Elucidating Fluctuating Asymmetry in Dental and Cranial remains from Tepe Hasanlu, Iran

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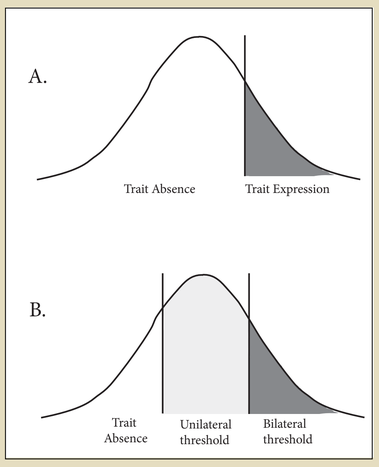
Introduction

The purpose of this study is to investigate fluctuating asymmetry in tooth dimensions by investigating the relationship between greater fluctuating asymmetry and increased mortality and whether increased asymmetry in tooth dimensions is associated with asymmetry in cranial and dental non-metric traits.

Background

Asymmetry in biological structures is a commonly used proxy for developmental disturbances. In the presence of such developmental noise, anatomical features will develop asymmetrically. As such, individuals or populations exhibiting greater levels of asymmetry are assumed to be "more stressed" (Saunders and Mayhall, 1982). **Fluctuating asymmetry** can be defined as "small, random departures from perfect asymmetry" (Palmer and Strobeck, 1992; pg. 58). Side differences are the result of "the inability of organisms to develop in precisely determined paths" (Van Valen, 1962; pg. 126).



The physiological interactions causing variation in trait expression are also unknown. The most widely accepted explanation is a threshold model of trait expression originally proposed by Grüneberg (1952). He theorized that the expression of these biological traits might be determined by an underlying continuous genetic distribution. If a necessary threshold on this distribution is reached, that trait will be expressed **(Figure 1A)**. Grüneberg suggested that the development of these continuous traits may likely be affected by environmental variables, especially those affecting the organism in utero and may also be influenced by gene interactions. Ossenberg (1981) builds upon this model by proposing that there are multiple thresholds for trait expression which may explain trait asymmetry **(Figure 1B).** Obtaining the minimum threshold will result in asymmetric trait expression while the maximum threshold will result in bilateral trait expression. While it makes sense for greater asymmetry in the teeth to be correlated with greater asymmetry in the skeleton, it is uncertain whether the type of stress or the timing of stress events could affect this relationship.

Hypotheses

The hypotheses guiding this research are as follows:

1. Individuals dying at younger ages will have higher asymmetry scores.
2. Individuals with greater dental asymmetry will have greater asymmetry in cranial non-metric traits
3. Teeth will exhibit less asymmetry than skeletal elements.

Materials

Forty-two individuals (n=42) from the Hasanlu skeletal collection housed at the University of Pennsylvania Museum of Anthropology were used for this study. Tepe Hasanlu is located in the Qadar River Valley south of Lake Urmia in the modern country of Iran. The site was occupied almost continuously for several thousand years; the deepest excavations at Tepe Hasanlu reveal the presence of human occupation since at least 6000 BC. Age-at-death was estimated using a combination of dental eruption (Buikstra and Ubelaker, 1994) and epiphyseal fusion patterns (Scheuer and Black, 2004) and for older individuals the Transition Analysis method was used (Boldsen et al., 2002).

Sample Composition

Sex	#	Age Category	#
Males	31	Juvenile	6
Females	4	Young adult	9
Indeterminate	7	Middle Adult	4
		Old Adult	19
		Indeterminate	4
Total			42

Figure 2. Map showing location of Hasanlu Tepe, Iran

Methods

Cervico-metrics

Mesio-distal (M-D) and bucco-lingual (B-L) cervical measurements were taken from the right and left maxillary canines, P3s and first molars, and the mandibular second incisor, first molar and second molar using a set of Paleo-Tech Hillson-Fitzgerald dental calipers. The methodology for measuring cervical dimensions largely follows those proposed by Aubry (2014).

