Enthesophytes: Correlation of Pathological Bony Growth at Tendon Insertion Sites with Sociodemographic Factors in European and African American Individuals

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INTRODUCTION

Enthesophytes are pathological bony growths at the insertion sites of tendons that result from mechanical stress, tendon injury, and age-related bone degeneration. Individuals who participate in high mechanical stress occupations or activities, such as construction work or marathon training/running, are more prone to enthesopathies, as tendons are injured, causing calcification and later ossification of soft tissues. Similarly, age is correlated with enthesopathies, as a lifetime of mechanical stress takes effect on the soft and hard tissues. The development of enthesophytes is further associated with genetics; individuals with the phenotype for high bone density are more likely to experience pathological bone growth. Genetically, African Americans are most prone to high bone density, followed by Hispanic, European American, and Asian individuals (Walker and Bilezikian 2008). Additionally, enthesophytes are correlated with other pathological conditions including DISH, spondylosis, and osteoarthritis, along with sociodemographic factors.

Research on enthesophytes typically focuses on the biology of entheses (fibrous and fibrocartilaginous), variations within one insertion site, or enthesophyte development in one population (i.e., Hawkey and Merbs 1995; Natsis et al. 2006; Niinimaki and Sotos 2012; Solano 2006). For example, a study of the Northwest Hudson Bay Inuit by Hawkey and Merbs (1995) found correlations between the enthesophytes and documented habitual and subsistence behaviors. In particular, enthesophytes of the wrist and elbow flexors in females were consistent with cutting and scraping animal skins, while those of the pectoralis major and pronator quadratus insertion sites in males were correlated with harpooning activities. Many studies have found correlations of enthesophyte development with sociodemographic categories, with greater development in individuals with laborious occupations, older age, and in males (Niinimaki and Sotos 2012; Solano 2006). However, the role of ancestry in enthesophyte development has been largely neglected. In the present study, it was hypothesized that ancestral origins, along with age, sex, and occupation, variably correlate with the development of enthesophytes. The primary goal of this study was to further expand knowledge of enthesophyte development and determine if such correlation exists with sociodemographic categories. The correlation of enthesopathies with occupation and ancestry could lend physical proof to historical or archaeological accounts of an individual's lifestyle, as well as aid in the individualization of unidentified skeletal remains when considering age, sex, and ancestry.

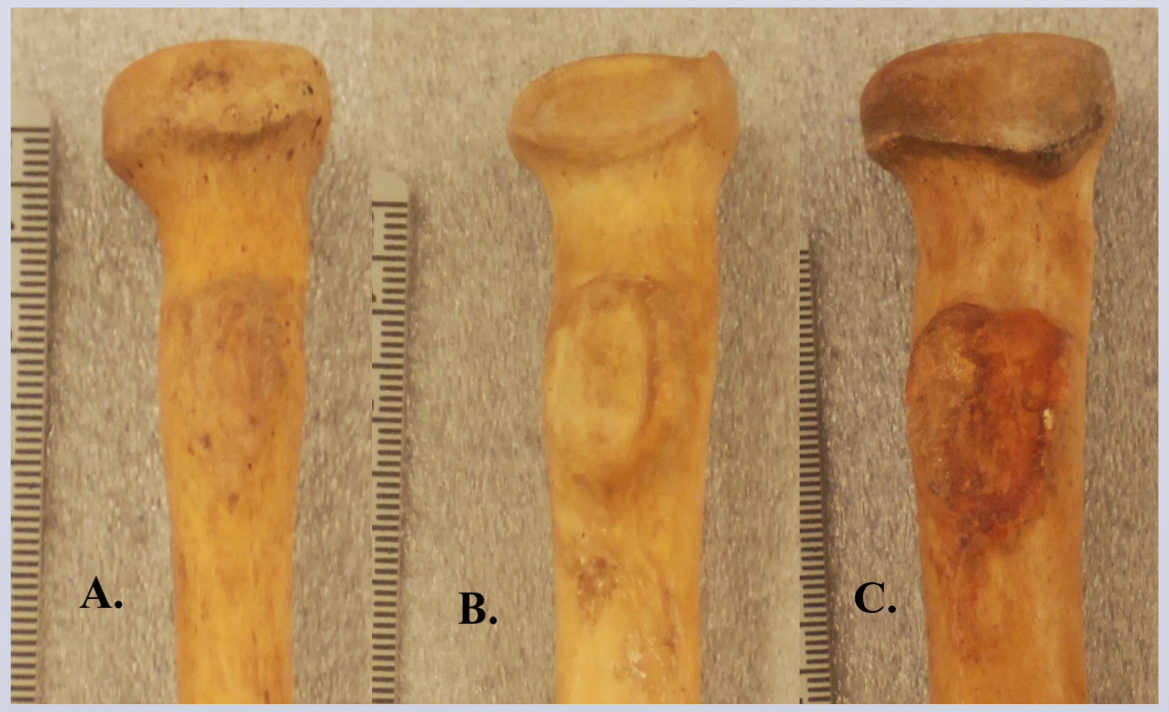

Figure 1. Proximal radii showing: A) slight (score = 1); B) moderate (score = 2); and C) severe (score = 3) enthesophyte development. Scales are in mm.

