Secular Change in the Length & Breadth of the Bones of the Upper Limb

Ashley C. Smith, M.Sc.

Program in Forensic Anthropology
Boston University School of Medicine
Boston, Massachusetts

Abstract: While much of the secular change literature to date has focused upon long bone length as it relates to stature, limited research has dealt with changes in bone breadth. The aim of the present study was to determine the changes that occur both in the breadth of upper limb long bones as well as their lengths. The current study took thirteen measurements in the humerus, radius, and ulna from 600 individuals from the Huntington and Terry collections and the Forensic Data Bank. The data was separated by sex and analyzed by decade of birth using a Pearson's correlation analysis with a 2-tailed t-test. The results indicated that while all lengths exhibited positive growth in males and females, the same could not be said for breadths. Specifically, in males, four of the nine breadth measurements exhibited no significant change, while three resulted in a reduction in size. Similarly, in females, three measurements resulted in no change, while four exhibited a reduction. The humeral epicondylar breadth and the transverse diameter of the ulna were the only breadth measurements to result in positive growth in both sexes. Finally, while the transverse diameter exhibits a positive growth, the dorso-volar diameter exhibits an almost equally negative growth in both sexes, with the transverse diameter overtaking the dorso-volar as the larger measurement. The results of this study suggest that while the length of the long bones increase over time, breadth has not necessarily changed in a proportional manner.

Introduction

Osteometric secular change in long bone lengths has been well established, particularly as it relates to stature (Jantz and Jantz 1999; Klepinger 2001; Meadows and Jantz 1995; Trotter and Gleser 1951; Trotter and Gleser 1952). However, while changes in long bone lengths have been a primary focus, little work has been conducted on changes in breadth measurements; specifically in the non-weight bearing bones of the upper limb.

Secular change in stature has been documented since the early part of the 20th Century (Hrdlička 1922; Meredith 1941; Sargent 1908; Seaver 1909 (orig. 1896)). Trotter and Gleser notably correlated this secular change using the Terry collection and the skeletal remains of World War II (WWII) dead (Trotter and Gleser 1951). The authors found an overall positive change, indicating progressively greater stature over time (Trotter and Gleser 1951). Fourteen years later, Trotter et al. (1968) published one of the few studies on the secular change of long bone breadth, specifically that of the femur because of its effects on stature. The results of this study found that while the lengths of the femur increased, its breadth did not.

In 1995, Lee and Richard Jantz furthered the study of osteometric secular change, specifically investigating for allometric changes in long bones (Meadows and Jantz 1995). Using the numbers accrued in Trotter's second study on stature estimation, as well as individuals from the Forensic Data Bank (FDB), the authors found that the bones of the lower limb are more positively allometric, while the upper limb bones are more isometric (Meadows and Jantz 1995; Trotter and Gleser 1952).

In 1999, Lee and Richard Jantz published again on osteometric secular change, examining long bone lengths, as well as their proportions (Jantz and Jantz 1999). Similar to the 1995 study, this paper sampled individuals from the FDB and the Huntington collection, as well as utilizing the measurements of WWII remains and the Terry collection taken by Trotter in 1952. Using linear regression formulae, the results of this study showed that there was positive osteometric growth in long bone lengths and proportionality (Jantz and Jantz 1999). This study, coupled with their previous study and the work of Trotter and others, confirms that the long bones, particularly lower-limb long bones, have positively affected the stature of Americans since the late 1800s (Jantz and Jantz 1999; Meadows and Jantz 1995; Meredith 1941; Trotter and Gleser 1951).

Much like the previous studies, Jantz and Jantz (1999) utilized long bone lengths as the predominant bone measurements, primarily due to their effect on statural changes. In both Meadows and Jantz (1995) and Jantz and Jantz (1999), it was shown that secular change is proportional, particularly with regards to the upper-limb bones. It was also shown, however, that the shape of the long bones exhibited positive secular change, contradicting Trotter *et al.* (1968). The current study was conducted to examine the contention that if the shape of the long bones maintains proportionality to its length, then the individual breadth measurements should remain closely proportional to those of the lengths. In other words, if the length of a bone exhibited positive osteometric secular change, then the breadth measurements should likewise exhibit positive growth.

