# Craniofacial asymmetry as a marker of socioeconomic status among undocumented Mexican immigrants in the United States

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A B S T R A C T

This study examines levels of fluctuating asymmetry (FA) in Mexican residents, U.S. residents, and undocumented border crossers (UBCs) from Mexico to the United States. Craniofacial structures develop symmetrically under ideal circumstances; however, during periods of developmental stress random deviations from perfect symmetry, or FA, can occur. It is hypothesized that the UBC sample would represent individuals of a lower socioeconomic status (SES) who experienced higher stress levels during development, and that these individuals would consequently have higher levels of FA. Three-dimensional cranial landmarks were collected from 509 individuals representing the three resident groups. Geometric morphometric methods were used to calculate an FA score for each individual. The FA score provides a distance measure that is a scalar measure of the magnitude of FA in each individual. The results show that the difference in the means of the FA scores between UBCs and U.S. residents is 0.43 ($p = 0.02$), with UBCs showing significantly higher levels of FA compared to U.S. residents. Moreover, Mexican residents' FA levels are intermediate between and not significantly different from the other two samples. These results suggest that levels of FA may prove useful for reconstructing individuals' social and economic circumstances, and that craniofacial asymmetry provides a suitable biological marker for analyzing differences in SES among different groups.

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## 1. Introduction

Stress during growth and development can be documented in adults in a number of ways, including short stature, enamel hypoplasias in teeth, and Harris lines in long bones. Developmental stress may result from inadequate nutrition, high disease loads, low socioeconomic status, or other environmental stresses such as exposure to high altitudes or extreme cold (Amoroso et al., 2014; Geber, 2014; Özener and Fink, 2010; Zhou and Corruccini, 1998). Markers of developmental stress thus provide a record of an individual's experience from the perinatal environment through the completion of skeletal growth. Reconstructing the environments of past people is of interest to a variety of researchers from economic historians to anthropologists. Many studies have used stature as a measure for documenting the economic characteristics of nations and regions (Carson, 2009; Johnson and Nicholas, 1995; López-Alonso and Condey, 2003; Steckel, 1987; Steckel, 1995).

Through the wide availability of stature documents, this measure has provided a wealth of information about height variation in many different groups from many different time periods. In this paper, we report on another measure of phenotypic variation which also provides a measure of environmental conditions in past populations: craniofacial fluctuating asymmetry. Under ideal circumstances, bilateral structures should develop to be perfectly symmetrical; under conditions of developmental stress, however, small deviations from perfect symmetry can occur. These random deviations are defined as fluctuating asymmetry (FA). Variation in levels of FA has been examined by a number of researchers and has been associated with an assortment of stressors including socioeconomic status, noise stress, inbreeding, mutation load, and poor health (Bigoni et al., 2013; DeLeon, 2007; Hope et al., 2013; Livshits and Kobyliansky, 1991; Milne et al., 2003; Mooney et al., 1985; Van Dongen et al., 2010; Weisensee, 2013).

Two recent studies have examined the relationship between facial asymmetry and socioeconomic status (SES). Hope et al. (2013) found that men who experienced a lower SES in early life had higher levels of FA as older adults; the relationship was non-significant in women, however. The authors suggest that environmental stresses during early development—including inadequate

medical care, insufficient access to nutritional resources, and exposure to toxins such as secondhand smoke or alcohol—result in differential levels of facial symmetry in individuals over 70 years old. In another study, Özener and Fink (2010) found a relationship between facial symmetry and SES from a sample of Turkish youths. In their sample of 17- and 18-year-olds, the authors reported that individuals who lived in an urban slum had significantly higher facial asymmetry compared to youths from an affluent neighborhood. Similar to Hope et al. (2013), Özener and Fink also found that males had significantly higher facial asymmetry compared to females. The present study examines the levels of FA between three groups that likely represent differing SES groups: U.S. residents, Mexican residents, and undocumented border crossers (UBCs) who died while crossing the U.S.–Mexico border.

