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DEGENERATIVE DISC DISEASE IN THE LOWER ILLINOIS RIVER VALLEY: MIDDLE WOODLAND, LATE WOODLAND, & MISSISSIPPIAN COMPARISONS

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ABSTRACT. Assessing degenerative disc disease during changes in prehistoric subsistence-settlement patterns can help to elucidate changes in levels of physical activity patterns during this transition. The present study compares rates and severity of degenerative disc disease in adults during the Middle Woodland, Late Woodland, and Mississippian periods in the Lower Illinois River Valley. The disease was assessed by sex and two age-at-death categories (young $\leq$ 45 years, old = 45+ years) in 317 individuals. Results indicate that degenerative disc scores for both young and old females decreased between the Middle Woodland (A.D. 150–400) and Late Woodland periods (A.D. 400–1050), then increased in the Mississippian period (A.D. 1050–1500). These trends were statistically significant in the older female category. Male individuals, both young and old, demonstrated significant decreases in degenerative disc scores between the Late Woodland and Mississippian periods. Within a single period, both young and older males were found to have higher degenerative disc scores than females during the Late Woodland period, while older females were found to have higher degenerative disc scores than older males during the Mississippian period. It is interesting to note the opposing directionality in male and female trends between the Late Woodland and Mississippian periods at these sites. The trends of increasing female degenerative disc scores at the same time as decreasing male scores with the intensification of maize agriculture may indicate cultural or technological changes.

Keywords: Pete Klunk mounds, Schild mounds, maize, agriculture, vertebral osteophytosis

INTRODUCTION

Degenerative joint disease is an overarching term that refers to the breakdown of joints from continuous "wear and tear" due to physical activity or repetitive motion(s), as well as aging (Jurmain 1990; Wentz 2010; Myszka et al. 2014). This process may occur as osteoarthrosis at the synovial (apophyseal) facet joints and degenerative disc disease (DDD), or vertebral osteophytosis, at the (symphyseal) intervertebral joint. Important as a differential diagnostic, other non-infectious reactive processes also involve the vertebral column (e.g., diffuse idiopathic skeletal hypertrophy [DISH] and ankylosing spondylitis), and mechanical injury may have contributing factors that likely influence incidence and severity. These factors can include age, body mass, sex, genetics, trauma, and physical activity to name just a few (e.g., Brown et al. 2008; Rojas-Sepulveda et al. 2008; Bernard et al. 2010; Chang 2010; Duncan et al. 2012; Listi & Manhein 2012; Goode et al. 2013; Suri et al. 2013, Myszka et al. 2014).

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DDD (vertebral osteophytosis) occurs at the intervertebral joint, consisting of two adjacent vertebral bodies and the intervertebral disc. It is most commonly attributed to continual pressure on the vertebral column inducing breakdown of the intervertebral disc (Kim et al. 2012; Van der Merwe et al. 2006). The vertebrae then attempt to stabilize the joint through reactive bone changes including progressive osteophytes, lipping, and porosity of the superior and (mostly commonly) inferior surfaces of the vertebral body (Fardon & Milette 2001; Rojas-Sepulveda et al. 2008). Schmorl's nodes have also sometimes been attributed to DDD, but while these marks may relate to herniation of the nucleus pulposus, why and to what degree DDD contributes to these phenomena is unknown (Plomp et al. 2012). For this reason, Schmorl's nodes were not included in the present analysis.

Recent studies also have found that the vertebrae farthest from the direct line of gravity between the top of the head and the floor (e.g., C5, T9, T10, L4) are most likely to show signs of DDD. This is believed to be due to higher levels of pressure on those vertebrae (Knusel et al. 1997; Van der Merwe et al. 2006; Kim et al. 2012) and

relates to the argument that Maat et al. (1995) make that DDD is more strongly affected by weight-bearing, while vertebral osteoarthrosis may be more affected by specific body movements. The association between DDD and entheseal changes, particularly in the lower limb, provides further evidence that DDD is associated with weight-bearing physical activity (Myszka et al. 2014).

