Face Shapes Of Diabetics And Non-Diabetics Described Using Geometric Morphometrics
C Demayo, M Torres, C Veña

Abstract
Introduction: Analysis of the face is not only important for facial recognition, historical research, investigations, telecommunications or even games but also important in many health-related fields. Facial data is commonly obtained by direct anthropometric measurements but in this study we applied new tools in geometric morphometrics (GM) to describe morphological variations in the face of people with diabetes mellitus. Methods: Digital images of the faces of 54 non-diabetic and 63 diabetic patients were taken. For the males, images analyzed were those without moustache, beard, and eyeglasses and with neutral face expression were used in this study. A total of 63 manually positioned anthropomorphic landmarks were collected, the Cartesian coordinates of which were extracted using an image analysis and processing software. The faces were then aligned using Procrustes superimposition of the Cartesian coordinates to eliminate size differences and rotational translation. The size residuals left after the alignment were then used to reconstruct the face’ truss network using thin-plate spline grids. Variations in facial morphology were then explored using the methods of relative warps analysis and partial warps analysis supplemented with various multivariate statistical analyses. Results: While facial asymmetry seems to be a common feature among the individuals surveyed as shown by the first partial warp, relative warps revealed drooping of the brow ridge portion of the face, drooping of the chin and bulging of the cheek surface were observed among the diabetics. Ordination of the samples based on the shape residuals showed differences in face shapes between diabetics and non diabetics although no sexual dimorphism in face shapes was observed. The face shape of diabetics was found to be rounder and less tapered compared to that of non-diabetics. Common features among diabetics include facial asymmetry (elongation towards the right), drooping of the brow ridge, compression of the face towards the center, and downward folding of the skin in the area of the eyes. Conclusion: Geometric morphometrics is effective in describing face shapes between diabetics and non-diabetics and could be used in describing face shapes of other patients with specific health problems.

INTRODUCTION
Analysis for facial recognition, historical research investigations is commonly based on obtained data by direct anthropometric measurements. Landmarks are identified, measured, and compared linear, angular and surface contours and proportions of the face in people. Advances in computational biology and image capture and processing softwares have resulted to more defined detection of features of faces. One of the newer tools is ‘geometric morphometrics’ (GM), an adaptation of multivariate statistics and graphics to the study of phenotypic variation has proven to be useful in describing and understanding shape variations in living organisms. 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 (Hammer et al, 2002). The statistical properties of GM have been proven superior to those of distance-based or angle-based methods and the supply graphics are far more legible and interpretable thus are used in this study to describe the face of individuals afflicted with diabetes.

Diabetes is the resulting condition when the body doesn’t produce enough insulin or cannot use the insulin properly in the system thus glucose in the blood cannot move into cells and convert into energy, but rather builds up in the bloodstream harming both the cells seeking fuel as well as the organs and tissues exposed to higher glucose levels. It is influenced by obesity, genetics, race and ethnicity, age, medical history, smoking, diet, alcohol use and stress. It is likewise linked with edema, the accumulation of an excessive amount of body fluid in the tissue spaces between cells or in body cavities that are also noticeable in the overall physical appearance of the individual especially the face.
In this study, the changes caused by edema to the faces of diabetics will be described using GM methods. Since most morphometric studies have complex variations in shapes showing complicated geometries, GM reduce the complex shapes to just a few variables in order to simplify the problem. The new method of GM which is based on the study of landmarks, have made it easier to parameterize shape in this way, to visualize shape change and test hypotheses statistically thus are used in this study.