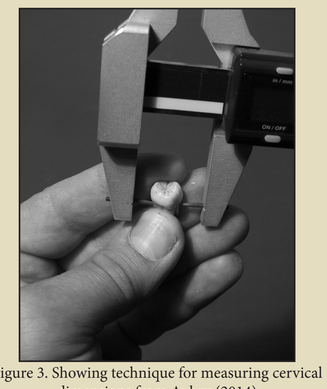


Figure 3. Showing technique for measuring cervical dimensions from Aubry (2014)

Non-metric Traits

The following 12 dental non-metric traits from the Arizona State University Dental Anthropology System (Turner et al., 1991) and 10 cranial nonmetric traits were collected following Hauser and DeStefano (1989) were collected.

ASUDAS Dental Non-Metric Traits

- Shoveling
- Double-Shoveling
- Tuberculum Dentale
- Upper Canine distal accessory ridge (DAR)
- Metacone
- Hypocone
- Carabelli's trait
- Parastyle
- Protostylid
- Cusp 6
- Cusp 7
- Enamel Extensions

Cranial Non-Metric Traits

- Mylohyoid bridging (location and degree)
- hypoglossal canal bridging
- infraorbital foramen/notch
- frontal grooves (number and location)
- foramen spinosum
- suprameatal spine
- suprameatal depression
- zygomaxillary tubercle
- squamomastoid suture persistence
- parietal foramina (position and number)

Fluctuating Asymmetry

The following equation from Palmer and Strobek (2003) was used to calculate fluctuating asymmetry for each individual.

$$\text{FA14:} \qquad (Ai) = \frac{\Sigma \frac{|FA_{ij}|}{|FA_{j}|}}{N_{observable\ traits}}$$

where FAij "is the deviation from symmetry of trait j" and |FAj| is "the average absolute deviation from symmetry of trait j for the entire sample" (pg 293). This number was also divided by the number of observable traits for each individual to compensate for missing data.

Gower Coefficient of Similarity

To combine continuous, ordinal and binary data and metric and non-metric data to produce comparable skeletal and dental measures of asymmetry. The distance between the right and left sides using the raw data for each individual was calculated using the coefficient of similarity proposed by Gower (1971). Three different Gower coefficients were calculated for each individual: 1) using all the data types (total Gower), 2) using only metric dental data (metric Gower), and 3) using only non-metric cranial data (non-metric Gower). All calculations were performed in RStudio version 1.0.136.

Results

Unfortunately due to small sample size (n-42) the majority of the statistical tests yielded non-significant results.

Hypothesis 1 predicted if asymmetry is associated with developmental disturbances, then younger individuals would present higher asymmetry scores. Numerous statistical tests assessing the relationship between asymmetry scores and age were performed using both the FA14 score, the Gower coefficients and using age categories and collapsed age categories (juvenile and adult). None yielded significant results.

Figure 3 shows the mean right-left distance for adults versus juveniles using the total Gower coefficients, demonstrating that the mean total Gower coefficient for juveniles is slightly higher than for adults. This suggests that individuals dying at younger ages might exhibit greater fluctuating asymmetry. The number of juveniles was small (n=6), so additional testing with larger samples could reveal significant results.

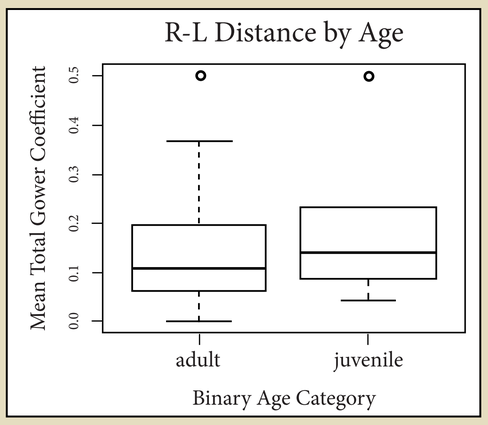


Figure 3

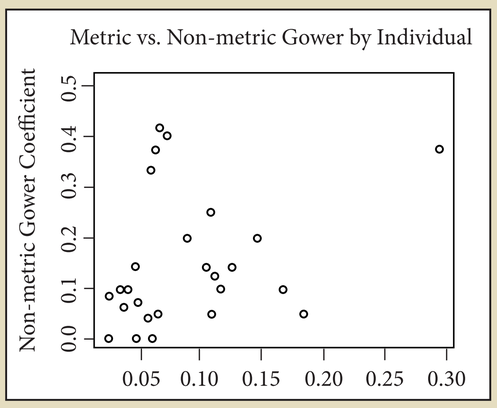


Figure 4

Hypothesis 2 predicted that individuals with greater asymmetry in cervical dimensions would also present greater asymmetry in cranial traits. **Figure 4** plots the metric Gower coefficients versus the non-metric Gower coefficients for each individual. There is a weak positive correlation between the two, suggesting the tendency for a person with asymmetry to express it in both the teeth and the skeleton.

