Human & Veterinary Medicine
International Journal of the Bioflux Society HVM

OPEN ACCESS
Research Article

Describing the shape of the face of hypertensive and non-hypertensive adult females using geometric morphometric analysis

Christine Cherry E. Solon, Mark Anthony J. Torres, and Cesar G. Demayo

Department of Biological Sciences, College of Science and Mathematics, MSU-Iligan Institute of Technology, Iligan City, Philippines.

Abstract. Objective: This study describes morphological variations of the face of hypertensive women when compared to non-hypertensives. Material and Methods: Digital images of the faces of 54 non-hypertensive and 41 hypertensive women were used in this study. Forty-one manually positioned landmarks were on front face images, while twenty-eight landmarks were collected on left and right face images, the Cartesian coordinates of which were extracted using an image analysis and processing software. The faces were then aligned using Procrustes alignment 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. Results: Principal Component Analysis revealed that in both populations of females, five or six principal components contribute most to the variation that exist among individuals. Results for fluctuating asymmetry are higher compared to individual variation, with even higher values in hypertensive individuals compared to non-hypertensive. Scatterplots of residual asymmetry between the two groups further revealed the distinct differences existing between them.

Key Words: hypertension, geometric morphometrics, fluctuating asymmetry

Copyright: This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Corresponding Author: C. C. E. Solon, solonchristine@gmail.com

Introduction

Face analysis had been quite important in studies of health-related concerns (O'Callaghan *et al* 1991; Lohr *et al* 1997; Hammond *et al* 2001; McGrath *et al* 2002). While there are studies that show minor anomalies occuring in normal human populations at low frequencies, deviations from normal values can be indicative of a health problem (Hammond *et al* 2001; McGrath *et al* 2002). Studies on craniofacial anthropometry have allowed for identification and quantification of syndromic clinical features, treatment planning, monitoring of operative outcomes, and assessment of longitudinal change (Deutsch & Farkas 1994; Farkas & Deutsch, 1996). Anthropometric studies on the face had been limited to measurement using traditional instruments (e.g., sliding and spreading calipers) during an examination (Douglas 2004). Landmarks have been used in qualifying cranial variation 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 (Farkas 1996; Douglas *et al* 2003; Douglas 2004). While direct anthropometric measurements are reliable and inexpensive to make, it is labor-intensive, time-consuming and requires on-site expertise especially those requiring serial measurements of those abnormalities in craniofacial disorders that undergo changes in time (Deutsch & Mulliken, 2001; Mulliken *et al* 2001). To minimize these concerns, the use of computer-based techniques to capture craniofacial surface images including advances in computational biology and image analysis and several other methods were explored to minimize the problems of conventional anthropometric measurements (Turk & Pentland 1991; Craw *et al* 1992; Yang & Huang 1994; Lanitis *et al* 1995; Kjeldsen & Kender 1996; Rowley *et al* 1998; Schneiderman & Kanade 1998; Yang *et al* 2002; Grayson *et al* 1988; Al-Omari *et al* 2005). Of these, the new method of 'geometric morphometrics' (GM), an adaptation of multivariate statistics and graphics for study of phenotypic variation proved to be useful for detection of form changes and is very useful in understanding shape variations in living organisms thus we used it for studying hypertensive women. Since edema is also closely linked with hypertension, and because the accumulation of an excessive amount of body fluid in the tissue spaces between cells or in body cavities are noticeable in the overall physical appearance of the individual especially the face (Stephan *et al* 2005), the changes to the faces of hypertensives caused by edema will be described using GM methods.

Materials and Methods

A survey was made for both hypertensive and non-hypertensive women after they were formally asked to participate in the study. Formal consent from the participants was secured and their identity was made confidential. Upon approval, the digital images of faces of one hundred eight hypertensive (N=54) and non-hypertensive (N=54) females from the same age group

were digitized using tpsDig2. Object symmetry, where frontal face images are utilized, is applicable in this case and a single landmark configuration provides information about asymmetry and about the left-right average of shape. The methodological approaches of geometric morphometrics (GM) make use of two-dimensional coordinate data to describe size and shape at the same time (Rohlf & Bookstein 1990; Marcus *et al* 1996; Dryden & Mardia 1998; Slice 2005, 2007). 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 statistical properties of GM have been proven superior to those of distance-based or angle-based methods (Rohlf 2004, 2006, 2007) and the supply graphics are far more legible and interpretable to the applied biologist thus the tools of GM was therefore used in describing differences between the faces of hypertensive and non-hypertensive women. The 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.

