Secular Change in the Human Innominate: From the 19th to the 20th Century

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Introduction

The overall adaptability of the human skeletal system is exemplified with evolutionary changes and is well documented in the anthropological literature (cf. Boas, 1912). Secular change, in particular, focuses on the plasticity and modifications of the human skeletal form over a short period of time or within successive generations (Relethford, 2009). From the 19th to the 20th century in the United States, positive secular change in human stature, body size, and long bone lengths has been documented (Steckel, 1994; Jantz & Jantz, 1999).

Presumably, corresponding changes would be expected to occur in the human innominate during this time period as well. Within the United States, medical care, sanitation, nutrition, and overall living conditions have improved dramatically through time and likely have contributed to the aforementioned changes in skeletal form between 19th and 20th century populations. While no studies to date have focused solely on the changes of the innominate for this temporal period and geographical locale, secular change of the entire articulated pelvis has been evaluated and described by both Delprete (2006) and Driscoll (2010).

Research Questions

The goal of the present research is to explore secular changes in the innominate by addressing the following research questions:

1. Is secular change occurring in the human innominate of American Whites and Blacks from the 19th to the 20th century?

2. If yes, is there enough change occurring to accurately differentiate between the two temporal groups based on metrics of the innominate. Secondly, what is the degree of these changes? Are size and shape differences *both* occurring?

3. Do findings from this research support or refute findings from other studies exploring secular change in the United States from the 19th to the 20th century? Specifically, does this research correspond with studies of secular change in the articulated human pelvis?

Materials and Methods

A sample of 224 left, adult innominates with documented sex and ancestry were used from the Hamann-Todd Collection (HTH), composed of individuals born during the 19th century, and also from the W. M. Bass Donated Collection (UTK), composed of individuals born during the 20th century. Data were collected from males (M) and females (F) of two populations: American Blacks (B) and American Whites (W) (Table 1). A stratified random sample of individuals was selected from each collection so that both sexes and ancestral groups were represented as evenly as possible. Both collections primarily consist of individuals of low socio-economic status in the United States, which implies similar living and environmental conditions, thereby making them comparable. The skeletal sample was grouped by ancestry/sex cohorts and also by temporal period for analyses.

Table 1. Sample used in this study.

SAMPLE	BF	BM	WF	WM
HTH (n=124)	28	39	26	31
UTK (n=100)	7	23	30	40

Table 2. Alphabetized list of landmark abbreviations used in this study.

ABBREV	LANDMARK
AI	Anterior Incurvature
AIIS	Anterior Inferior Iliac Spine
AP	Auricular Point
AR	Acetabular Rim
ASIS	Anterior Superior Iliac Spine
DSF	Dorsal Symphyseal Face
HOF	Horizontal Obturator Foramen
IC	Iliac Crest
IOF	Inferior Obturator Foramen
IS	Ischial Spine
ISF	Inferior Symphyseal Face
IT	Iliac Tubercle
LOF	Lateral Obturator Foramen
MOF	Medial Obturator Foramen
PIIS	Posterior Inferior Iliac Spine
PSIS	Posterior Superior Iliac Spine
SOF	Superior Obturator Foramen
SN	Sciatic Notch
SSF	Superior Symphyseal Face
TPHI	Ischial (Total Pelvic Height)
TPHS	Iliac (Total Pelvic Height)
VSF	Ventral Symphyseal Face

Twenty-two 3D landmark coordinates of the innominate were collected for each individual in the sample using a digitizer and the 3Skull software program (Ousley, 2004) (Table 2; Figure 1). From these coordinate data, 231 inter-landmark distances (ILDs) were calculated primarily to explore size differences between ancestry/sex cohorts by temporal group. An independent sample t-test was used to determine if significant differences existed between the HTH and UTK sample in each ILD. Linear discriminant function analysis (LDFA) was then utilized to classify individuals from both time periods based on a forward Wilks' stepwise selection of the ILDs.

Geometric Morphometric Analyses (GMA) were also performed to assess shape changes between temporal periods using MorphoJ (Klingenberg, 2011). The raw coordinate data were first subjected to a Generalized Procrustes Analysis to translate, scale, and rotate the data to Procrustes Coordinates, thereby removing size from the analysis (Slice, 2007).

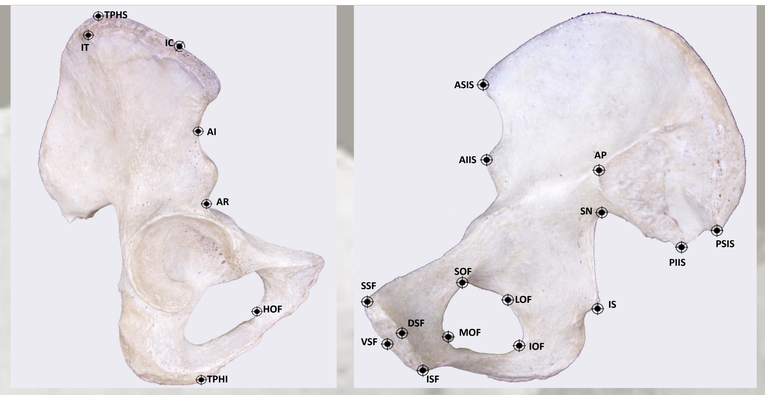

Figure 1. Lateral (left) and medial (right) view of the innominate with landmarks used in this study.