Methods

- Bones and Measurements
  - Humerus
    - Maximum Length (HUMXLN)
    - Epicondylar Breadth (HUMEBR)
    - Diameter of the Head (HUMHDD)
    - Maximum Midshaft Diameter (HUMMXD)
    - Minimum Midshaft Diameter (HUMMWD)
  - Radius
    - Maximum Length (RADXLN)
    - Anterior-Posterior Diameter (RADAPD)
    - Transverse Diameter (RADTVD)
  - Ulna
    - Maximum Length (ULNXLN)
    - Dorso-Volar Diameter (ULNDVD)
    - Transverse Diameter (ULNTVD)
    - Physiological Length (ULNPHL)
    - Ulnar Circumference (ULNCIR)
- Equipment:
  - Length measurements were taken with Paleo-Tech Concepts field osteometric board
  - All others were taken with a calibrated GPM™ Swiss-Made sliding caliper with following exceptions:
    - ULNPHL – calibrated GPM™ Swiss-Made spreading caliper
    - ULNCIR – standard measuring tape
  - *Fractional measurements were rounded up to the nearest whole number*
- Sample
  - The study population was comprised of 600 individuals
    - 100 males and females from three collections:
  - The Huntington Collection
    - Dates of birth: 1810 to 1881
    - Dates of death: 1893 to 1902
    - Average age at death 48
    - Approximately 92% were European
  - The Terry Collection
    - Dates of birth: 1848 to 1943
    - Dates of death: 1923 to 1964
    - The average age at death 66
    - Approximately 53% were listed as "Black" and 47% as "White"
  - The Forensic Data Bank
    - Dates of birth: 1943 to 1985
    - Dates of death ranging: 1972 to 2008.
    - The average age at death was 37
    - Approximately 80% were "American White," 15% "American-Black," and 5% "Hispanic"
- Statistical Analysis
  - Age:
    - Utilized Pearson's Correlation Analyses with 2-tailed t-tests
    - Conducted on individual collection groups
      - Divided by sex
    - Between age at death and individual measurements
    - Results found no significant correlation
  - Secular Change
    - Populations were then categorized into groups based on decade of birth
    - A Pearson's Correlation Analysis with 2-tailed t-tests also conducted
      - Utilized decade of birth and the measurements to determine if a statistical correlation existed

Results

- *LENGTHS:*
  - Results of the correlation analysis confirmed that the lengths of the bones increased in size
    - HUMXLN, RADXLN, ULNXLN, and ULNPHL all indicated a positive correlations
- *BREADTHS:*
  - Female Results (Table 4)
    - Only 2 measurements indicated positive correlation, or growth
      - HUMBER (0.260) and ULNTVD (0.552)
    - 2 indicated no significant changes, or static growth
      - HUMHDD (0.086) and ULNCIR (-0.021)
    - Remaining 5 resulted in negative correlations, or "slimming"
      - HUMMXD (-0.342), HUMMWD (-0.309), RADAPD (-0.127), RADTVD (-0.302) and ULNDVD (-0.473)
  - Male Results (Table 5)
    - 2 measurements indicated positive correlation
      - HUMEBR (0.375) and ULNTVD (0.463)
    - 4 measurements indicated no significant correlation
      - HUMHDD (0.029), HUMMWD (-0.097), RADAPD (0.073), and RADTVD (-0.080)
    - Remaining 3 indicated a negative correlation
      - HUMMXD (-0.132), ULNDVD (-0.470), and ULNCIR (-0.237)

Decade of Birth		Frequency	%	Cumulative %
Female Group	1810-1819	6	2.0	2.0
	1820-1829	11	3.7	5.7
	1830-1839	16	5.3	11.0
	1840-1849	13	4.3	15.3
	1850-1859	42	14.0	29.3
	1860-1869	74	24.7	54.0
	1870-1879	15	5.0	59.0
	1880-1889	10	3.3	62.3
	1890-1899	5	1.7	64.0
	1900-1909	8	2.7	66.7
	1940-1949	22	7.3	74.0
	1950-1959	37	12.3	86.3
	1960-1969	27	9.0	95.3
	1970-1979	12	4.0	99.3
	1980-1989	2	.7	100.0
	Total	300	100.0	
Male Group	1810-1819	1	.3	.3
	1820-1829	6	2.0	2.3
	1830-1839	15	5.0	7.3
	1840-1849	26	8.7	16.0
	1850-1859	64	21.3	37.3
	1860-1869	37	12.3	49.7
	1870-1879	26	8.7	58.3
	1880-1889	9	3.0	61.3
	1890-1899	9	3.0	64.3
	1900-1909	5	1.7	66.0
	1910-1919	1	.3	66.3
	1940-1949	1	.3	66.7
	1950-1959	29	9.7	76.3
	1960-1969	50	16.7	93.0
	1970-1979	15	5.0	98.0
	1980-1989	6	2.0	100.0
	Total	300	100.0	

