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TECHNICAL NOTE

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Sex Differences and Aging of the Vertebral Column*

ABSTRACT: Morphological changes in the adult human skeleton have been recognized as useful for estimating the age at death. In the vertebral column, the development of osteophytes has been shown to be a general indicator of age, although substantial variation has been documented. The technique used for estimating age from osteophyte development is based exclusively on males and it is unknown whether patterns of osteophyte development are comparable between the sexes. This study examines sex differences in osteophyte development in the thoracic and lumbar regions of 384 individuals from the Terry Collection. Males and females in this sample show remarkably similar patterns of age-related changes in osteophyte development; however, females show greater variability in osteophyte stage for a given age. This was confirmed with age-matching a subsample of 128 individuals. Therefore, slightly larger confidence intervals should be used when assessing age from the vertebral column in females.

KEYWORDS: forensic science, forensic anthropology, vertebral osteophyte, spondylosis, age determination

Morphological changes in the skeleton of adults can be important indicators of age and have been used extensively in forensic anthropology and bioarchaeology. These aging techniques have generally focused on the pelvis, including the pubic symphysis and the auricular surface, and the sternal ends of the ribs. However, degenerative changes in the vertebral column—in the form of osteophytes or bony lipping on the margins of the vertebral centra—have been shown to be useful indicators of age (1). Stewart recorded substantial variation in osteophyte development with age and cautioned "osteophytosis by itself does not permit close ageing (sic) of the skeleton" (1). While osteophyte development may allow only a general assessment of age at death, it can be important for establishing upper or lower limits on age. Additionally, this technique can be used in conjunction with other methods or when other skeletal elements more commonly used in aging are unavailable. One limitation of the technique is that it is based exclusively on males.

The objective of this study is to examine osteophyte production in a large sample of adult females and males to establish patterns of morphological changes and to examine potential sex differences. The investigation of sex differences in age-related changes has important implications in forensic anthropology. Without information on patterns of osteophyte development in females, criteria for males are often substituted to estimate age at death. However, it is unknown whether patterns of osteophyte production are similar in males and females. Given that there are sex differences in age-related changes in bone mineral density in the vertebral column (2) and differences in the absolute and relative sizes of vertebral bodies (3–5), this merits further investigation. Other anatomical regions, including the pubic symphysis, have been shown to exhibit substantial sex differences in age-related changes (e.g., 6–8).

Methods

In order to examine variation in osteophytosis, a random sample of 384 individuals (192 males, 192 females) was examined from the Terry Collection, housed at the National Museum of Natural History (Smithsonian Institution) in Washington, D.C. Individuals were randomly selected according to sex and age categories. All individuals were adult (20–80 years old) and include appropriate skeletal elements and associated provenience information (age, sex, ancestry, stature, and decade of death). Individuals with pathological changes to the vertebral column, congenital or trauma-related abnormalities, atypical numbers of vertebrae for a particular region, or paralytic diseases were excluded. Similarly, individuals with evidence of crush, central collapse, or wedge fractures of the thoracic or lumbar vertebrae were excluded.

Each vertebra in the thoracic and lumbar segments of the vertebral column was scored for osteophytosis according to criteria established by Stewart (1). This five-stage classification system assesses the stage of osteophytosis separately for each of the superior and inferior surface margins of the vertebral centra on a scale of 0 to 4 (0 indicates no osteophytes and 4 indicates maximum lipping). Stewart noted the difficulties of assigning individuals to the intermediate stages of osteophyte development and did not precisely define the criteria of each. Explicit criteria (both descriptive and photographic) for assigning osteophyte scores are provided in Fig. 1.