Next, Principal Components (PC) Analysis was used. Fifteen PC scores (PCS) explained over 85.6% of the variation. These PCS were then entered into LDFA to explore classification accuracy based on shape between the two periods. Shape differences were then visualized for each ancestry/sex cohort between the two periods with MorphoJ. Finally, the PCS were entered into Canonical Variate Analysis (CVA) to further compare all four cohorts (BF, WF, BM, WM) within the two temporal periods.

Results

Of the four ancestral groups, BF were the most stable through time with only 18 of 231 ILDs being significantly different between the HTH and UTK samples. Differences in BF were most pronounced in the anterior-posterior width of the blade. In both WF and BM, 51 ILDs showed significant differences primarily in the superior-inferior innominate width proportions and also in the regions of the obturator foramen and symphyseal face. In WF size differences were more pronounced along the anterior portion of the innominate, while in BM the opposite was true and most differences were seen along the posterior portion. Finally, WM showed the most variation with virtually 1/3rd (n=74) of the ILDs being significantly different. In WM, greatest size differences were found in pubis length and also in ilium width and height.

Using stepwise selection of the 231 ILDs in LDFA, correct classification between the two temporal periods was 94.3% cross-validated using 21 variables (Figure 2). The Mahalanobis Distance (D^2) between the two groups was significant at the $p<0.01$ level. Ten of the 21 ILDs accounted for 87.8% of the separation between groups and in all of these measurements, the UTK sample had significantly larger dimensions than the HTH sample.

With the PCS, the correct classification between the two periods using LDFA analysis of shape was 99.1%. Shape changes between the two time periods, when all ancestry/sex groups were pooled, occurred in all bones of the innominate.

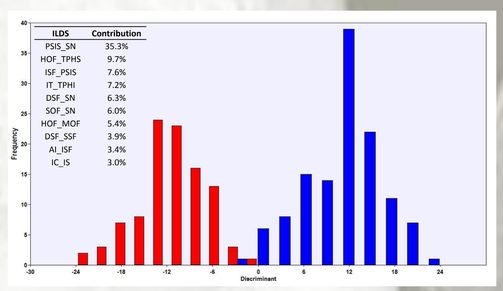

Figure 2. LDFA results using 21 forward stepwise selected variables. HTH/19th C (red), UTK/20th C (Blue). Contribution of top ten ILDs listed in table.

Greatest differences were found along the blade of the ilium, the obturator foramen, and the symphyseal face (Figure 3). Specific shape changes in the innominate for each ancestry/sex group by time period localized in the same regions as the aforementioned size differences.

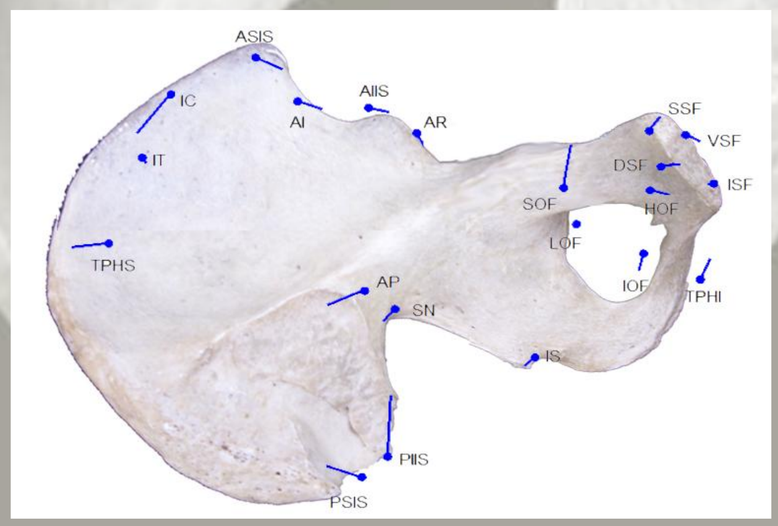

Figure 3. Visualization of the shape differences between the HTH (blue dots) and the UTK (blue lines) samples. Innominate image is roughly aligned to help visualize and differentiate the landmark changes.

Because of high classification accuracy, specific differences in pelvic dimensions were explored further using CVA. In the CVA, sex groups within each sample grouped along canonical variate (CV) one, while temporal groups pooled along CV2 (Figure 4). CV 1 accounted for 64.89% of the variance, while CV2 represented 16.97% of the variance. Significant differences were found between all eight groups (Table 3).