This single configuration contains all the information that analyses of matching symmetry consider separately for the left and right sides, but it also contains additional information on the arrangement of the two halves relative to each other. The analysis would therefore include an additional preliminary step: reflecting all configurations from one body side to their mirror images. The variation among individuals is analyzed using the averages of the left and right configurations, and asymmetry is measured from the differences between configurations from the left and right sides of each individual (Klingenberg *et al* 2002). Measurement error is assessed by digitizing each landmark configuration thrice in three different sessions and computing the differences between replicates, all of which will be done using tps series of programs by Rohlf (2006).

Figure 1 shows the location of the landmarks and the characteristics are presented in Table 1. Landmarking was done without changing the orientation using tpsDig2 software. This was done three times in three different sessions thus completing three replicates. This is needed to quantify and minimize measurement error (Palmer 1994; Klingenberg *et al* 1998). The software SAGE was used to reflect the landmarks on one side of the face to their mirror image to align corresponding landmarks on both sides. Both landmark configurations on the left and right sides of the faces were scaled to have the same unit centroid size. The centroid sizes of the left and right sides of the faces were determined by calculating the square root of the sum of the squared distances from the landmarks to the common centroid or the geometric center. Then, a technique in SAGE was applied to superimpose the left and right sides of the faces by shifting the left and right centroids to a common set of x and y coordinates [0, 0]. Then, the landmark configurations from both sides of the faces were rotated around their centroids to achieve the optimal fit of corresponding landmarks. This is a least-squares approach where the optimal fit minimizes the sum of the squared deviations between the paired landmarks. Then, the difference between homologous landmarks on right and left sides of the face was calculated as xy_{il}- xy_{ir}. The total difference between landmarks within an individual is was calculated as $\Sigma=(xy_{il}- xy_{ir})/k$ where k = the number of landmarks. The xy_{il}- xy_{ir} in the formula is conceptually the same as $(l_i-r_i)/[(l_i+r_i)/2]$, which is the most common index of asymmetry for a single trait. In summary, the magnitude of facial asymmetry for each respondent was measured following three steps. First step, reflected copies of each landmark were generated by reversing the side of its x-coordinate. Then, the Procrustes average of each face is then defined as the middle of the line passing between the original landmark and the reflected copy of the corresponding landmark. The new face shape created by connecting these average landmarks is perfectly symmetrical. Lastly, the asymmetry of each face is calculated as the difference between the original and the mirror configurations, or equivalently, the landmark deviations of the original configuration from the average landmarks.

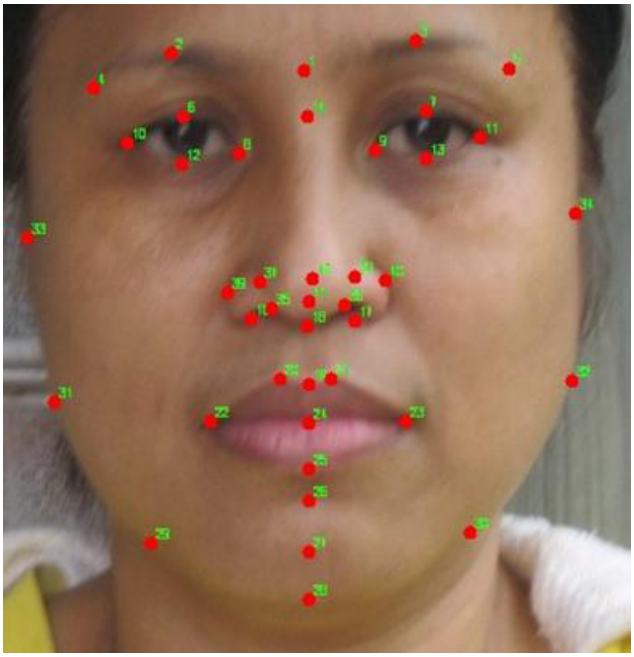

Figure 1. Landmarks on the frontal face image (photograph used with permission from the subject)

Results

Using the 41 landmarks, the scatter plots show significant shape differences between hypertensive and non-hypertensive women (Fig. 2). This result confirms studies that the face of hypertensives differs from non-hypertensives (Table 2). Significant differences in face shapes of the two women groups can be seen based on the distribution of the samples along the first two component axes (Fig. 2).