Assessing DDD during prehistoric subsistence-settlement transitions provides insights into the changes in physical activity that accompanied changes in food procurement strategies (Stout 1978; Ruff et al. 1984; Bridges 1991, 1992; Bridges et al. 2000; Robling & Stout 2003). Such a subsistence-settlement transition occurred in the Lower Illinois River Valley from the Middle Woodland period (A.D. 150–400), through the Late Woodland period (A.D. 400–1050), to the Mississippian period (A.D. 1050–1500) (Pickering 1984; Rose 2008; Husmann 2011; Spencer 2014). Degenerative disc disease in the Lower Illinois River Valley has not been well studied. The present preliminary assessment of DDD is one piece in a larger study that assesses changes in health status associated with the transition from early horticulture to agriculture in the Lower Illinois River Valley (Husmann 2011). The human remains investigated are from two sites that straddle three adaptational periods: the Pete Klunk mound group and the Schild mound group (Fig. 1). These remains are currently housed in the Osteology and Paleopathology Laboratory at Indiana University, Bloomington.

ARCHAEOLOGICAL CONTEXT

The Middle Woodland period in this area dates to A.D. 150–400. The subsistence strategy in the Lower Illinois Valley during the Middle Woodland complex was both foraging (nuts, wild plants, animals) and horticulture of the local cultigens known as the Eastern Agricultural Complex (EAC), which included goosefoot (*Chenopodium berlandieri* Moq.), knotweed (*Polygonum erectum* L.), and marsh elder (*Iva annua* L.) (Gregg 1974; Yerkes 2005). With this combination of foraging and horticulture, there is still some debate about the level of sedentism during the Middle Woodland period. Yerkes (2006) suggests that high mobility was still necessary to obtain sufficient food and dietary fiber in Ohio, while Mangold & Schurr (2006) advocate a similar situation for northern Indiana Middle Woodland groups.

The Late Woodland period in the Lower Illinois River Valley dates from A.D. 400–1050 (Reynolds et al. 2015). During the Late Woodland, people continued to cultivate the EAC. However, we also begin to see some of the first forays into maize consumption in this area (Asch et al. 1979; Studenmund 2000; Rose 2008). Rose (2008) completed isotopic analyses on skeletal remains from the Late Woodland components of the Knight, Joe Gay, and Yokem sites. She found little evidence of maize consumption in the early Late Woodland remains, but by the latter part of the Late Woodland, many more remains (over half of the remains sampled from Yokem) were found to have ^{13}C levels indicative of maize consumption. However, her analysis of skeletal remains from the Schild site produced more negative ^{13}C levels throughout the Late Woodland period, an indication that these individuals were not yet uniformly participating in significant maize consumption. Simon (2014) has posited that these Late Woodland forays into maize represent early "experiments" with maize that ultimately failed, necessitating a later re-introduction of maize to the area. Her research, however, focuses only on the botanical evidence for maize and does not consider the skeletal isotopic data. The isotopic data support a more continual progression throughout the region, though additional research is necessary to elucidate how the botanical and isotopic data fit together.

According to other studies of skeletal remains, Late Woodland females (including those from Pete Klunk, Koster, Schild, Yokem, Ledders, Hacker, and Kuhlmann) had an increase in upper limb strength compared to females of the Middle Woodland period (including remains from Pete Klunk, Gibson, and L'Orient) (Bridges et al. 2000). This additional robustness may be the result of increased food processing demands and is most likely due to increased consumption of the EAC starchy seed plants. Buikstra et al. (1987, 1994) also have noted both the minimal maize consumption and the beginning of sexual distinctions in diet during the Late Woodland period. Their studies were completed on numerous sites from the Lower Illinois River Valley, including Ledders, Helton, Schild, and Gibson, and found that males were consuming more protein while females were consuming more carbohydrates. Settlement patterns in the Illinois River Valley varied during the Late Woodland: some sites likely had year round occupation while others appear to be seasonal (VanDerwarker et al. 2015).

