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TECHNICAL NOTE

ANTHROPOLOGY

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The Use of Vertebral Osteoarthritis and Osteophytosis in Age Estimation*

ABSTRACT: Previous research on age and vertebral degenerative change has focused on osteophytosis. The present study expands this research by examining the association between osteoarthritis and osteophytosis and by assessing their relationship to age. Researchers scored the bodies and facets in 104 individuals. Statistical analyses assessed relationships between age and degenerative change for the bodies and facets, both separately and combined, for all vertebrae collectively, and for subcategories of vertebral types. Separate analyses were conducted which included only regions that experience heavier stress loads. Results indicate that osteophytosis and osteoarthritis are not associated with each other for all subcategories of vertebrae. Also, the inclusion of osteoarthritis does not enhance the relationship between age and degenerative change, nor does limiting analyses to areas of heaver stress. Finally, although both conditions are significantly correlated with age, the relationship is not strong enough to yield predictive power for establishing age beyond a general estimate.

KEYWORDS: forensic science, forensic anthropology, vertebral osteophytosis, osteoarthritis, age estimation, skeletal pathologies

For more than 50 years, research has been conducted on various regions of the human skeleton to establish techniques for determining age at death; however, the accuracy of those techniques generally decreases as chronological age increases (1–5). Degenerative changes in the skeleton, which are caused in part by repetitive motion or stress and, thus, are exacerbated by the aging process, potentially could yield patterns of data that are helpful either in establishing or narrowing age estimates for older individuals.

In the vertebral column, multiple elements function as a unit to support the cranium and torso, stabilize the body during erect posture and bipedal locomotion, and protect the spinal chord. With each different function, the vertebrae are subject to a variety of stressors, with some regions experiencing heavier stress loads than others (6–8). Osteological responses to these stressors include bone deposition on the vertebral body margins (or osteophytosis) and degenerative changes in the zygapophyses (or osteoarthritis).

With regard to aging and the vertebrae, research on degenerative change has been conducted in the past (7–11). While these studies found a correlation between age and osteophyte development, they also noted that individual variation precluded its usefulness for assessing age beyond a general estimate. The relationship between age and vertebral osteoarthritis has been addressed only indirectly by Fujiwara et al. (7) who noted that disc degeneration, which is associated with aging, precedes "facet joint osteoarthritis" (p. 396). Research limited to areas of the vertebrae that experience the heavier stress loads has not been conducted.

The purpose of the present study was to expand upon previous research using a modern, contemporary collection composed of individuals whose deaths postdated 1980. Our goals were to (i) examine the association between osteophyte development in the vertebral body margins and osteoarthritis in the facets, (ii) test whether or not the inclusion of osteoarthritis can enhance age estimation, (iii) assess whether or not the relationship to age is strengthened by limiting analyses to areas that experience the heavier stress loads, and (vi) if possible, generate regression formulae for estimating age.

Materials and Methods

One hundred and four individuals, aged between 30 and 90 years (mean age 57.49 years, SD 12.335), were evaluated for this study (Fig. 1). The sample was derived from the William M. Bass Donated Collection housed at the University of Tennessee and the Donated Forensic Collection housed in the Forensic Anthropology and Computer Enhancement Services Laboratory at Louisiana State University. For each individual, all vertebrae were evaluated for osteoarthritis; however, the atlas and axis were not considered in the assessment of osteophytes. If an individual had either missing or extra vertebrae, the individual was still scored, but the affected regions were excluded from statistical analyses. Although data were collected from individuals of both sexes and multiple ancestry groups, sex and ancestry differences in osteophyte development and osteoarthritis were not assessed because of small sample sizes.

The methodology for assessing osteophyte development was based on Stewart's (10) five-scale classification technique in which the superior and inferior borders of each vertebra were assigned a score based on the degree of bony lipping present (Table 1). Because osteophyte expression can vary considerably within each vertebra, the maximum expression across an entire border was recorded. Mean osteophyte scores were computed for the entire column and for each subcategory of vertebrae. These scores were calculated by dividing the sum of scores for all surfaces by the total number of surfaces examined (9). For example, with two surfaces

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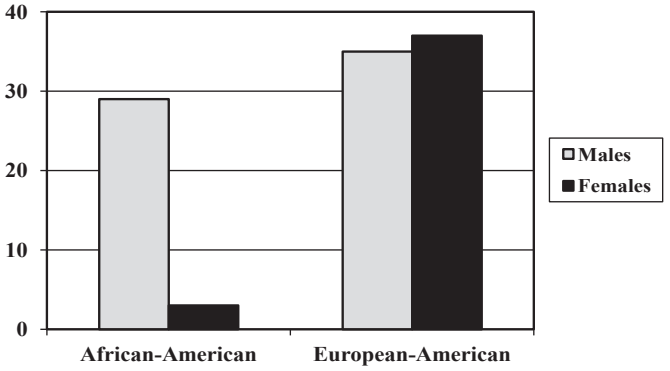