Osteophytes were scored when located on the anterior or lateral regions of the vertebral centra, while osteophytes on the posterior aspect of the centra (i.e., in the vertebral canal) were not scored. It

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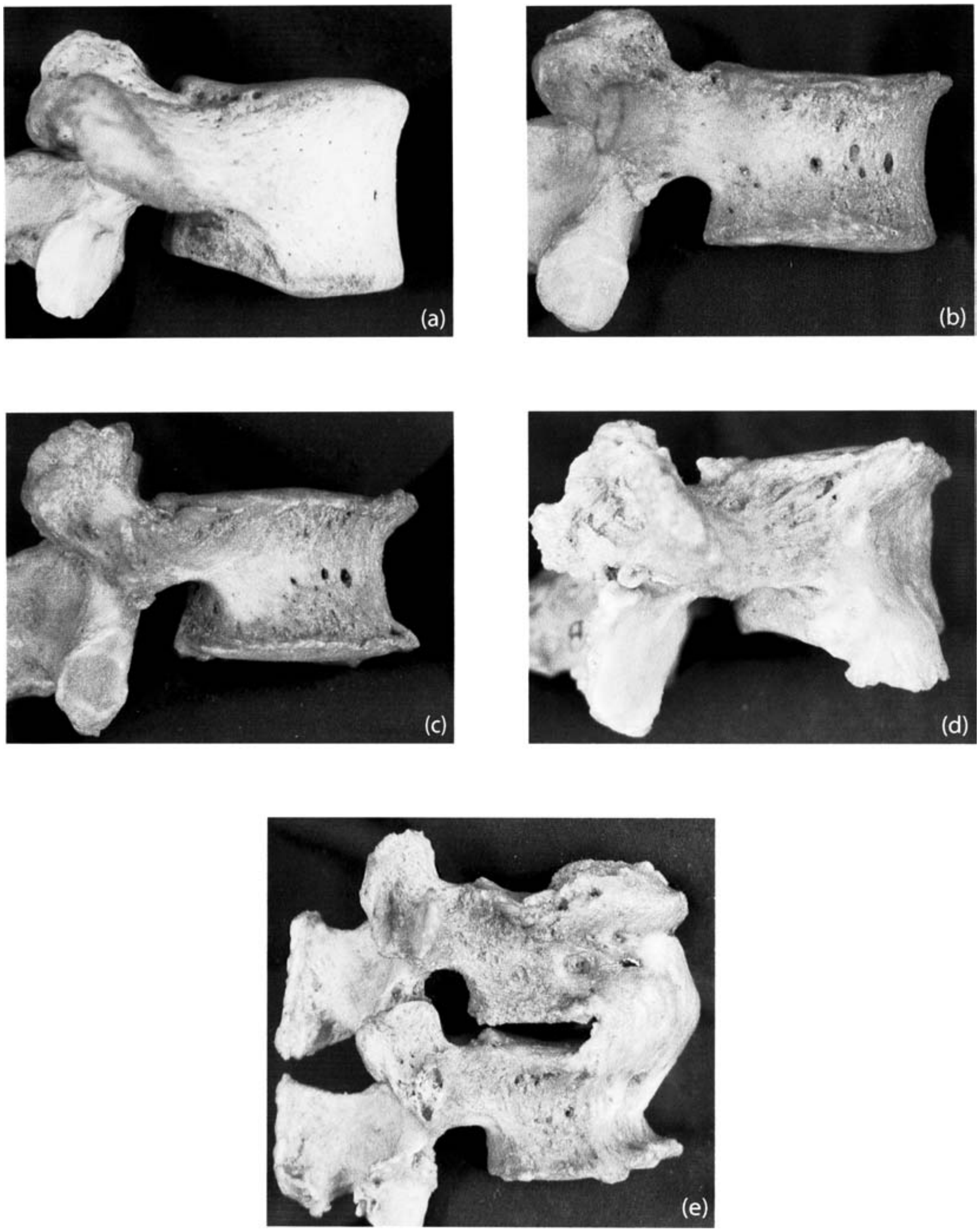