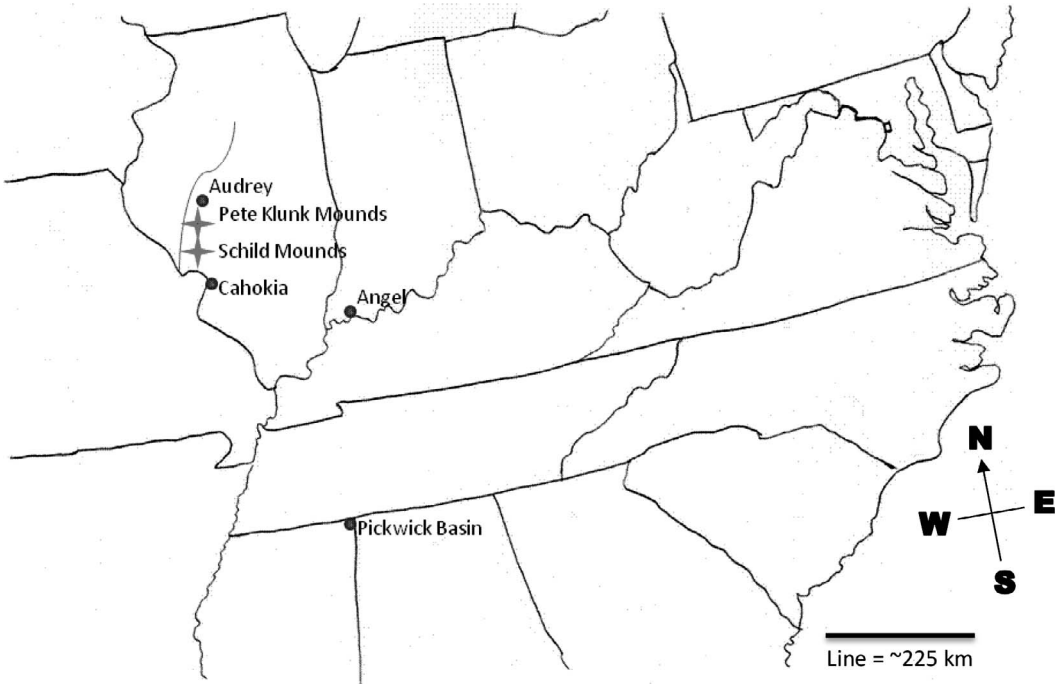

Figure 1.—Map of the Eastern United States with locations of the Pete Klunk & Schild mound groups with other relevant sites ($1'' = \sim 200$ km)

Maize agriculture ultimately took off in the Lower Illinois River Valley by the Mississippian period (A.D. 1050–1500) resulting in much more sedentary, aggregated village settlements than either of the previous periods (Reynolds et al. 2015). With this increase in maize consumption, Bridges et al. (2000) found a decrease in female upper limb strength indicators compared to the Late Woodland. Possible food processing-related interpretations of these data include lower processing requirements for maize or potentially increased efficiency in processing, possibly related to new soaking or boiling technologies (Bridges et al. 2000). With these new soaking or boiling technologies came the advent of gruel. Gruel allowed weaning to occur at an earlier age and, thus, may have facilitated (along with immigration into these sites from surrounding areas) the population growth (Buikstra et al. 1986). Thus, the period from the Middle Woodland through the Mississippian demonstrated an overall change from foraging and horticulture of local cultigens to a dependence on maize agriculture in order to sustain the population. This span also demonstrated new innovations in food processing as the subsistence patterns changed.