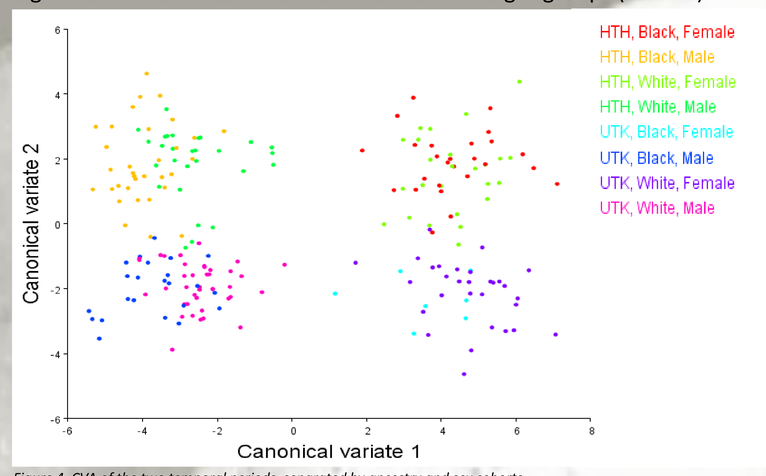

Figure 4. CVA of the two temporal periods, separated by ancestry and sex cohorts.

Table 3. Mahalanobis distance matrix for each ancestry/sex cohort in the two samples.

	HTH BF	HTH BM	HTH WF	HTH WM	UTK BF	UTK BM	UTK WF
HTH BM	8.5933						
HTH WF	3.9741	8.7405					
HTH WM	7.977	3.8192	7.562				
UTK BF	5.8619	9.4445	6.4709	8.8295			
UTK BM	9.1984	4.5529	9.4288	5.8332	8.4762		
UTK WF	5.0132	9.7425	4.5614	8.6362	4.6926	9.0121	
UTK WM	8.3465	4.797	7.8508	4.46	7.6661	3.8613	7.5139

Discussion and Conclusions

Positive secular change in the size of innominate is shown here by greater lengths and widths of the innominate from the 19th to 20th century and supports previous research using long bone lengths and stature. Through time, the American Black and White populations are becoming larger, which is likely the result of changes in environmental and social conditions during the time periods under study. Larger ILDs measurements found in the UTK sample when ancestry/sex cohorts were pooled overwhelmingly reflected the longer length of the pubic bone and to a lesser degree the greater superior-inferior width of the ilium.

Findings from this research support similar conclusions for the entire pelvis by both Delprete (2006) and Driscoll (2010). Using ILD, the stability and number of significantly different measurements matched closely with Driscoll (2010). Black females were the most stable through time in both studies and white males were the most variable. It should be noted, however, that the considerably lower number of significant differences found in BF in this study may be an artifact of the small UTK sample size.

Shape differences between the two groups were also high. In contrast to the size analysis, greatest shape differences between the samples were found primarily in the ilium followed by the pubic region. Although there are limitations of sample size for one subset (BF), analyses controlling for ancestry and sex further separated groups by temporal period, suggesting that secular change in the human innominate occurred.

Secular change in the innominate occurred in American Blacks and Whites from the 19th to the 20th century with changes in both pelvic size and shape. Differences between the two temporal periods were shown with high classification accuracies using ILDs and even higher classification accuracy using GMA. This research supports past studies looking at secular change in the United States that have indicated positive secular change in skeletal morphology.

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References

Boas F. 1912. Changes in the bodily form of descendants of immigrants. *Am Anthrop* 14:530-562.

Delprete HA. 2006. Secular changes in the morphology of the modern human pelvis and the implications for human evolution [PhD Dissertation]. New Brunswick, NJ: Rutgers.

Driscoll KRD. 2010. Secular change of the modern human bony pelvis: Examining morphology in the United States using metrics and geometric morphometry [PdD Dissertation]. Knoxville, TN: University of Tennessee.

Jantz LM, Jantz RL. 1999. Secular change in long bone length and proportion in the United States, 1800-1970. *Am J Phys Anthrop* 110:57-67.

Ousley SD. 2004. 3Skull. Version 2.1.111.

Klingenberg CP. 2011. MorphoJ: an integrated software package for geometric morphometrics. *Mol Ecol Resour* **11:** 353-357.

Relethford J. 2009. *The human species: An introduction to biological anthropology*. New York: McGraw-Hill Humanities.

Slice DE. 2007. Geometric Morphometrics. *Ann Rev Anthrop* 36:261-281.

Steckel RH. 1994. Heights and health in the United States, 1710-1950. In Komlos J. (ed) *Standards and economic development: Essays in anthropometric History*. Chicago: University of Chicago Press.

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