Discussions

The results of this study confirm the many studies that there are changes in the face of people with chronic diseases such as diabetes, hypertension and arthritis (Hagley 2005; Murphy *et al* 2004; Fogel 2005; Martin-Gronert & Ozanne 2006; Marvicsin 2008; Demayo *et al* 2010). Other studies also show craniofacial changes in people with behavioral disorders such as schizophrenia (O'Callaghan *et al* 1991; Nopoulous *et al* 1997; Lane *et al* 1997; Lohr *et al* 1997; Waddington *et al* 1999; McGrath *et al* 2002; Buckley *et al* 2002; Hennessy *et al* 2004) and those

Table 1. Craniofacial landmarks (frontal image)

No.	Landmark	Region	Definition/Description
1	Nasion (n)	Face	The midpoint of the nasofrontal suture
2, 3	Superciliare (sci)	Orbits	The highest point on the upper margin of the middle portion of the eyebrow
4, 5	Frontozygomaticus (fz)	Head	The most lateral point on the frontozygomatic suture
6, 7	Palpebrale superius (ps)	Orbits	The highest point on the upper margin of the middle portion of the eyelid
8, 9	Endocanthion (en)	Orbits	The inner corner of the eye fissure where the eyelids meet, not the caruncles (the red eminences at the medial angles of the eyes)
10, 11	Exocanthion (ex)	Orbits	The outer corner of the eye fissure where the eyelids meet
12, 13	Palpebrale inferius (pi)	Orbits	The lowest point in the middle of the margin of the lower eyelid
14	Sellion (s)	Nose	The deepest point of the nasofrontal angle
15	Pronasale (prn)	Nose	The most protruded point of the nasal tip
16, 17	Lateral subalare	Nose	Medial to alare (the most lateral point on the nasal ala), it is the inner wall of the nose
18	Subnasale (sn)	Face	The junction between the lower border of the nasal septum (the partition that divides the nostrils) and the cutaneous portion of the upper lip in the midline
19	Labiale superius (ls)	Orolabial	The midpoint of the vermilion border of the upper lip
20, 21	Crista philter (cph)	Orolabial	The point on the crest of the philtrum, the vertical groove in the median portion of the upper lip, just above the vermilion border
22, 23	Cheilion (ch)	Orolabial	The outer corner of the mouth where the outer edges of the upper and lower vermilions meet
24	Stomion (sto)	Orolabial	The midpoint of the labial fissure when the lips are closed naturally
25	Labiale inferius (li)	Orolabial	The midpoint of the vermilion border of the lower lip
26	Sublabiale (sl)	Face	The midpoint of the labiomental sulcus
27	Pogonion (pg)	Face	The most anterior point in the middle of the soft tissue chin
28	Gnathion (gn) or menton	Face	The lowest point in the middling on the lower border of the chin
29, 30	Tubercular	face	The slight depression of the jawline somewhere between the gnathion and the gonion
31, 32	Gonion (go)	Face	The most lateral point at the angle of the mandible
33, 34	Zygion (zy)	Face	The most lateral point on the zygomatic arch
35, 36	Supra subalare	Nose	the slight notch on the anterior nasal wall somewhere between the alare and pronasale; usually at the level of the subalare
37, 38	Lateral pronasale	Nose	Slight depression on each side of the pronasale
39, 40	Superior alare	Nose	The outer margin of the most flared portion of the nose
41	Infrapronasale	nose	The point below pronasale, usually the point between the pronasale and the subnasale

Table 2. Procrustes ANOVA in frontal face images of female individuals

	Non-hypertensive					Hypertensive			
	Individual	**Side**	**Interaction**	**Measurement error**		**Individual**	**Side**	**Interaction**	**Measurement error**
SS	0.977	0.024	0.161	0.128	**SS**	1.189	0.016	0.232	0.091
Df	2067	39	2067	8424	**Df**	2067	39	2067	8424
MS	0.001	0.001	0.000	0	**MS**	0.001	0.000	0.000	0
F	6.081	8.034	5.107	--	**F**	5.118	3.742	10.464	--
P	<0.000	<0.000	<0.000	--	**P**	<0.000	<0.000	<0.000	--

SS – sum of squares; df – degrees of freedom; MS – mean squares; F statistic; P – level of significance (significant values are presented in bold fonts)

Table 3. PCA-implied deformation for individual variation of directional asymmetry frontal images of non-hypertensive and hypertensive females