The Pete Klunk and Schild mound groups.—The Pete Klunk mound group (11C4) in Calhoun County, Illinois was excavated during the 1960 and 1961 seasons by Gregory Perino and consists of 14 mounds running north – south on a bluff overlooking the Illinois River (Perino 1968). The mounds were associated with the Kampsville village site and are believed to be part of the mortuary population for that site. Excavations of these mounds uncovered 300 Middle Woodland burials and about 80 Late Woodland burials. Early uncalibrated radiocarbon dates placed the Middle Woodland component in Mound 1 at A.D. 175 ± 75 (Perino 1968). The Late Woodland component was dated to A.D. 613 ± 110 in Crematory B of Mound 8, and to A.D. 780 ± 120 in Crematory A of Mound 10 (Perino 1973a).

Perino excavated the Schild mounds in 1962 and 1963. This site included nine Late Woodland mounds and two non-mounded knolls (A & B) containing interments of Mississippian origin (Perino 1973b). Within the mounds were over 200 Late Woodland burials and approximately 250 Late Woodland – Emergent Mississippian

Table 1.—Classifications and descriptions of degenerative disc disease (DDD) scoring.

Original classification	Specific classification	Numeric score	Description
A	A	1	No sign of additional bone growth, porosity, or pitting
	A-	2	
B	B+	3	Minimal additional bone growth, no restriction of movement
	B	4	
	B-	5	
C	C+	6	Bone growth present, but no fusion and/or only minor restriction of movement
	C	7	
	C-	8	
D	D+	9	Prolific additional bone growth resulting in limited movement or fusions of vertebrae
	D	10	

burials. Recent calibrated radiocarbon dates average around A.D. 830 for the Late Woodland component at Schild (see Spencer 2014 for more detailed dates).

The two knolls at Schild contained nearly 300 Mississippian individuals (Perino 1971) with recent calibrated radiocarbon dates that average around A.D. 1030 (Spencer 2014). Unfortunately, the habitation site with which Schild was affiliated remains something of an enigma (Perino 1971; Goldstein 1980). Delaney-Rivera (2004, 2007) completed a ceramic analysis that proposed that the Audrey village site and the Schild mounds were part of the same sociopolitical climate, yet she posits that these two sites have their origins in two different groups. The Audrey site is thought to be the result of Mississippian colonization from the area around Cahokia, known as the American Bottom, while the Schild mounds were associated with descendants of the local Late Woodland population who had acculturated to a Mississippian lifestyle due to interactions and movements of people. The Schild site is located roughly 15 km south of the Audrey site.

METHODS

The superior and inferior surfaces of all present vertebral bodies were examined for signs of DDD. All vertebrae present were aligned in anatomical position prior to observation. Of the 317 individuals assessed, only 26 individuals did not include representation from all three vertebral regions assessed (cervical, thoracic, and lumbar). Of these 26 individuals, 11 did not include any lumbar vertebrae (four from the Middle Woodland, six from the Late Woodland, and one Mississippian), while 15 did not include any cervical vertebrae (four from the Middle Woodland, six from Late Woodland, and five Mississippians). In addition, the average number of vertebrae present from each region was as follows: cervical – 5.8 vertebrae, thoracic – 10.7 vertebrae, and lumbar – 4.4 vertebrae. Thus, these individuals were all quite well preserved.

Evidence of DDD, including osteophytic lipping, porosity, and pitting of the vertebral surfaces was categorized as A, B, C, or D. See Table 1 for descriptions of these categories. For photographs comparable to the four stage system initially utilized here, see Jurmain & Kilgore (1995).

A system of pluses and minuses (A, A-, B+, B, B-, etc.) was later implemented for additional detail resulting in scores assigned between one and ten (A=1, D=10) and all vertebrae were re-analyzed according to the new system. The vertebrae with the worst degeneration were scored first and then the number of vertebrae that demonstrated that level of degeneration was evaluated to determine if the score for the vertebral column as a whole should be at a less severe level. For example, if the worst degeneration present on an individual set of vertebrae was a 7 (C), but it only occurred on two or three vertebrae, the vertebral column from this individual would be more likely to receive a 5 (B-) or a 6 (C+) while an individual where half or more of the available vertebrae demonstrated that 7 (C) level of degeneration would receive a 7 for the entire vertebral column. This provides a broad assessment to evaluate differences through time among male and female adults. All individuals were scored by the author within a six month timeframe and several individuals were rechecked to ensure consistency across time. For additional detail, see Husmann (2011).