Table 1: Breakdown of samples by decade of birth

Female Population					
	Population	Frequency	%	Valid %	Cumulative %
Huntington	White	91	91.0	91.0	91.0
	Black	5	5.0	5.0	96.0
	Unknown	4	4.0	4.0	100.0
	Total	100	100.0	100.0	
Terry	White	47	47.0	47.0	47.0
	Black	53	53.0	53.0	100.0
	Total	100	100.0	100.0	
FDB	White	89	89.0	89.0	89.0
	Black	10	10.0	10.0	99.0
	Hispanic	1	1.0	1.0	100.0
	Total	100	100.0	100.0	
Total Population	White	227	75.7	75.7	75.7
	Black	68	22.7	22.7	98.3
	Hispanic	1	.3	.3	98.7
	Unknown	4	1.3	1.3	100.0
	Total	300	100.0	100.0	

Table 2: Breakdown of female group by ancestry

Male Population					
	Population	Frequency	%	Valid %	Cumulative %
Huntington	White	96	96.0	96.0	96.0
	Black	4	4.0	4.0	100.0
	Total	100	100.0	100.0	
Terry	White	48	48.0	48.0	48.0
	Black	52	52.0	52.0	100.0
	Total	100	100.0	100.0	
FDB	White	72	72.0	72.0	72.0
	Black	20	20.0	20.0	92.0
	Hispanic	8	8.0	8.0	100.0
	Total	100	100.0	100.0	
Total Population	White	216	72.0	72.0	72.0
	Black	76	25.3	25.3	97.3
	Hispanic	8	2.7	2.7	100.0
	Total	300	100.0	100.0	

Table 3: Breakdown of male group by ancestry

Female Correlations	humxln	humebr	humhdd	hummxd	hummwd	radxln	radapd	radtvd	ulnxln	ulndvd	ulntvd	ulnphl	ulncir
Pearson Correlation	.156**	.260**	.086	-.342**	-.309**	.268**	-.127*	-.320**	.218**	-.473**	.552**	.245**	-.021
Sig. (2-tailed)	.007	.000	.136	.000	.000	.000	.027	.000	.000	.000	.000	.000	.720
N	300	300	300	300	300	300	300	300	300	300	300	300	295

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 4: Results of female correlation analysis

Male Correlations	humxln	humebr	humhdd	hummxd	hummwd	radxln	radapd	radtvd	ulnxln	ulndvd	ulntvd	ulnphl	ulncir
Pearson Correlation	.140*	.375**	.029	-.132*	-.097	.327**	.073	-.080	.318**	-.470**	.463**	.351**	-.237**
Sig. (2-tailed)	.015	.000	.620	.022	.092	.000	.207	.166	.000	.000	.000	.000	.000
N	300	300	300	300	300	300	300	300	300	300	300	300	296

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 5: Results of male correlation analysis

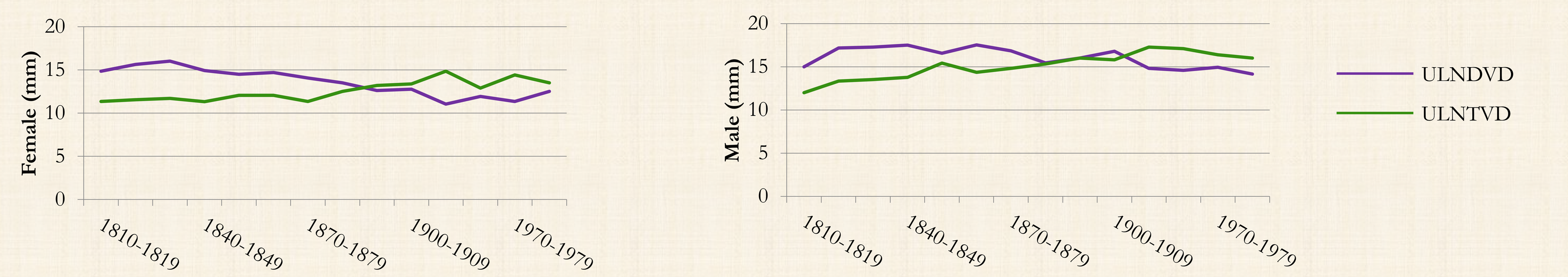
Graphs of Results

The "Ulnar Phenomenon"