FIG. 1—*Classification stages of osteophyte development. (a) Stage 0: Vertebral centra shows no (or virtually no) evidence of osteophytosis or formation of a vertebral rim. (b) Stage 1: Minor development of osteophytes; may be one or two small bony spurs or the beginnings of formation of a vertebral rim. (c) Stage 2: Osteophytes more developed (larger or more than two small osteophytes) or extensive rim remodeling with pronounced lipping. (d) Stage 3: Enlarged osteophytes with severe modeling of the rim and/or formation of a large osteophyte or osteophytes that extend towards the center of the vertebral body (i.e., either superior or inferior) or projecting towards the adjacent vertebra (i.e., into the intervertebral space). (e) Stage 4: Most extreme stage of osteophyte development, with extensive osteophyte development that, like in Stage 3, extends toward the intervertebral space or the center of the vertebral body, but is partially or completely (in contact with but not fused and in contact and fused, respectively) bridged to the adjacent vertebra.*

should be noted that the definition of osteophytes used here (and by Stewart) includes syndesmophytes, as well as osteophytes. Lipping on the margins of the costal foveae (of the thoracic vertebrae) was not included in the osteophyte score. For each vertebral region a mean score was calculated and a total osteophyte score was calculated by combining the scores of the thoracic and lumbar regions. These scores were calculated by summing the degree of lipping for the superior and inferior margins of the vertebral centra and dividing by the number of vertebral surfaces present in each region (i.e., 24 for the thoracic region and 10 for the lumbar region).

In order to examine the relationship of age and osteophyte development, the average osteophyte score for the thoracic, lumbar, and combined thoracic and lumbar were separately regressed on age (by year) using ordinary least squares regressions. Student's t-tests and ANCOVA were used to examine the relationship of sex and age to osteophyte development. All statistical analyses were performed using SPSS 8.0.

In order to control for the effects of minor age differences in the male and female samples, age matching was employed for a subsample of individuals. These 128 individuals (64 males, 64 females) were randomly selected from the larger dataset by age matching within five-year intervals, for individuals between 20–74 years old. Each age interval contained six members of each sex, with the exception of the 20–24 year old category, where only four were selected from each sex because of the limited sample size.

Results

Females had a mean (±SD) age of 47.7 ± 15.2 (range 22–80) years, while males had a mean age of 47.8 ± 13.4 (range 20–80) years (n.s.).

An average thoracic score was calculated for 350 individuals (182 females, 168 males). There were no significant differences in age between males and females in this sample (47.3 ± 13.3 years in males vs. 47.2 ± 15.0 years in females; n.s.). Regression slopes of thoracic average vs. age were not significantly different between the sexes ($p = 0.97$) (Fig. 2*a*) and there were no significant differences in means by sex ($p = 0.85$), when analyzed using ANCOVA. Correlation coefficients (r^2) were slightly higher in males than in females (0.44 vs. 0.41) and indicate slightly more variation in females.

An average lumbar score was calculated for 377 individuals (188 females, 189 males). There were no significant differences in age between males and females in this sample (47.8 ± 13.4 years in males vs. 47.4 ± 15.1 years in females; n.s.). Regression slopes of lumbar average vs. age were significantly different when assessed using ANCOVA. The slope for males was significantly higher than females (0.047 in males vs. 0.036 in females; $p < 0.01$) (Fig. 2*b*). To further test differences between males and females, independent sample t-tests were used. Males and females did not differ significantly in standardized residuals (z-scores), although male mean values were slightly higher than females (0.07 ± 1.03 in males and −0.07 ± 0.96 in females; n.s.). Correlation coefficients (r^2) were slightly higher in males than in females (0.53 vs. 0.49) and indicate slightly more variation in females. The slope (±SE) of the combined sex regression line for the lumbar region was significantly steeper than that of the thoracic region (0.041 ± 0.002 vs. 0.035 ± 0.002, $p < 0.05$).