FIG. 1—*Sex and ancestry distribution in the sample.*

TABLE 1—*Categories for scoring osteophyte development.*[*]

Score	Description
0	No degenerative change
1	Slight lipping
2	Moderate lipping
3	Severe lipping
4	Ankylosis of adjacent vertebrae

[*]Based on Stewart (10).

in each vertebra, the mean thoracic osteophyte score was the sum of all borders divided by 24.

The methodology for scoring osteoarthritis is a four-stage classification system that assesses each joint surface for the degree of bone formation, destruction, or deformation (12) (Table 2). As with the bodies, the maximum expression for the entire facet was recorded. Mean osteoarthritis scores were computed for the entire column and for each subcategory of vertebrae. These scores were calculated by dividing the sum of scores for all facets by the total number of facets examined. For example, with four facets in each vertebra, the mean thoracic osteoarthritis score was the sum of all facets divided by 48.

In addition to the two sets of variables described earlier, a third set of variables was created, which combined the osteophyte and osteoarthritis scores for the entire column and for each subcategory of vertebrae. Multiple statistical tests were used to examine the association between age and degenerative change. These included a Wilcoxon signed-rank test to evaluate the association between mean osteophyte and osteoarthritis scores and linear regression to determine the usefulness of the two pathologies as age predictors.

Separate analyses also were conducted which considered only the vertebrae in regions that are subject to the heaviest stress loads. These regions include C5-6, T8-9, and L4-5 for osteophytosis and C6-7, T1-5, L2-4 for osteoarthritis (13). Mean osteophyte, mean osteoarthritis, and mean combination scores were computed for these vertebrae and the same statistical analyses were completed on these variables.

Finally, intra- and inter-observer errors were examined using the Wilcoxon signed-rank test and the Mann–Whitney *U*-test, respectively. For all analyses, significance was noted if $p < 0.05$.

TABLE 2—*Categories for scoring osteoarthritis.*[*]

Score	Description
0	No degenerative change
1	Slight lipping
2	Moderate lipping and/or pitting
3	Severe lipping, pitting, and/or eburnation

[*]Based on Ubelaker (12).

Results

Table 3 shows results of the Wilcoxon signed-rank test assessing the relationship between mean osteophyte and osteoarthritis scores. When the entire column is examined, significant differences are found in all categories except the thoracics. When the areas of heavier stress are examined, only the thoracics and lumbars show significant differences.

Correlation and R^2 values from the regression analyses for the entire column and for areas of heavier stress are reported in Table 4. For the entire column, all variables show a significant relationship to age. With the exception of the cervical vertebrae, osteophyte development is a better predictor of age (as indicated by R^2) than osteoarthritis alone or the combination of the two pathologies. In the cervicals, however, osteoarthritis is a better predictor than osteophyte development and the two pathologies used in combination are better still. Nevertheless, all R^2 values are low and range from 0.393 in the lumbar bodies to 0.108 in the thoracic facets. For the areas of heavier stress, all variables show a significant relationship to age and osteophyte development alone generally is a better predictor than osteoarthritis. The predictive value does improve when the two pathologies are combined for the cervicals, but not for any other category. As with the entire column, all R^2 values are low and range from 0.408 in the collective bodies to 0.116 in the thoracic facets.

TABLE 3—*Wilcoxon signed-rank test between mean osteophyte and osteoarthritis scores.*

	Entire Column		Areas of Heavier Stress	
	Z	Sig.	*Z*	Sig.
Cervical	−4.503	0.000	−0.159	0.873
Thoracic	−0.971	0.331	−4.370	0.000
Lumbar	−6.046	0.000	−4.905	0.000
All	−6.152	0.002	−0.901	0.367