All available remains also were evaluated morphologically for signs of systemic infection

Table 2.—Age data for each period. MW = Middle Woodland, LW = Late Woodland, Miss = Mississippian.

Period	N	Mean	Standard deviation	Median
MW	110	36.6	9.7	35.7
LW	77	37.0	9.8	37.0
Miss	130	41.7	10.9	42.0

(e.g., periostosis, osteomyelitis, lytic lesions) or other pathological conditions that may present confounding variables (e.g., DISH, ankylosing spondylitis, trauma). Any remains with confounding or predisposing conditions were excluded from the analysis.

All statistical analyses were completed using SPSS 23 (IBM Corp. 2013). Non-parametric tests (Kruskal-Wallis tests, Mann-Whitney U tests, and associated Dunn-Bonferroni post-hoc tests) were utilized because normality tests were not supported. However, equal variances were calculated using the Brown-Forsythe method ($p = 0.405$).

The skeletal sample.—Sample selection was limited to adults, as determined by the eruption of the third molar, and the presence of the eighth or ninth thoracic vertebrae (these were necessary for additional analyses not presented here). The adult age criteria were used because DDD is generally not present until around age twenty (Jurmain 1990; Maat et al. 1995; Van der Merwe et al. 2006).

The total sample for this study consisted of the following adults: 117 individuals found in Middle Woodland contexts, 81 individuals found in Late Woodland contexts, and 132 individuals found in Mississippian contexts. The Middle Woodland sample, by necessity, came completely from the Pete Klunk mounds, while the Mississippian sample was equally limited to Schild. The Late Woodland sample was drawn from both sites depending on the presence of vertebrae and the ability to determine other necessary parameters (age, sex, etc.). The present study evaluates two sites in close proximity (Pete Klunk & Schild) in order to reduce the confounding influence of genetics and attempts to control for age and sex by completing separate analyses based on these factors. Age was determined using multifactorial methods developed by Lovejoy et al. (1985) with ecto-cranial suture closure (Buikstra & Ubelaker 1994), pubic symphyses (Brooks & Suchey 1990), auricular surfaces (Buckberry & Chamberlain 2002), and first ribs (DiGangi et al. 2009) as the components. See Table 2 for descriptive statistics for age in each period examined. Sex was determined by assessing the pelvis and/or skull, as preservation allowed, and following the standards put forth by Buikstra & Ubelaker (1994). Additional explanation and examples of age calculations may be found in Husmann (2011).

Analyses of these data were undertaken by period (Middle Woodland, Late Woodland, or Mississippian) and segregated by sex and age (Table 3). Individuals aged above and below 45 years were analyzed separately to help identify the effects related to aging in each cultural period. The age of 45 years was chosen due to the potential impact that hormone-related changes accompanying the onset of menopause may have to the individual's ability to maintain bone density. In modern populations, this perimenopausal period generally occurs in the mid-forties (Moore et al. 2014; McKinley et al. 2015).

RESULTS

The results will be presented in two subdivisions: young to middle adults (aged below 45 years) and older adults (aged above 45 years). These must be presented separately due to the confounding factor that age (especially postmenopausal ages) can have on DDD scores and the fact that previous studies (Bridges 1991; Pickering 1994) have focused solely on the young

Table 3.—Sample sizes divided by age, sex, and period association.