An average osteophyte score (i.e., pooled thoracic and lumbar totals) was calculated for 348 individuals (179 females, 169 males). There were no significant differences in age between males and females in this sample (47.3 ± 13.3 years in males vs. 47.0 ± 15.1 years in females; n.s.). Regression slopes of total osteophyte average vs. age were not significantly different ($p = 0.37$) and there were no significant differences in means by sex ($p = 0.273$), when analyzed using ANCOVA. Correlation coefficients (r^2) were slightly higher in males than in females (0.52 vs. 0.46) and indicate slightly more variation in females.

When a subsample of individuals (64 females, 64 males) was age-matched by half-decade, females had a mean age of 47.7 ± 15.5 years, while males averaged 47.6 ± 15.6 years (n.s.). Females had substantially lower correlation coefficients than males for the thoracic ($r^2 = 0.50$ in males and 0.30 in females), lumbar ($r^2 = 0.60$ in males and 0.50 in females), and combined ($r^2 = 0.59$ in males and 0.39 in females) regions.

Discussion

The degree of vertebral osteophyte development has been used extensively in forensic and bioarchaeological contexts to estimate age from an unknown set of human skeletal remains, especially in instances where other age markers (e.g., pubic symphysis) are unavailable. These age estimates rely on a study by Stewart (1), which continues to be reproduced in review articles and osteology manuals (e.g., 9–11). The present study, like that of Stewart (1), documents a significant correlation between age and degree of osteophyte development in the thoracic and lumbar regions (Fig. 3). Like Stewart (1), this study notes considerable variation in the degree of lipping with age.

The thoracic region shows a general pattern of osteophyte development with age that can be useful for age determination, especially for establishing upper or lower limits on age. Individuals over 40 years old always show some lipping, although this lipping was often extremely minor. Osteophyte scores that averaged over 2.0 were very rare in individuals under 50 years old and were not documented in individuals under 35 years old.

The lumbar region shows less variation in osteophyte development with age than the thoracic region and, consequently, is more useful (i.e., accurate) for estimating age. This is consistent with Howells' (12) calculation based on a subset of Stewart's (1) data. Like the thoracic region, there is considerable variation in degree of lipping with age, but a general pattern exists that can help place upper or lower limits on age. Individuals over 45 years old always show some lipping, although this was often extremely minor. Average osteophyte scores of over 2.0 never occurred in individuals under 40 years old; this degree of osteophyte development was rarely seen in individuals under 50 years old.

The total osteophyte score, calculated by combining the lumbar and thoracic regions, did not increase predictive power in age estimation, as there was a higher correlation coefficient in the lumbar region alone ($r^2 = 0.48$ vs. 0.51). Therefore, the use of the total osteophyte score in forensic and bioarchaeological contexts is not advised. In the remainder of this paper only data on the individual segments are reported.

In his classic study, Stewart (1) assessed osteophyte development in 455 individuals from the Terry Collection and American soldiers from the Korean War. Only 17 females were examined, and none were included in his analysis. Roche (13) examined sex differences in osteophyte development, but his criteria for describing osteophyte development are unclear and his results were never fully published. A study by Schmorl and Junghanns (14) examined thoracolumbar osteophyte development in a large (>4000 persons) sample of autopsy cases and documented some sex differences. For example, in middle age (40–49 years), osteophytes were found to be present in 60% of women and 80% of men. Unfortunately, Schmorl and Junghanns (14) documented only the presence or absence of osteophytes and were not explicit in regard to criteria used to identify osteophytes. The current study documents that all males and females between the ages of 40–49 years exhibit some osteophyte development, although this is often relatively minor. The differences between the two studies may have more to do with the criteria for documenting osteophyte development than differences between the populations, though this latter factor should not be discounted. Occupational and lifestyle factors have been suggested to play an important role in the development of osteophytes (15). Gantenberg (cited in 14) documented important differences in osteophyte development by occupation—miners had the most pronounced vertebral osteophytosis, while individuals in occupations not requiring heavy physical labor showed the least osteophytosis. In addition, a study of skeletal remains from 10th–12th century Hungarian cemeteries found the lowest prevalence of vertebral osteophytosis in the Zalavár Castle site, whose population lived under the best social and economic conditions of the cemeteries studied (16). Interestingly, this study also found that in all four cemetery series examined, males were far more likely to have vertebral osteophytosis than females.