TABLE 4—*Regression analysis of mean osteophyte and osteoarthritis scores.*

	Entire Column			Areas of Heavier Stress		
	F-value	*p*-Value	R^2	*F*-value	*p*-Value	R^2
Osteophytes						
Cervical	24.658	0.000	0.213	32.014	0.000	0.243
Thoracic	35.513	0.000	0.297	35.587	0.000	0.268
Lumbar	57.547	0.000	0.393	44.022	0.000	0.319
All	38.891	0.000	0.348	61.423	0.000	0.408
Osteoarthritis						
Cervical	36.446	0.000	0.305	24.075	0.000	0.204
Thoracic	9.092	0.004	0.108	11.964	0.001	0.116
Lumbar	30.642	0.000	0.256	30.258	0.000	0.244
All	11.928	0.001	0.168	20.115	0.000	0.199
Combined						
Cervical	45.480	0.000	0.362	38.405	0.000	0.290
Thoracic	15.737	0.000	0.205	24.402	0.000	0.217
Lumbar	41.176	0.000	0.334	41.617	0.000	0.319
All	13.703	0.001	0.222	31.770	0.000	0.298

Analysis of inter-observer error indicates that differences in the authors' assessments were significant for 11/143 categories of data (7.7%). Of those 11, 10 (90.9%) were related to osteoarthritis, while one (9.1%) was associated with osteophytosis. Intra-observer error rates were somewhat higher. Author "A" had significant differences in her assessments for 28/143 (19.6%) categories of data; author "B" had significant differences in 35/143 (24.5%) categories of data. As with inter-observer error, the majority of differences for both authors were related to osteoarthritis (100% for "A," 85.7% (30/35) for "B").

Discussion and Conclusion

Previous research has demonstrated that a relationship exists between age and osteophyte development in the vertebrae. The present study attempted to expand upon this research by examining facet degeneration in conjunction with osteophyte development and also by analyzing areas of heavier stress separately from the entire column. Our results indicate that a significant correlation exists between age and osteophyte development and between age and osteoarthritis, both separately and when combined, for the entire column as well as for areas of heavier stress.

Our first goal was to examine the association between the different types of vertebral degenerative change. We found that mean scores for osteophytosis and osteoarthritis are significantly different from each other with the exception of thoracics (entire column), and cervical and collective vertebrae (in heavier stress areas). This finding is not entirely unexpected. Normal activities (such as sitting, standing, bending, and lifting) require the vertebrae to compress, flex, extend, and rotate. These motions impact differently the regions of the column and the individual vertebrae themselves, and, therefore, they can result in separate bony responses. While osteophytes are believed to develop in reaction to, and to help compensate for, intervertebral disc degeneration, osteoarthritis results from excessive posterior load-bearing forces or from joint malalignment caused by vertebral body compression. Some clinical research also indicates that osteoarthritis follows, and may even result from, osteophytosis (6,7,14). Thus, the difference in mean scores of the two pathologies likely is reflecting this difference in etiology. The exceptions could signify that, for these regions, either a common stressor will produce a multifaceted response or that degenerative changes from multiple stressors will progress at similar rates, or possibly both.

Our second goal was to test whether or not the addition of osteoarthritis could enhance age estimation. With the exception of the cervicals, the additional information did not produce a stronger relationship. For the thoracic and lumbar regions, as suggested with the results earlier, this outcome also may be a result of etiological differences. With regard to the cervicals, however, it is interesting to note that the region in which the strength of the relationship increases with combined data also demonstrates no significant differences between the two pathologies. Perhaps, these results are reflecting a differential response to stress in the neck compared with the chest or lower back.

Our third goal was to test whether or not the relationship with age would be strengthened by limiting analyses to areas of heavier stress. Of the 12 variables examined, six do show a strengthened relationship when data are limited to these areas. However, even in these six variables, R^2 is low; therefore, these data are not helpful for narrowing age estimates.

Last, we hoped to generate regression formulae that would be useful for estimating age for older individuals. Once again, the low R^2 values make any such formulae ineffective. This result is consistent with what W.W. Howells found in 1965 when he performed regression analyses using Stewart's data. Based on his results (or lack thereof), Howells suggested that osteophytes do not represent age per se, but instead may reflect "the effects of function and stress... the passage of time rather than a process of aging" (cited in Işçan and Loth [15, p. 27]). Further, some clinical research indicates that genetic and nutritional factors also may impact how the intervertebral discs respond to stress, which would, in turn, affect osteophyte development (14). Ultimately, although a relationship exists between age and degenerative changes in the vertebrae, the singular effect of age cannot be separated from the other mechanical or genetic factors that also produce osteological changes.

In conclusion, the current study assessed the relationship between age and vertebral degenerative changes with the hope of generating predictive models for estimating age in older individuals. To differentiate from previous research, data from multiple indicators were considered both individually and collectively and a contemporary population was used. In general, results from this study add to, but ultimately mirror, previous research. That is, both osteophytosis and osteoarthritis are significantly correlated with age; however, the relationship is not strong enough to yield predictive power for establishing age beyond a general estimate.

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