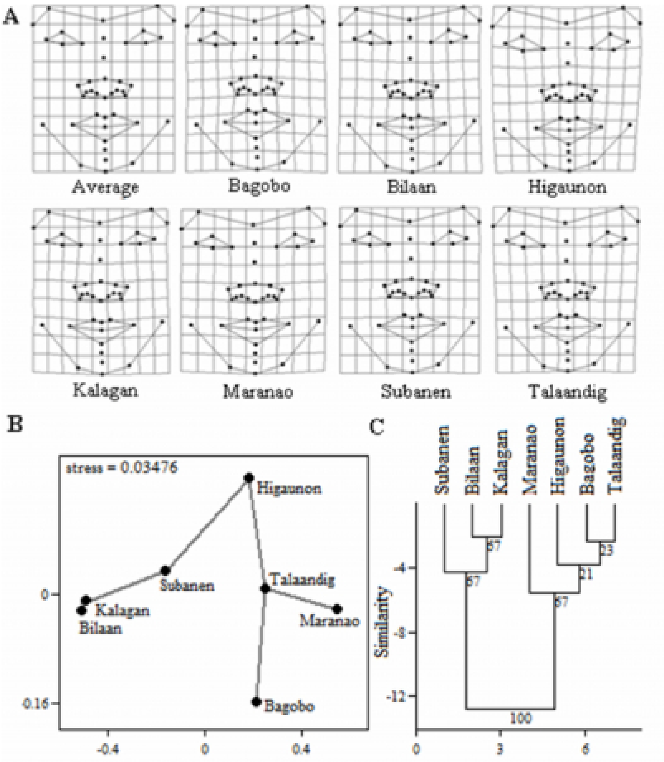
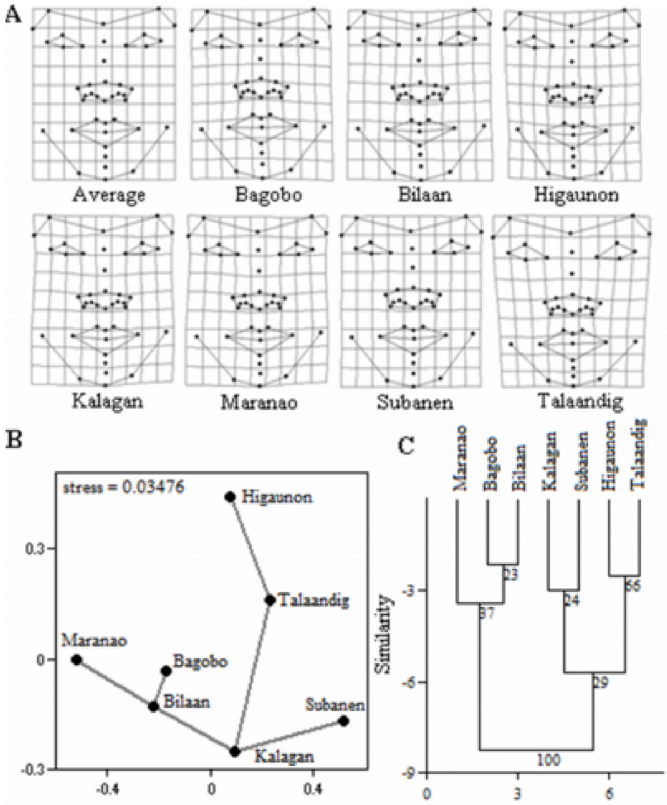


Figure 8

Figure 5. Comparison of face shape of the female population: (A) Mean shapes of the face of the different indigenous peoples groups derived from relative warp analysis; (B) Non-metric multidimensional scaling with stress value of 0.03476; (C) Dendogram based on Euclidian distances computed from relative warp scores.



For the males (Fig. 3A and B, 5B), the grouping patterns vary from that of the females. While significant variations exist among indigenous groups (i.e. stress value = 0.3476) (Fig. 5B), two major groupings can be observed - the Maranao-Bagobo-Bilaan cluster and Kalagan-Subanen-Higaunon-Talaandig cluster (Fig. 5C). The Maranao, Bagobo and Bilaan males showed more similarities in the face shape that are different from those of the Kalagan, Subanen, Higaunon and Talaandig male cluster. Based on the RW grids (Figs. 3A, 5A) specific differences can be observed among these indigenous peoples' groups. The Higaunon males possess the thinnest lips. The Talaandig males exhibit the broadest face shape. The Bagobo, Bilaan and Subanen males more or less share similar configurations and also closely resemble the consensus configuration. The Kalagan shows a very distinct configuration, showing a prominent cheekbone.

Discriminant analysis showed more than 90% of original group cases were correctly classified (Tables 4 and 5) indicating that the different indigenous peoples' groups were distinctly different from each other. While many studies have applied various anthropometric methods in describing human populations[19-26], results of this study showed that geometric morphometrics is as important in providing a quantitative description of the nature of face shapes and could be used to fingerprint distinct populations, race or ethnic groups.

Figure 9

Table 4. Reclassification of the female indigenous peoples groups.

		PREDICTED GROUP MEMBERSHIP							
		Bagobo	Bilaan	Higaunon	Kalagan	Maranao	Subanen	Talaandig	Total
Count	Bagobo	127	0	3	0	3	0	2	135
	Bilaan	0	113	0	11	0	5	0	129
	Higaunon	0	0	83	0	0	0	1	84
	Kalagan	0	7	0	108	0	2	0	117
	Maranao	0	0	0	0	79	0	2	81
	Subanen	0	0	0	1	0	215	0	216
	Talaandig	4	0	5	0	1	0	65	75
Percentage (%)	Bagobo	94.07	0	2.22	0	2.22	0	1.48	100
	Bilaan	0	87.60	0	8.53	0	3.88	0	100
	Higaunon	0	0	98.81	0	0	0	1.19	100
	Kalagan	0	5.98	0	92.31	0	1.71	0	100
	Maranao	0	0	0	0	97.53	0	2.47	100
	Subanen	0	0	0	0.46	0	99.54	0	100
	Talaandig	5.33	0	6.67	0	1.33	0	86.67	100

94.4% of original grouped cases correctly classified

Figure 10

Table 5. Reclassification of the male indigenous peoples groups.

		PREDICTED GROUP MEMBERSHIP							
		Bagobo	Bilaan	Higaunon	Kalagan	Maranao	Subanen	Talaandig	Total
Count	Bagobo	118	5	2	1	0	1	2	129
	Bilaan	8	69	0	4	6	0	0	87
	Higaunon	0	0	53	0	0	0	4	57
	Kalagan	1	0	0	48	0	1	1	51
	Maranao	2	7	0	0	69	0	0	78
	Subanen	0	1	1	2	0	205	1	210
	Talaandig	1	0	0	4	0	3	31	39
Percentage (%)	Bagobo	91.47	3.88	1.55	0.78	0	0.78	1.55	100
	Bilaan	9.20	79.31	0	4.598	6.90	0	0	100
	Higaunon	0	0	92.98	0	0	0	7.02	100
	Kalagan	1.96	0	0	94.12	0	1.96	1.96	100
	Maranao	2.56	8.97	0	0	88.46	0	0	100
	Subanen	0	0.48	0.48	0.95	0	97.62	0.48	100
	Talaandig	2.56	0	0	10.26	0	7.69	79.49	100

91.1% of original grouped cases correctly classified

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