Sample demographics		Middle woodland	Late woodland	Mississippian
< 45	Females:	52	34	40
	Males:	33	25	38
45+	Females:	13	9	30
	Males:	12	9	22
Total		**110**	**77**	**130**

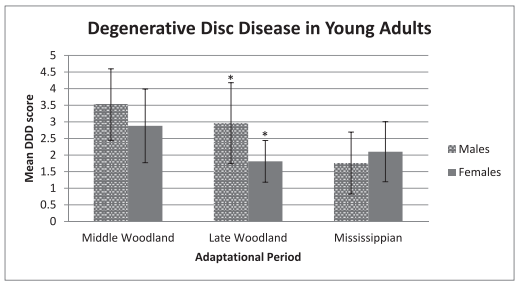

Figure 2.—Graph of the mean degenerative disc disease scores for male and female remains aged less than forty-five during the Middle Woodland, Late Woodland, and Mississippian periods. (* indicates periods in which male and female scores were significantly different.)

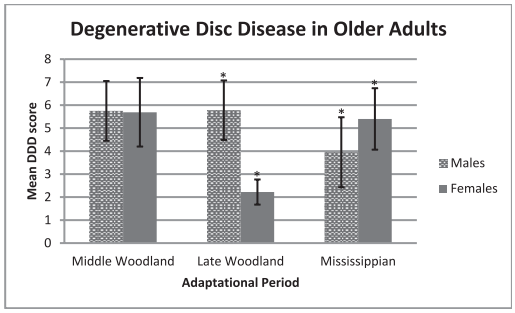

Figure 3.—Graph of the mean degenerative disc disease scores for male and female remains aged more than forty-five years during the Middle Woodland, Late Woodland, and Mississippian periods. (* indicates periods in which male and female scores were significantly different.)

to middle adults. Within each section, I will present the results comparing males across periods and females across periods (Middle Woodland, Late Woodland, and Mississippian), followed by the results of pairwise comparisons between males and females within each period.

Young to middle adults.—The average DDD scores for young male and female remains are listed in Table 4 and trends are shown in Fig. 2. For males, lower DDD scores were noted in individuals from the Late Woodland contexts than those from the Middle Woodland contexts. This trend continued into the Mississippian period, which showed the lowest mean scores of all three groups. For young males, Kruskal-Wallis tests demonstrated that the differences in DDD levels among the three periods were significant ($p < 0.000$). Pairwise comparisons found a significant difference between males from Middle Woodland and Mississippian complexes ($p < 0.000$) and also between males from the Late Woodland and Mississippian complexes ($p = 0.009$).

For females, a decrease in DDD scores was found between the Middle Woodland and the Late Woodland periods, with a slight increase during the Mississippian (see Fig. 2). Kruskal-Wallis tests demonstrate no significant differences between young females in the different periods ($p = 0.061$).

Mann-Whitney U tests between males and females within each period revealed no significant differences during the Middle Woodland and Mississippian periods. However, during the Late Woodland period males were found to have significantly higher DDD scores than females ($p = 0.025$).

Older adults.—The average DDD scores for older male and female remains are listed in Table 4 and trends are shown in Fig. 3. For males, a drop in DDD scores is seen between the Late Woodland and Mississippian periods. However a Kruskal-Wallis test returned no significant differences in DDD scores among any of the periods in question for males in this age bracket.

For females, a sizeable drop in mean DDD scores was seen during the Late Woodland, but the scores rebounded during the Mississippian period (see Fig. 3). Thus, significant differences were found between the Middle and Late Woodland ($p = 0.009$) and between the Late Woodland and Mississippian ($p = 0.004$).

Table 4.—Mean degenerative disc disease (DDD) scores for male and female remains from the Middle Woodland (MW), Late Woodland (LW), and Mississippian (Miss) periods. SD = standard deviation.