	Non-hypertensive		Hypertensive
PC1 (33.43%)	Landmark 1 shows downward displacement; The landmarks of the eye area are displaced downward (6, 7, 12, 13), downward and obliquely (2, 4, 10 to the right and 3, 5, 11 to the left); nose landmarks (15-18; 35-41) as well as upper lip (19-21, 24, 25), upward cheek landmarks (33 and 34) in downward and outward directions; jaw: 29 and 30 – downward; 31 and 32 are displaced outward to a greater degree; Chin (28) downward	**PC1 (28.87%)**	jaw landmarks (28-32) are displaced upward and inward; downward displacement of landmarks of the nose (numbers 15-18, 35-41) and mouth (numbers 19-21, 24); upward displacement of the chin (28); upward displacement of the cheeks (33-34); very slight movements of the eyes: 6 and 10 upward and outward to the right; 7 and 11 upward and outward to the left; Very notable is the direction of movements of the landmarks involved, most of which are opposite compared to movements exhibited by landmarks of the Non-hypertensive females.
PC2 (13.67 %)	Variation involves mostly the lateral landmarks of the jaws (29-32) which are displaced at a quite greater degree to posteromedial directions.	**PC2 (17.74%)**	Greatly due to movements of jaw landmarks 29 to 32 downwards and towards the middle; cheeks (33 and 34) medially directed; upward movement of the nasion (1); slight movements of the eye (2, 4, 6, 8, 10, 12 upward and centrad from the right; 3, 5, 7, 11, 13 upward and centrad from the left); chin (26) downward; mouth region (19-21, 24-25) slightly downward
PC3 (9.12%)	Inward displacements in the area of the eyes (2, 4, 6, 12 coming from the left; 3, 5, 7, 13 coming from the right) and cheeks (33 and 34); Outward displacements of jaw region (29, 31 coming from the right and 30, 32 coming from the left) ; Chin (26-28) shows downward movements	**PC3 (11.17%)**	Jaw landmarks 31 and 32 are displaced downwards; 29 (from the right) and 30 (from the left) downwards and towards the midline; Eyebrow area shows outward displacements: 2 and 4 to the right, 3 and 5 to the left; Chin landmarks 26-28 and lower lip (25) upward; Very slight downward shift of the tip of the nose (15)
PC4 (7.06%)	movements of the jaws (31 and 32) downward and towards the center	**PC4 (7.70%)**	Eyebrow show downward and outward movements: 2 and 4 to the right; 3 and 5 to the left; cheek area shows upward and outward displacements: 33 to the right and 34 to the left; downward movement of nasion (1)
PC5 (5.05%)	slight downward and inward displacement in the jaws (31-32)	**PC5 (5.59%)**	Jaws show upward and outward movements: 29 to the right and 30 to the left; Nose: 35-36 upward; 15 very slightly upward; Lip: 19 and 24 very slightly downward

Table 4. PCA results for fluctuating asymmetry of frontal images of Non-hypertensive and hypertensive females.

	Non-hypertensive		Hypertensive
PC1 (35.63%)	movements of the cheek landmarks 33-34 to the right; jaw landmarks 29-32 to the right eyebrow: 4, upward to the right and 5, downward to the right	**PC1 (41.92%)**	Great degree of displacement of cheek (33-34) to the right jaws (29-32) towards the right; slight degree of displacement of the nose landmarks to the left (15, 18, 35-41)
PC2 (15.74%)	very slight leftward displacements of yebrow landmarks 4 and 5 (blue arrows are barely visible)	**PC2 (14.40%)**	Chin: landmark 28 to the left eyebrow landmark 2 midanteriorly, landmark 4 anteriorly (both from the right side); landmark 3 posteriorly to the left, landmark 5 posteriorly
PC3 (10.34%)	Eyebrow landmark 3 upward to the right 31 (jaw) upward to the left; bottom of chin's (28) movement to the right	**PC3 (8.10%)**	cheek landmarks: 33 (from the right) is displaced upward to the center; 34 (from the left) is displaced downward and outward jaws: 31 (from the right) is displaced upward; 32 (from the left) is displaced downward
PC4 (6.41%)	all landmarks contribute equally to the variation as shown by the absence of the blue arrows though there is a noticeable distorted area at the nose region	**PC4 (6.71%)**	involves upper cheeks landmarks 33 and 34 which are displaced anteriorly and posteriorly, respectively
PC5 (5.44%)	all landmarks contribute equally to the variation as shown by the absence of the blue arrows though there is a noticeable distorted area at the mouth region	**PC5 (5.51%)**	involves eyebrow landmarks 2 at the right side (moved obliquely anterior to the right), 3 at the left side (moved obliquely posterior to the right); cheek landmarks show obliquely directed displacements, 31 at the right side (moved midposteriorly) and 32 from the left side (moved anteriorly)