In the current study, occupation was known in only a limited number of individuals, so the relationship of occupation and osteophyte

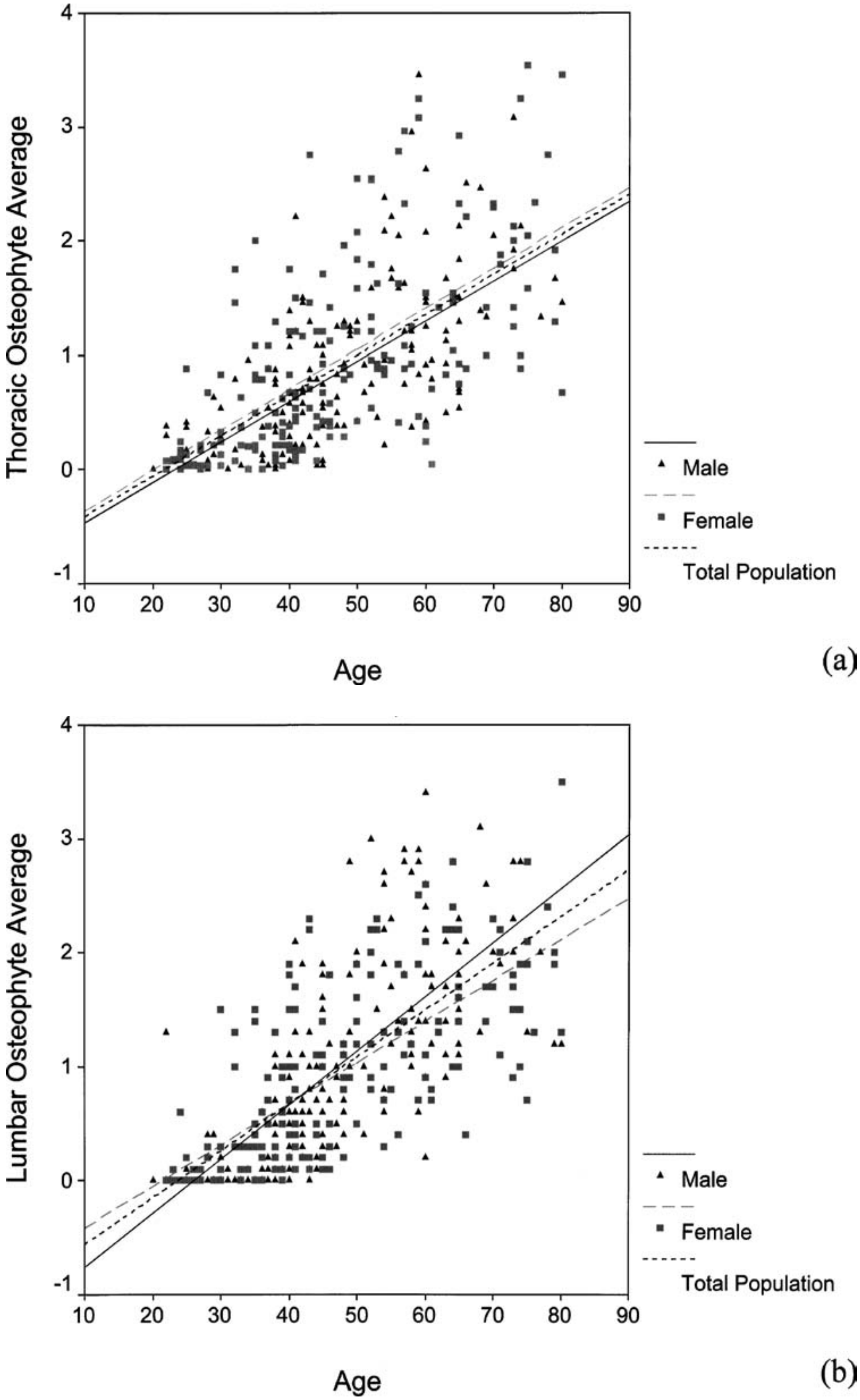

FIG. 2—*Least squares regression of osteophyte average vs. age (by year) for males, females, and the total sample. (a) Regression for the thoracic region for females (n = 182; $r^2 = 0.40$), males (n = 168; $r^2 = 0.44$), and the total population ($r^2 = 0.42$). (b) Regression for the lumbar region for females (n = 188; $r^2 = 0.49$), males (n = 189; $r^2 = 0.53$), and the total population ($r^2 = 0.51$).*

development could not be examined. However, according to death certificate records available for this small number of people, most individuals of both sexes (as well as most individuals classified as either "black" or "white") participated in occupations that can be considered manual labor intensive. Sex differences in osteophyte development may become pronounced in populations with a division of labor in which heavy physical labor is structured by sex. This does not appear to be the case in the Terry Collection sample, although a good deal of variation exists. The vast majority of individuals in the Terry Collection came from lower incomes, although