Mean DDD scores	Males < 45	Females < 45	Males > 45	Females > 45
MW	3.52 (SD: 2.15)	2.88 (SD: 2.22)	5.75 (SD: 2.60)	5.69 (SD: 2.98)
LW	2.96 (SD: 2.44)	1.81 (SD: 1.26)	5.78 (SD: 2.59)	2.22 (SD: 1.09)
Miss	1.76 (SD: 1.87)	2.10 (SD: 1.81)	3.95 (SD: 3.05)	5.40 (SD: 2.67)

Mann-Whitney U tests also were run between males and females within each period. Significant differences were seen in both the Late Woodland and the Mississippian periods. During the Late Woodland, males were found to have higher DDD scores ($p < 0.000$) while during the Mississippian, females were found to have higher DDD scores ($p = 0.037$).

DISCUSSION

Young to middle adults.—This analysis found no significant differences between DDD scores of young male and young female remains aged less than 45 years when the remains were found in Middle Woodland or Mississippian contexts. This is consistent with Bridges (1992) review of arthritis in the prehistoric Americas, who reported no significant differences in appendicular or vertebral osteoarthrosis (OA) between males and females of hunter-gatherer societies in the prehistoric Americas (most similar to Middle Woodland, though admittedly Middle Woodland individuals were practicing some horticulture). However, these results are not consistent with studies of agricultural populations outside of the American Midwest, which found significant differences in DDD scores between males (higher) and females (lower) (Van der Merwe et al. 2006; Wentz 2010; Kim et al. 2012). This difference may relate to unidentified biological differences between the populations studied, the terrain being worked, or cultural divisions of labor in those societies that were unlike those at Klunk and Schild. In addition, it must also be remembered that DDD may be more strongly affected by weight-bearing, while vertebral OA may be more affected by specific body movements (Maat et al. 1995), so these differences may also relate to different specific body movements between the sexes while weight-bearing activities remained comparable.

Pickering (1984) also found no significant differences in OA scores between the sexes based upon his analysis of young to middle adult appendicular and vertebral remains from Middle Woodland, Late Woodland, and Mississippian components of the Lower Illinois River Valley, including the Pete Klunk and Schild mound groups. However, in the present analysis, Late Woodland young male remains from these sites were found to have significantly higher degenerative disc scores than young female remains. Pickering (1984) may not have found these results because he split the Late Woodland period into early and late components, which he grouped with the Middle Woodland and Mississippian periods, respectively. Unfortunately, in doing so, he lost some of the resolution for the Late Woodland period itself. However, weight-bearing versus non-weight-bearing activities also may be affecting these results.

Cross-period analyses for young males demonstrated a general trend of decreasing degenerative disc scores from the Middle Woodland to the Mississippian period with the Late Woodland to Mississippian transition showing a significant decrease. This is consistent with the general trend toward decreasing degenerative scores with the advent of intensive agriculture, as noted by Bridges (1992), who reviewed OA literature, and Jurmain (1990), who examined vertebral OA and DDD. On the other hand, Bridges (1992) also found the Lower Illinois River Valley (including Klunk and Schild) to be an exception to this rule and suggested regional variation with the new subsistence economy as one explanation. Nonetheless, she does note that the Lower Illinois Valley trend she reports (increasing degenerative scores) was generally less prevalent in males, which she attributes to less involvement of males in agricultural related chores.

For young to middle aged females, the cross-period analysis demonstrated no significant results. This does not fit with the pattern of increasing OA with agriculture in the Lower Illinois River Valley, as reported by Bridges (1992). Pickering (1984) overall also found more severe degenerative disease scores for females with the intensification of maize agriculture, though differences in the categorizations of age and period make direct comparisons difficult. One interpretation of these results would be that the weight-bearing activities for young to middle aged females were fairly consistent, or at least comparable, throughout this transition while the need for other movements (e.g., twisting) were increasing.