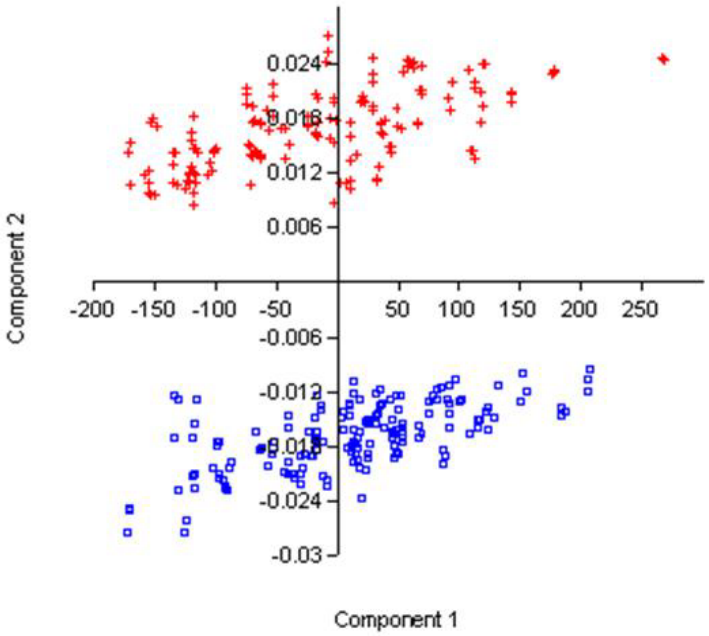

Figure 2. Scatterplot showing relationship between and among hypertensive (red) and Non-hypertensive (blue) females

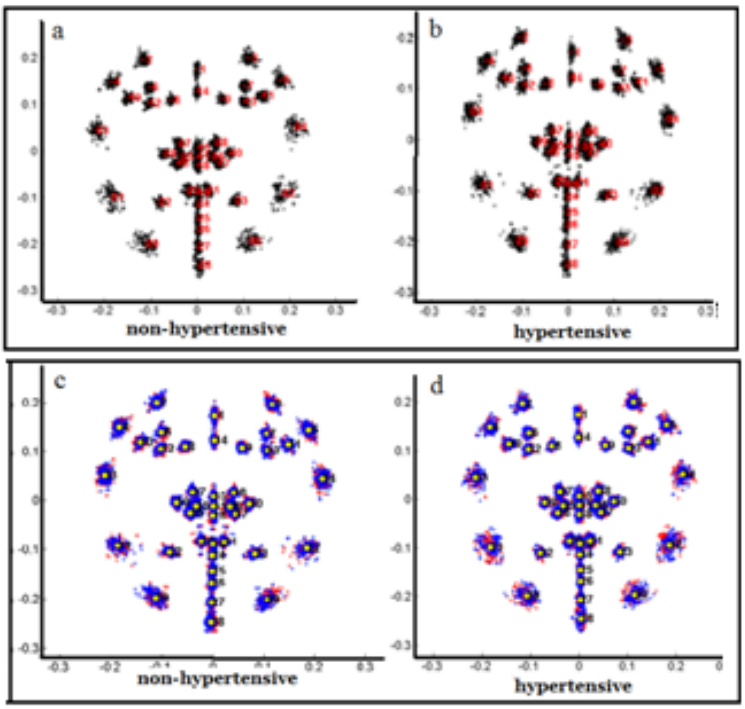

Figure 3. Procrustes fit of (a) original and (b) original (red) and reflected (blue) data of female facial front images

with a genetic disorder such as Fetal alcohol syndrome (Astley & Clarren, 1995; Astley & Clarren, 1995, 1996, 2000; Moore *et al* 2001, 2002, 2007; Meintjes *et al* 2002; Mutsvangwa & Douglas, 2007; Fang *et al* 2008). Studies on the changing face of people with chronic diseases such as diabetes, hypertension and arthritis were argued to be accounted for by either maternal nutrition during pregnancy (Martin-Gronert & Ozanne 2006), diet (Merchant *et al* 2007) and the environment (Fogel 2005) or it can also be due to the fact that a majority of hypertensives are fat which have been observed with thicker skin on the face (Demayo *et al* 2010). A majority of hypertensives have edematous face characterized by puffiness around the eyes just like diabetics (Demayo *et al* 2010) and could explain the compressed appearance of the mean face of hypertensives (Healthyroads: Edema 2000).