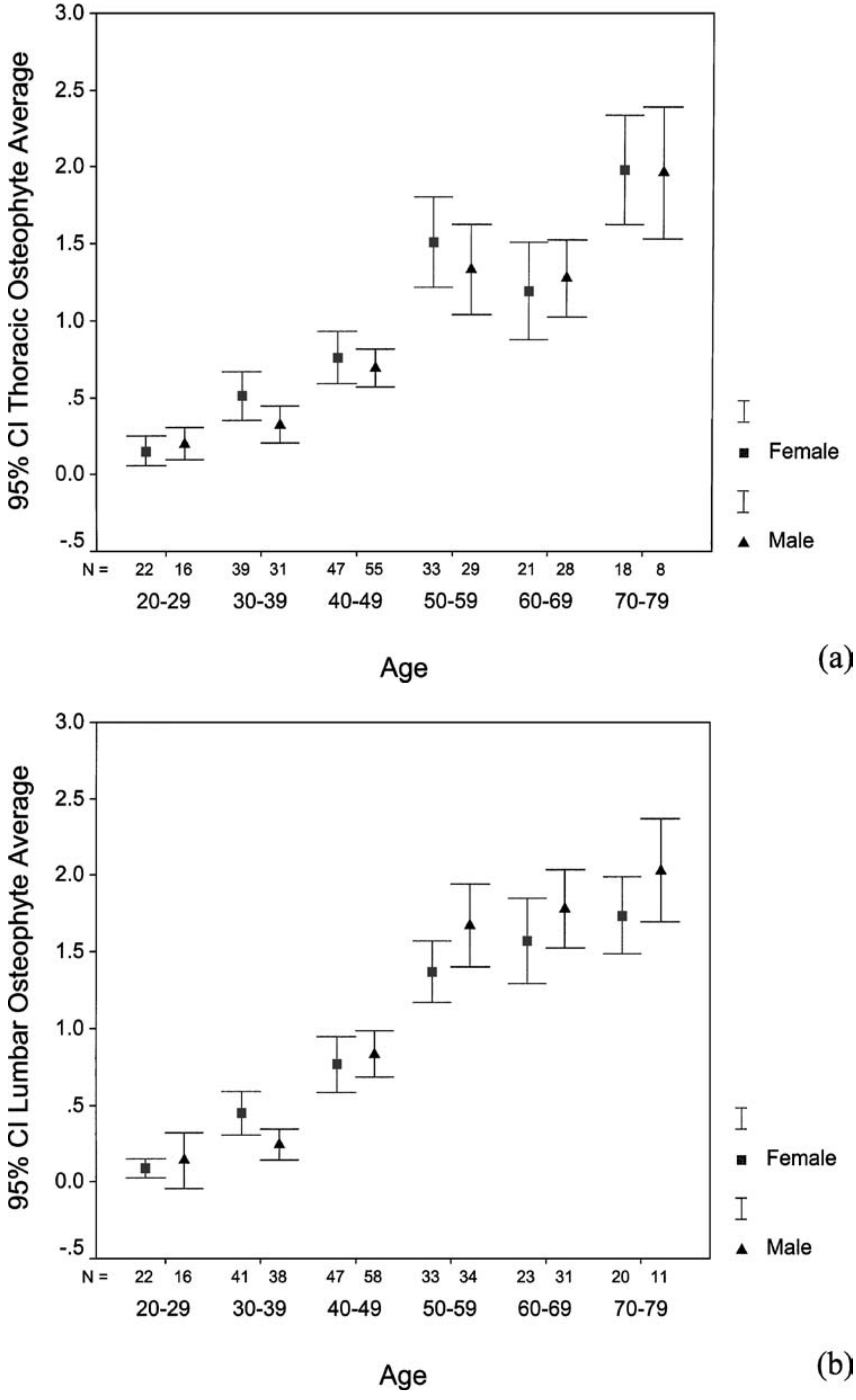

FIG. 3—*95% confidence intervals for (a) thoracic and (b) lumbar osteophyte averages for males and females by decade.*

this changed in 1956 with the passage of the Willed Body Law of Missouri (17). This could explain differences between this study and the studies of Schmorl and Junghanns (14) and Acsádi and Nemeskéri (16). Future research should examine the interaction of multiple variables, including age, sex, ancestry, body size, and occupational and lifestyle factors in the development of osteophytes. These studies should focus on more modern collections. Finally, future studies should seek to clarify the mechanisms involved in the production of osteophytes.

Males and females in the current study show remarkably similar patterns of osteophyte development with age. In the thoracic region, the regression lines are parallel for males and females and do not significantly differ. In the lumbar region, the slopes of the regression lines do significantly differ, although they are overlapping and the residuals from a pooled regression do not differ for males and females. This is surprising given known sex differences in age-related changes in the other parts of the skeleton, as well as microstructural differences seen during the aging process.

While the regression parameters are similar for males and females, males have a modestly higher correlation coefficient than females for both the thoracic and lumbar regions; this indicates a higher accuracy of osteophyte score for predicting age in males. Given the importance of accuracy in predictive power, additional tests were used to examine sex differences in variation in osteophyte score with age.