In both females and males, the ulndvd resulted in a significant negative correlation (females = −0.473, males = −0.470), while the ulntvd resulted in a similarly significant positive correlation (females = 0.552, males = 0.463). When the means were graphed, the trend forms an "x"-shape, indicating that the ulntvd overtook the ulndvd in size. This trend was verified by determining which the larger measurement in all three collections was. In both the males and females of the Huntington Collection, the ulndvd was the larger measurement in all sampled individuals. For the Terry Collection, the ulndvd was the larger measurement in 45% of males and 53% of females. The ulndvd and ulntvd were the same in 15% of males and 17% of females. In the FDB, the transverse diameter was overwhelmingly the larger measurement, with 83% of the males and 81% of the females having the ulntvd the larger measurement. In approximately 1% of both sexes the ulndvd and ulntvd were equal in size.

	ULNDVD > ULNTVD	ULNDVD < ULNTVD	ULNDVD = ULNTVD
Huntington (Female)	100.00%	0.00%	0.00%
Huntington (Male)	100.00%	0.00%	0.00%
Terry (Female)	52.54%	30.51%	16.95%
Terry (Male)	44.54%	40.34%	15.13%
FDB (Female)	17.72%	81.40%	1.09%
FDB (Male)	16.21%	82.80%	0.99%

Table 6: Percentage of collection where the ulnar dorso-volar diameter is greater-than, less-than, or equal to the transverse diameter



Discussion

The results of this study shed new light on our understanding of osteometric secular changes in bone. To date, a majority of the published studies have demonstrated that long bones are exhibiting positive growth over time; a fact which this study does not dispute (Jantz and Jantz 1999; Meadows and Jantz 1995; Trotter and Gleser 1951). In fact, the results of this study confirm that understanding, with 100% of the length measurements exhibiting growth in persons with birth-years spanning the past two centuries.

While the results of this study indicate that the lengths of the long bones are increasing, the same cannot be said for the breath of the bones which appear to be mostly static for males and are shrinking in females. These results are similar to that of Trotter *et al.* (1968). This is particularly seen in the radius where both breadth measurements in the females resulted in significant negative correlations, while in males resulted in no significant correlation. This pattern is also demonstrated in the humerus where both breadth measurements indicated significant negative correlations in females, but only the maximum breadth exhibited the same correlation in males. The fact that a negative correlation exists in the maximum breadth of both males and females is further indicative of a "thinning" of the upper limb bones.

Within the last decade, work in the area of secular change has been focused on determining the causes of osteometric secular change with primary attention paid toward dietary and nutritional changes (Klepinger 2001). However, while the consensus in the field has been that nutritional changes are the primary cause for osteometric secular change, the results of this study indicate that there is much more to the equation. If secular change was the result of a metabolic processes altered by nutritional variations, then one would expect to see the breadth measurements expand at a similar rate as the length measurements. In other words, the bones would be getting larger and maintaining proportionality throughout. However the results indicate that upper limb bones are not increasing in breadth. Rather, they are thinning. This is particularly seen in ulna, where over time one measurement (ulntvd) has overtaken its perpendicular measurement (ulndvd) as the larger measurement. This study indicates that an external force element must also be considered as the bones are not proportionally increasing. While it is not within the scope of this paper to examine potential causes of secular change, future research into the effects of occupational and activity changes in similar populations may help close this knowledge gap.

Acknowledgements: I would like to acknowledge and thank Dr. David Hunt and all of the staff at the Smithsonian Institute's Museum Support Center for granting me access to their collections and for all of the assistance they offered. I would also like to thank Dr. Stephen Ousley for granting me permission to utilize the data in the Forensic Data Bank. Additionally, I would like to thank the Program in Forensic Anthropology at Boston University School of Medicine for funding this project, as well as Amelia Boaks, Darryl Ricketts, and Dr. Farzad Motizavi for all of the assistance that they provided.

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*Presented at the 82nd Annual Meeting of the American Association of Physical Anthropologist in Knoxville, Tennessee – 13 April 2013