Acknowledgement

The senior author would like to acknowledge the Commission on Higher Education (CHED) and MSU-IIT for the scholarship grant and for the people who have given their consent in participating in this study.

References

Al-Omari, I., Millett D. T., Ayoub A.F., 2005. Methods of assessment of cleft-related facial deformity: a review. Cleft Palate Craniofac J 42:145–156.

Astley, S. J., Clarren, S.K., 1995. A fetal alcohol syndrome screening tool. Alcohol Clin Exp Res 19:1565–1571.

Astley, S. J., Clarren, S. K., 1996. A case definition and photographic screening tool for the facial phenotype of fetal alcohol syndrome. J Pediatr 129:33–41.

Astley, S. J., Clarren, S. K., 2000. Diagnosing the full spectrum of fetal alcoholexposed individuals: Introducing the 4-Digit Diagnostic Code. Alcohol Alcohol 35:400–410.

Buckley, P. F., Friedman, L. F., Jesberger, J. A., Schulz, S. C., Jaskiw, G.,2002. Head size and schizophrenia. Schizophr Res 2002 55:99–104.

Craw, I., Tock, D., and Bennet, A., 1992. Finding face features. Proc. Second European Conf., Computer Vision pp. 92-96.

Demayo, C. G., Torres M. A. J., and Veña, V., 2010. Face Shapes Of Diabetics And Non-Diabetics Described Using Geometric Morphometrics. The Internet Journal of Endocrinology 6(1):1-12.

Deutsch, C. K., Farkas, L. G., 1994. Quantitative methods of dysmorphology diagnosis. In: Farkas LG, ed. Anthropometry of the Head and Face. New York: Raven Press 94:151–158.

Deutsch, C. K., Mulliken, J. B., 2001. Discussion of surface anatomy of the face in Down's syndrome: anthropometric indices in the craniofacial regions. J Craniofac Surg 12:525–526.

Douglas, T. S., 2004. Image processing for craniofacial landmark identification and measurement: a review of photogrammetry and cephalometry. Computerized Medical Imaging and Graphics 28:401-409.

Douglas, T. S., Meintjes, E. M., Vaughan, C. L., Viljoen, D. J., 2003. Role of Depth in Eye Distance Measurements: Comparison of Single and Stereo-Photogrammetry. American Journal of Human Biology 15: 573-576.

Dryden, I. L., and Mardia, K. V., 1998. Statistical shape analysis. Chichester: Wiley.

Fang, S., McLaughlin, J., Fang, J., Huang, J., Autti-Ramo, I., Fagerlund, A., et al, 2008. Automated diagnosis of fetal alcohol syndrome using 3D facial image analysis. Orthod Craniofac Res 11:162–171.

Farkas, L.G., 1996. Accuracy of Anthropometric Measurements: Past, Present, and Future. Cleft Palate-Craniovacial Journal 33:10-22.

Farkas, L. G., Deutsch, C. K.,1996. Anthropometric determination of craniofacial morphology. Am J Med Genetics 65:1–4.

Fogel, R. W., 2005 Changes in the disparities in chronic diseases during the course of the 20th century. Perspect Biol Med 48:S150-S165.

Grayson, B., Cutting, C., Bookstein, F. L., Kim, H., McCarthy, J. G., 1988. The three-dimensional cephalogram: theory, technique and clinical application. Am J Orthod Dentofacial Orthop 94:327–337.

Hagley, K.E., 2005. Diabetes mellitus – the deluge. In: Morgan O, editor. Health issues in the Caribbean. Kingston: Ian Randle. p. 115-121.

Hammond, P., Hutton, T. J., Patton, M. A., Allanson, J. E., 2001. Delineation and visualisation of congenital abnormality using 3D facial images. In: Bellazzi R, Zupan B, Liu X, editors. Proceedings of the Workshop Intelligent Data Analysis in Medicine and Pharmacology. London, UK:IDAMAP2001 at MedInfo.