The results of the analysis of the subsample of age-matched individuals supports the conclusion that females exhibit more variation than males in the relationship of average osteophyte score with age for both thoracic and lumbar regions. There were considerable differences in correlation coefficients between males and females in the thoracic ($r^2 = 0.50$ in males and 0.30 in females) and lumbar ($r^2 = 0.60$ in males vs. 0.50 in females) regions; these differences in variation between males and females actually increased with age matching, and suggest that sampling in the original dataset obscured some of the variation. Despite similarities in general aging patterns between the sexes in osteophyte development, females exhibit more variation than males. This has important implications when used for assessing age from osteophyte development. When assessing ages, slightly larger confidence intervals should be used to account for this increased variation in females. Studies of the pubic symphysis have also supported the higher degree of variation in females than males (18); however, additional studies are needed to quantify these sex differences in osteophyte development as well as to investigate their underlying cause(s).

In summary, this study documents a general pattern of osteophyte development with age that can be useful for determination of age. While substantial variation exists in osteophyte development with age, a general pattern emerges that can provide an estimate of age or help to establish upper or lower limits on age. Males and females show remarkably similar patterns of osteophyte development with age, although females show significantly greater variability in osteophyte stage for any given age. Therefore, slightly larger confidence intervals should be used when assessing age from the vertebral column in females.

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