MATERIALS AND METHODS

The Hawkey and Merbs (1995) enthesophyte scoring system was applied to tendon insertion sites and compared to the documented sociodemographic records for 230 African and European American individuals from the William M. Bass Donated Skeletal Collection at the University of Tennessee, Knoxville (Table 1). The system follows a 0-3 scale, with 0 = no development, 1 = slight, 2 = moderate, and 3 = severe growth (Figure 1). Ten insertion sites were included for the upper limb (Table 2), while nine insertion sites were included for the lower limb (Table 3). The scored insertion sites consisted mainly of fibrocartilaginous entheses, with one fibrous insertion site included on each of the upper and the lower limbs (Figure 2). Both the upper and the lower limbs were included in this study to determine possible ancestral differences; a component which was not examined in earlier studies. The individuals were placed into age groups of 39 years or younger, 40-59 years, 60-79 years, and 80 years or older, and were separated by sex for each ancestral group. Occupation was divided into four groups for analysis: unknown occupation, unemployed with no further records, laborious occupations such as construction, and non-laborious occupations such as office clerk and secretarial work. Each of these categories were analyzed with Spearman's rho statistics to determine significant correlations. Lastly, Cohen's kappa analyses were calculated to determine intraobserver agreement for a second set of scores from 14% (n = 32) of the total sample.

Table 1. Total number of European and African American individuals per age group.

Age (years)	Male, European	Male, African	Female, European	Female, African	Total
≤39	5	4	3	2	14
40-59	46	25	24	2	97
60-79	48	14	37	5	104
80+	3	2	9	1	15
Total	102	45	73	10	230

Table 2. Insertion sites of the upper limb.

Element	Muscle
Humerus	Teres major
	Teres minor
	Extensor carpi ulnaris
	Pectoralis major
	Common insertion of supraspinatus & infraspinatus
	Deltoid
Radius	Biceps brachii
Ulna	Triceps brachii
	Brachialis
Scapula	Pectoralis minor

Table 3. Insertion sites of the lower limb.

Element	Muscle
Pelvis	Gluteus medius origin
Femur	Gluteus medius insertion
	Adductor magnus
Patella	Common insertion of the quadriceps
	Patellar tendon
Tibia	Popliteus
	Femoris & iliopsoas
	Semitendinosus & sartorius
Calcaneus	Gastrocnemis

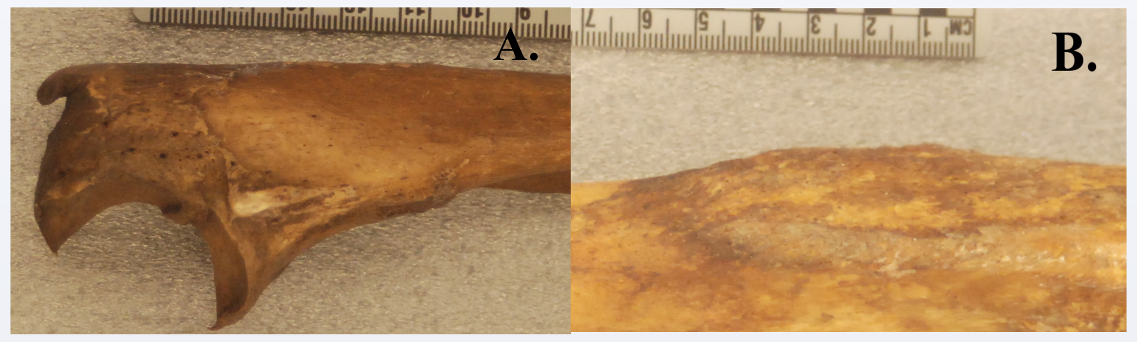

Figure 2. Proximal ulna showing a fibrocartilaginous insertion site for triceps brachii (A); humeral diaphysis showing fibrous insertion site for deltoid (B). Scales are in mm.

RESULTS

Table 4. Statistically significant sexual dimorphism of the upper (left) and lower (right) limbs.

Teres major	Left & Right - Male
Pectoralis major	Left & Right - Male
Biceps brachii	Left & Right - Male
Triceps brachii	Left & Right - Male
Brachialis	Left - Male
Deltoid	Left & Right - Male

Gluteus medius insertion	Left & Right - Male
Quadriceps femoris & iliopsoas	Left & Right - Male
Semitendinosus & sartorius	Left & Right - Male
Gluteus medius insertion	Left & Right - Male

Table 5. Statistically significant occupation in the upper limb*.