Healthyroads. Edema 2000, Its Causes and Symptoms. Available at http://www.healthyroads.com. Accessed on May 5, 2010.

Hennessy, R. J., Lane, A., Kinsella, A., Larkin, C., O'Callaghan, E., Waddington, J. L., 2004. 3D morphometrics of craniofacial dysmorphology reveals sex-specific asymmetries in schizophrenia. Schizophr Res 67:261–268.

Kjeldsen, R., and Kender, J., 1996. Finding Skin in Color Images. Proceedings of the Second International Conference on Automatic Face and Gesture Recognition pp. 312-317.

Klingenberg, C. P., and McIntyre, G. S., 1998. Geometric morphometrics of developmental instability: analyzing patterns of fluctuating asymmetry with Procrustes methods. Evolution 52:1363–1375.

Klingenberg, C. P., and Savriama, Y., 2002. Geometric morphometrics of complex symmetric structures: Shape analysis of symmetry and asymmetry with Procrustes methods. Evolution 56(10):1909-1920.

Klingenberg, C. P., McIntyre, G. S., and Zaklan, S. D., 1998. Left-right asymmetry of fly wings and the evolution of body axes. Proceedings of the Royal Society of London B, Biological Sciences 265:1255–1259.

Lane, A., Kinsella, A., Murphy, P., Byrne, M., Keenan, J., Colgan, K., et al, 1997.The anthropometric assessment of dysmorphic features in schizophrenia as an index of its developmental origins. Psychol Med 27:1155–1164.

Lanitis, A. A., Taylor, C. J., Cootes, T. F., 1995. Automatic face identification system using flexible appearance models. Image and Vision Computing 13(5):393-401.

Lohr, J. B., Alder, M., Flynn, K., Harris, M. J., McAdams, L. A., 1997. Minor physical anomalies in older patients with late-onset schizophrenia, early-onset schizophrenia, depression, and Alzheimer's disease. Am J Geriatr Psychiatry 5(4):318-323.

Marcus, L. F., Corti, M., Loy, A., Naylor, G. J. P., and Slice, D., 1996. Advances in morphometrics. NATO ASI Series New York:Plenum Press.

Martin-Gronert, M. S., Ozanne, S. E., 2006. Maternal nutrition during pregnancy and health of the offspring. Bioch Soc Transact 34: 779-782.

Marvicsin, D., 2008. School-age children with diabetes: role of maternal self-efficacy, environment, and management behaviors. Diabetes Educ 34: 477-483.

McGrath, J., El-Saadi, O., Grim, V., Cardy, S., Chapple, B., Chant, D., et al, 2002. Minor physical anomalies and quantitative measures of the head and face in psychosis. Arch Gen Psychiatry 59: 458 -64.

Meintjes, E. M., Douglas, T. S., Martinez, F., Vaughan, C. L., Adams, L. P., Stekhoven, A., Viljoen, D., 2002. A stereo-photogrammetric method to measure the facial dysmorphology of children in the diagnosis of fetal alcohol syndrome. Med Eng Phys 24:683–689.

Merchant, A. T., Dehghan, M., Behnke-Cook, D., Anand, S. S., 2007. Diet, physical activity, and adiposity in children in poor and rich neighborhoods: a cross-sectional comparison. Nutr J 2007 6:1.

Moore, E. S., Ward, R. E., Jamison, P. L., Morris, C. A., Bader, P. I., Hall, B. D., 2001. The subtle facial signs o:f prenatal exposure to alcohol: An anthropometric approach. J Pediatr 139:215–219.

Moore, E. S., Ward, R. E., Jamison, P. L., Morris, C. A., Bader, P. I., Hall, B.D., 2002. New perspectives on the face in fetal alcohol syndrome: What anthropometry tells us. Am J Med Genet 109:249–260.

Moore, E. S., Ward, R. E., Wetherill, L. F., Rogers, J. L., Autti-Ramo, I., Fagerlund, A., et al, 2007. Unique facial features distinguish fetal alcohol syndrome patients and controls in diverse ethnic populations. Alcohol Clin Exp Res 31:1707–1713.

Mulliken, J. B., Burvin, R., Farkas, L. G., 2001. Repair of bilateral complete cleft lip: in- traoperative nasolabial anthropometry. Plast Reconstr Surg 107:307–314.

Murphy, M. J., Metcalf, B. S., Voss, L. D., Jeffery, A. N., Kirby, J., Mallam, K. M., Wilkin, T. J., 2004. Girls at five are intrinsically more insulin resistant than boys: the programming hypotheses revisited – the early bird study (Early Bird 6). Pediatrics 113:82-86.