The many individuals who migrate from Mexico to the United States every year as either authorized or unauthorized immigrants often differ significantly in SES in comparison to non-immigrant groups living in the United States (Passel and Cohn, 2009). Hispanic migrants, particularly unauthorized immigrants, have been found to have significantly different standards of living compared to U.S.-born residents. A 2009 study found that adult unauthorized immigrants are more likely to be poorly educated compared to U.S.-born residents. Unauthorized immigrants have much lower median household incomes ($36,000 vs. $50,000 for U.S.-born residents), and nearly twice the number of adult unauthorized immigrants live in poverty compared to U.S.-born individuals (Passel and Cohn, 2009). Unauthorized immigrants are likely similar in demographic composition to the UBC sample used in the current study as, should the latter individuals have survived the border crossing, they would have become part of the unauthorized immigrant population. Since 2001 the number of UBCs who have died while crossing the U.S.–Mexico border has risen dramatically. This is likely the result of increases in U.S. Border Patrol operations at some urban routes that have pushed individuals to attempt border crossing along more rural and hazardous routes (Anderson, 2008). Individuals who die while crossing the border put themselves at great personal risk, and the circumstances surrounding their deaths often make positive identification of their remains very difficult (Anderson, 2008). The Pima County Office of the Medical Examiner (PCOME) uses biological markers of ancestry, along with patterns related to geographic location and personal effects, to characterize this group. Personal effects commonly associated with the remains of border crossers examined at the PCOME include specific types and brands of clothing, foreign currency, and religious icons (Birkby et al., 2008). In addition to these characteristics, a suite of traits related to developmental stress markers, such as high levels of FA, may also aid in the identification of this population (Birkby et al., 2008). For

instance, forensic anthropologists examining these individuals report that the majority show markers of developmental stress, including dental enamel hypoplasias and short stature, in addition to indicators of low SES such as poor oral health (e.g., untreated carious lesions) (Birkby et al., 2008). Undocumented border crossers whose remains have been positively identified at the PCOME are overwhelmingly Mexican nationals from rural areas (Anderson, 2008).

The present study examines the levels of FA in UBCs (i.e., unauthorized immigrants who died while crossing the border into the United States) in comparison to the levels of FA in residents of Mexico and residents of the United States. High levels of FA may be associated with individuals who experience stress during growth and development, and have also previously been associated with lower SES (DeLeon, 2007; Hope et al., 2013; Little et al., 2008; Özener and Ertuğrul, 2011; Quinto-Sánchez et al., 2015). The purpose of this research is to determine whether levels of FA in UBCs differ from those of residents of Mexico or from those of residents of the United States.

## 2. Materials and methods

The samples used in this study were collected by the one of its authors (MKS). The UBC sample came from individuals examined at the PCOME in Tucson, Arizona (N = 215). The individuals in this sample died between 2008 and 2012, and their remains were discovered in the U.S.–Mexico border region. Individuals were identified as UBCs based on geographic and cultural context as well as biological indicators (Birkby et al., 2008). The Mexico resident sample came from two cemetery collections that originated in central and southern Mexico (N = 70). Zimapán is a cemetery collection from central Mexico. The majority of these individuals were blue-collar workers born in the mid-twentieth century (Figueroa-Soto, 2012). The second Mexico resident sample came from Xoclán, a cemetery collection from the Yucatan region of southern Mexico where there is a large Maya influence (Chi-Keb et al., 2013). These individuals also had birth years in the mid-twentieth century. The U.S. resident sample comes from individuals who ranged in age from 29 to 65 years and self-identified as White in the University of Tennessee William M. Bass Donated Skeletal Collection (N = 229). The Bass Donated collection is predominantly composed of documented specimens (i.e., individuals for whom demographic information such as sex, age, ancestry, birthplace, and SES are known) mainly from the southeastern United States. The birth years for this sample range from the early to late twentieth century, with most occurring around the middle of the century. The relatively short temporal span represented among the samples was intended to minimize differences due to

**Table 1**
Definitions of Landmarks Illustrated in Fig. 1.

| Landmark | Abbreviation | Midline or right/left | Definition |
|---|---|---|---|
| Alare | alar | R/L | Most lateral point on nasal aperture |
| Asterion | ast | R/L | Point where lambdoid, parietomastoid, and occipitomastoid sutures meet |
| Basion | bas | M | Point where anterior margin of foramen magnum intersects midsagittal plane |
| Bregma | brg | M | Point where coronal and sagittal sutures intersect |
| Dacryon | dac | R/L | Point where frontolacrimal and lacrimomaxillary sutures intersect |
| Ectoconchion | ect | R/L | Most lateral point on orbital margin |
| Frontomalare anterior | fma | R/L | Most lateral point on fronto-malar suture |
| Lambda | lam | M | Point where sagittal and lambdoid sutures meet |
| Nasion | nas | M | Point of intersection of nasofrontal suture and midsagittal plane |
| Nasale inferius | nlhi | R/L | Most inferior point on nasal aperture |
| Opisthocranion | ops | M | Point where midsagittal plane intersects posterior margin of foramen magnum |
| Porion | por | R/L | Point superior to external auditory meatus |
| Prosthion | pro | M | Most anterior point on alveolar border of maxilla between central incisors in midsagittal plane |
| Zygion | zyg | R/L | Most lateral point on zygomatic arch |