Pectoralis major	Right - Laborious
Supraspinatus & infraspinatus	Left - Laborious
Pectoralis minor	Right – non-laborious
Deltoid	Left & Right - Laborious
Pectoralis major	Right - Laborious
Supraspinatus & infraspinatus	Left - Laborious
Pectoralis minor	Right – non-laborious
Deltoid	Left & Right - Laborious

*No insertion sites of the lower limb were statistically significant for occupation.

Table 6. Statistically significant ancestral differences in the upper (left) and lower (right) limbs.

Triceps brachii	Left & Right - African
Pectoralis minor	Right - European
Deltoid	Left & Right- African

Gluteus medius attachment	Left & Right - European
Gluteus medius insertion	Left - European
Patellar tendon	Left - African

Table 7. Age correlations in the upper (left) and lower (right) limbs.

Teres minor	Left & Right – 60-79 yrs
Teres major	Left & Right - 60-79 yrs
Extensor carpi ulnaris	Left & Right - 60-79 yrs
Pectoralis major	Left & Right - 60-79 yrs
Supraspinatus & infraspinatus	Right - 60-79 yrs
Biceps brachii	Left & Right - 60-79 yrs
Triceps brachii	Left - 60-79 yrs
Brachialis	Left & Right - 60-79 yrs
Pectoralis minor	Left & Right - 60-79 yrs

Gluteus medius attachment	Left & Right - 60-79 yrs
Gluteus medius insertion	Left & Right - 60-79 yrs
Adductor magnus	Left & Right - 60-79 yrs
Patellar tendon	Left & Right - 60-79 yrs
Quadriceps tendon	Left & Right - 60-79 yrs

Table 8. Cohen's kappa agreement following Landis and Koch (1977) for the upper (left) and lower (right) limbs.

Teres Minor	Left & Right - Substantial
Extensor carpi ulnaris	Right – Substantial
Pectoralis major	Left – Substantial
Supraspinatus & infraspinatus	Left and Right – Substantial
Biceps brachii	Right – Substantial
Triceps brachii	Left - High
Brachialis	Left & Right - High
Pectoralis minor	Right - Substantial
Teres Minor	Left & Right - Substantial

Gluteus medius attachment	Left and Right - High
Gluteus medius insertion	Left - High
Adductor magnus	Right - Substantial
Quadriceps tendon	Left - High
Popliteus	Right - Substantial
Gastrocnemius	Right - High
Gluteus medius attachment	Left and Right - High
Gluteus medius insertion	Left - High
Adductor magnus	Right - Substantial

DISCUSSION AND CONCLUSIONS

The results of this study indicate that age is the most important sociodemographic category impacting enthesophyte development. This can be attributed to a lifetime of mechanical stresses on the body, as well as due to pathological bone growth increasing in older individuals, such as with osteoarthritis. The development of these pathologies was statistically significant for the 60-79-year age range, while some insertion sites of the lower limb were most significant for those individuals who were 80 years or older. Further, sex and occupation contribute to enthesophyte development, while ancestry had the least statistical significance. In every insertion site of statistical significance, males were more likely to display greater enthesophyte development than females. Individuals in more laborious occupations had greater development of the insertion sites for the muscles of the shoulders and chest, which are involved in heavy lifting. The lower limb, however, exhibited no significant insertion sites, which is similar to previous research (Niinimaki and Sotos 2012). The insertion sites that are correlated with ancestry were those of smaller muscles that play a minimal role in heavy lifting or the expression of sexual dimorphism, and thus may be most influenced by ancestry. While ancestral differences were observed, neither the African American individuals nor the European American individuals were overall more prone to enthesopathies. Thus, ancestry is likely not an indicator of whether individuals display overall *greater* enthesophyte development. However, the European American sample (n = 175) was older, with 49% of individuals in the 60-79-year age range, while the African American sample (n = 55) had 48% of individuals in the 40-59-year age range. Cohen's kappa analyses of intraobserver agreement in scoring displayed mostly substantial or better agreement for all insertion sites in the upper limb except for the deltoid, while there was moderate or substantial agreement for the insertion sites in the lower limb (Landis and Koch 1977). This indicates the overall reliability of the Hawkey and Merbs (1995) scoring system.

There were limitations to this study. Despite including 55 individuals of African American ancestry, the available sample was overwhelmingly European American, which is reflective of numerous skeletal collections. While the Bass Collection provides detailed records of sociodemographic data, the information provided by the donors is voluntary and thus is not always complete or accurate. Future studies on enthesophyte development should include additional modern samples to see if differences exist between other ancestral groups (i.e., Asian and Hispanic). Additionally, larger sample sizes of females with known ancestries and occupations from modern collections will provide a more accurate view of sex differences. Overall, studies using modern collections are needed to better understand the diversity in how today's occupations and habitual activities affect bone biology.

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