Mutsvangwa, T., Douglas, T. S., 2007. Morphometric analysis of facial landmark data to characterize the facial phenotype associated with fetal alcohol syndrome. J Anat 210:209–220.

Nopoulos, P., Swayze, V., Flaum, M., Ehrhardt, J., Yuh, W., and Andreasen, N., 1997. Cavum septi pellucidi in normals and patients with schizophrenia as detected by magnetic resonance imaging. Biol Psychiatry 41:1102–1108.

O'Callaghan, E., Larkin, C., Kinsella, A., Waddington, J. L., 1991. Familial, obstetric, and other clinical correlates of minor physical anomalies in schizophrenia. Am J Psychiatry 148:479-83.

Palmer, A. R., 1994. Fluctuating asymmetry analyses: A primer. p. 335-364. In: Developmental Instability: Its Origins and Evolutionary Implications. (T. Markow, Ed.). Kluwer, Dordrecht.

Rohlf, F. J., and Bookstein, F.L. (eds), 1990. Proceedings of theMichigan morphometrics workshop. Special Publication No. 2. Ann Arbor: The University of Michigan Museum of Zoology.

Rohlf, F. J., 2004. tpsSpline version 1.20, Department of Ecology and Evolution, State University of New York at Stony Brook, New York.

Rohlf, F. J., 2006. tpsDig version 2.10, Department of Ecology and Evolution, State University of New York at Stony Brook, New York.

Rohlf, F. J., 2007. tpsRelw version 1.45, Department of Ecology and Evolution, State University of New York at Stony Brook, New York.

Rowley, H. A., Baluja, S., and Kanade, T., 1998. Neural Network-based Face Detection. IEEE Trans. on PAMI 20(1):23-38.

Schneiderman, H. and Kanade T., 1998. Probabilistic modeling of local appearance and spatial relationships for object recognition. Proc. IEEE Int. Conf. Computer Vision and Pattern Recognition pp. 45 - 51.

Slice, D. E. (ed.), 2005. Modern morphometrics in physical anthropology. New York: Kluwer Academic Publishers.

Slice, D. E., 2007. Geometric morphometrics. Annu. Rev. Anthropol 36:261–281

Stephan, C. N., Norris, R. M., Henneberg, M., 2005. Does sexual dimorphism in facial soft tissue depths justify sex distinction in craniofacial identification? J Forensic Sci 50:513-8.

Turk, M. A., and Pentland, A.,P., 1991. Eigenfaces for recognition. Journal of Cognitive Neuroscience 3(1):71-96.

Waddington, J. L., Lane, A., Larkin, C., O'Callaghan, E., 1999. The neurodevelopmental basis of schizophrenia: clinical clues from cerebro-craniofacial dysmorphogenesis and the roots of a lifetime trajectory of disease. Biol Psychiatry 46:31–39.

Yang, G. Z., Huang, T. S., 1994. Human face detection in a complex background. Pattern Recognition 27(1):43-63.

Yang, M. H., Kriegman, J., and Ahuja, N., 2002. Detecting Faces in Images: A Survey, IEEE Transaction on Pattern Analysis and Machine Intelligence 24: 34-58.

Authors

•Christine Cherry E. Solon, Department of Biological Sciences, College of Science and Mathematics, MSU-Iligan Institute of Technology, 9200 Iligan City, Philippines, email: solonchristine@gmail.com

•Mark Anthony J. Torres, Department of Biological Sciences, College of Science and Mathematics, MSU-Iligan Institute of Technology, 9200 Iligan City, Philippines, email: torres.markanthony@gmail.com.

•Cesar G. Demayo, Department of Biological Sciences, College of Science and Mathematics, MSU-Iligan Institute of Technology, 9200 Iligan City, Philippines, email: cgdemayo@gmail.com

Citation	Solon, C. C. E., Torres, M. A. J., and Demayo, C. G., 2012. Describing the shape of the face of hypertensive and non-hypertensive adult females using geometric morphometric analysis. HVM Bioflux 4(1):45-51.
Editor	Ştefan C. Vesa
Received	27 December 2011
Accepted	2 May 2012
Published Online	31 May 2012
Funding	Scholarship grant from MSU-Iligan Institute of Technology
Conflicts/ Competing Interests	None reported