A Pearson's correlation test revealed no significant linear correlation between the two variables (t= 1.5174, p-value=0.1417,α=0.05).

Hypothesis 3 predicted that dental measurements should demonstrate less right-left asymmetry than cranial non-metric traits. A paired-t test between the metric and non-metric Gower coefficients demonstrated that the means are significantly different (t=2.5954, p-value=0.012919, α=0.05).

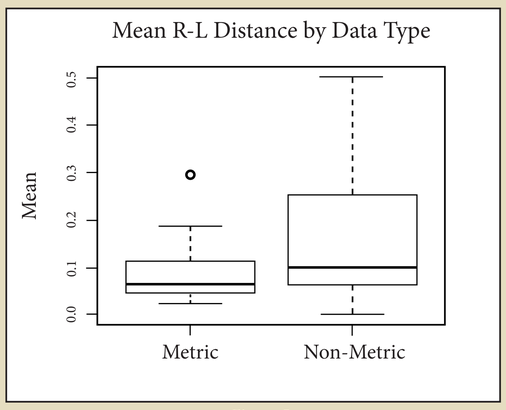
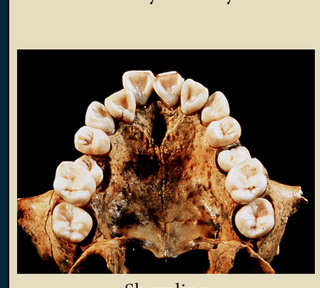


Figure 5

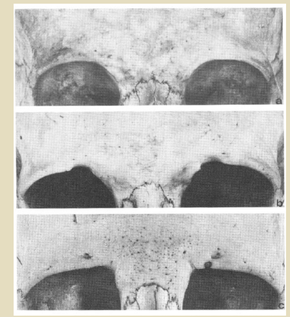
Discussion

The majority of the results of this paper are non-significant, possibly due to small sample size and large amounts of missing data. Additional study is needed with much larger sample sizes and with more cervical measurements and non-metric traits to collect as much data as possible. Only a few teeth could be measured and a small selection of non-metric traits due to time constraints. According to current assumptions that fluctuating asymmetry is associated with detrimental developmental disturbances, one might reasonably hypothesize that those with fluctuating asymmetry would be more frail and at greater risk for early mortality. Unfortunately no conclusions could be drawn about the relationship between fluctuating asymmetry and mortality.

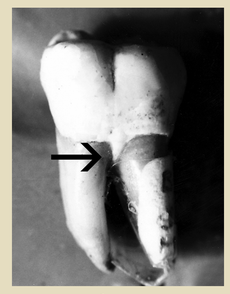
Palmer (1994) recommends a sample size of at least 40-50 though Smith et al. Smith et al. (1982) assert that samples containing several hundred individuals are necessary to detect dental asymmetry.



Shoveling



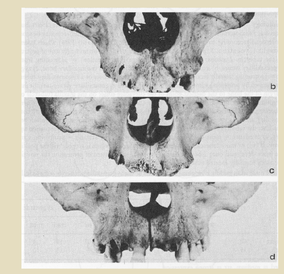
Supraorbital Foramen/Notch



Enamel Extension

Carabelli's Cusp

Parastyle



Zygomaxillary Tubercle

Limitations

The results of this project were limited by the small sample size (n=42). Increasing the sample size would augment the significance of the results. The Hasanlu skeletal sample also had very low trait expression overall. Additional study on a sample with a wider spectrum of non-metric trait scores is warranted.

Acknowledgements

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University of Pennsylvania Museum of Archaeology and Anthropology

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