**METHODOLOGY**

Fifty four (54) non-diabetics and 63 diabetics (the type of diabetes, whether type 1 or type 2, was not considered) were recruited to participate in this study. Adults aged 18-60 were selected based on the argument that the face of affected patients is already manifested well at age $18^{21}$. Images were taken with a Kodak Easy Share C300 Digital Camera from the subjects with neutral expressions and were directly facing the camera. All participants wore no make-up and spectacles, and the males did not have any beards. The photographs were downloaded to the computer and 43 facial landmark points were identified in the images of two dimensional face models $^{21}$ (Table 2, Fig. 2). All landmarks were first plotted on the photographs using Microsoft Paint to serve as a guide. Lines were also drawn between certain landmarks to ensure the consistency of the plotting of the points on all photographs.
Procrustes fitting was used to eliminate size, shape and rotational orientation. It treats all landmarks equivalently, avoiding the subjective weighting of two particular landmarks as in baseline fitting (Morphometry). Euclidean Matrix Algorithm (EDMA) was used to determine the interlandmark distance with the highest contribution to the overall size variation. Thin plate spline (TPS) was used to visualize variations in the face shapes using the mean shape as the source configuration. Individual image specimens will have its own partial warps, dependent upon the shape change from the mean to that specimen ordered according to how local their corresponding deformations are (Hammer, et al 2001). The relative warps provide a scatterplot that shows the similarities and differences between the compared groups visualized with grid deformations.

RESULTS AND DISCUSSION

Figure 2 shows that the difference in the face shapes before and after procrustes fitting. Before Procrustes fitting, it was observed that the figures representing the male and female diabetics, and male and female non-diabetics, varied greatly in size (Fig. 2a). The elimination of size differences after procrustes fitting then allowed comparison between face shapes (Fig. 2b). General observations of the shape of the face show there are tapering towards the anterior part of the face in the male diabetics. The difference is in the placement of the first landmark, or the trichion. Male diabetics were placed in a higher position than the female diabetics, male and female non-diabetics. Other obvious differences, like that of landmarks 2, 3, 4 (left euryon, left zygion, left gonion) from female diabetics and landmarks 6, 7, 8 (right gonion, right zygion, right euryon) of male diabetics were only represented by one or two individuals from the two groups and cannot be used to make generalizations.

The thin plate spline was used to visualize and compare the mean face shapes between the diabetics and non-diabetics (Fig. 3). This was done by superimposing the mean shapes based on the position of the different landmarks. The superimposition showed the differences between the faces of the diabetics and non-diabetics. The position of landmarks 1, (trichion), 6 (right gonion) and 7 (right zygion) of diabetics were farther from the center and placed in a higher position, compared to that of non-diabetics. This suggests that the mean face shape of the diabetics exhibits widening in this part of the face relative to the mean face shape of non-diabetics.
To have a clearer understanding of the variations in the shape of the face between sexes and between diabetic and non-diabetic patients based on the 43 landmarks, canonical variate analysis was done. CVA scatter plots revealed differences in face shapes between sexes within and between diabetics and non-diabetics (Fig. 4).

**Figure 5**
Figure 4. Distribution of the two sexes of diabetic and non-diabetic individuals along the first two canonical variate axes.

The result of the discriminant function analysis is shown in Table 2. While distinct differences were observed between diabetics and non-diabetics, gender differences were also observed. Referring from the results from relative warps (Fig. 5), males were observed to generally have prominent brow ridge and large nasal cavity, with a more vertical slope in the forehead. Females have smaller nasal cavity, as well as smaller curvature just above the teeth. Generally, females
do not have a brow ridge and the forehead is much more curvilinear.

**Figure 7**

Table 3. Reclassification of the diabetic and non-diabetic individuals using discriminant function analysis.

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<th>Original GROUP</th>
<th>Predicted Group Membership</th>
<th>Total</th>
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<td>Male_ Diabetic</td>
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<td>----------------</td>
<td>-----------------------------</td>
<td>---------------</td>
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The results of this study further support the observation that Diabetes mellitus is a common condition which has clinical skin manifestations where diabetic patients have generally thicker skin especially in the face than that of non-diabetics. Thicker skin of diabetics might be a reason for a less angular or rounder face shape of diabetics. The asymmetry towards the right side of the face might have been caused of thicker skin in this part of the face. Likewise, edema made the face feel puffy around the eyes causing for the folded or compressed appearance of the mean face shape of diabetics.

**CONCLUSION**

In this study, geometric morphometrics usefulness to describe differences in face shape between diabetics and non-diabetics is shown. Based on the analysis of landmarks as shape variables, the face shape of diabetics was found to be rounder and less tapered compared to that of non-diabetics. Common features among diabetics include facial asymmetry (elongation towards the right), drooping of the brow ridge, compression of the face towards the center, and downward folding of the skin in the area of the eyes.

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**References**

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