Older adults.—While many other studies have not examined older adults due to the relationship between age and degenerative diseases (Bridges 1991, Pickering 1984), this study specifically includes older adults in the analysis since these are the individuals that have been engaged in repetitive tasks (whatever they may be) the longest and thus are more likely to have their effects on the bones. By keeping the analyses separate from the younger

adults, the differences due purely to aging should be somewhat consistent across periods. This analysis found no significant differences between degenerative disc scores of male and female remains aged more than 45 years recovered from Middle Woodland contexts, which is consistent with the analysis of the young to middle adults. However, male remains from the Late Woodland period had significantly higher degenerative disc scores than female remains from this period. This is consistent with the analysis completed on young to middle adult remains for these periods and may suggest similar workloads throughout the life span. Of course, it must be acknowledged that the sample sizes are limited for this analysis (i.e., eight Late Woodland males and nine Late Woodland females aged over 45). In addition, female remains were found to have higher degenerative disc scores than male remains from the Mississippian period, which was not seen in the younger adults or reported with other populations (Van der Merwe et al. 2006; Wentz 2010; Kim et al. 2012). One factor in this aberration may be the potential for decreasing vertebral bone density caused by increased acidity in the diet (from increased maize consumption), though this would then be expected in other populations with high acidity diets as well.

Cross-period analyses for male remains aged over 45 years found no significant differences, though a marginally lower average degenerative disc score was noted for male remains from the Mississippian period than from Middle Woodland or Late Woodland contexts. Again, this lack of statistical significance may relate to the limited sample size in these categories. By contrast, in the cross-period analyses of females aged over 45 years, remains associated with the Late Woodland period had significantly lower degenerative disc scores than either of the other two periods assessed. This is consistent with the general directionality of the results from younger females, though the older females showed significant differences while the young female analyses did not reach significance (possibly because they had not been participating in the activities as long as the older females).

Comparisons.—Within this series of trends, a few of particular interest come to light. First, in both younger and older males there is a drop in degenerative disc scores between the Late Woodland and the Mississippian. This is indicative of some variation in the weight-bearing activities between these sites and the wide variety of those reviewed by Bridges (1992). Meanwhile, in both younger and older females, there is a drop in degenerative disc scores between the Middle Woodland and the Late Woodland. These may be related to changes in harvesting methods between these periods since this work is most commonly attributed to women (Bridges 1992; Pickering 1984). During the Late Woodland, innovations in harvesting of the EAC plants may have made these activities easier (Bridges 1989a, 1989b; Buikstra et al. 1986). With the reliance on maize in the Mississippian period, some of these innovations may have been discarded as less efficient or effective, resulting in an increase of female degenerative disc scores back toward their previous levels. Pickering (1984) also noted that increased carrying loads (upper spine) and increased bending with short handled hoes (lower spine) may be required for agricultural intensification. These may be reflected in the DDD scores since they are weight-bearing activities, and thus are more likely to appear as DDD than OA (Maat et al. 1995).

It is interesting to note that the directionality of these DDD changes (decreasing from Middle to Late Woodland, and increasing from Late Woodland to Mississippian) is in direct contrast to upper limb strength indicators (higher in Late Woodland compared to Middle Woodland or Mississippian) (Bridges et al. 2000). This combination of upper limb and DDD trends suggests that women in the Late Woodland were spending more time at upper limb repetitive activities and less time in weight-bearing activities than the preceding or following periods. Thus, it is possible that the females could have spent more time using processing techniques that utilized the upper limb and took stress off of the vertebral column during the Late Woodland (e.g., nut pounding), but spent more time during the other periods on activities that were easier on the upper limb, but more stressful for the weight-bearing vertebral column (e.g., harvesting or carrying loads).

Another interesting trend is that the directionality of the changes in degenerative disc scores between the Late Woodland and the Mississippian periods is positive (increasing) for females, but negative (decreasing) for males, regardless of age category. This is consistent with a change in the sexual division of labor between the Late Wood-

land and Mississippian periods at these sites more than simply just the decreased utilization of innovations from previous agricultural endeavors. If the men were continuing to do fewer weight-bearing activities, why weren't the women? One possible explanation may be a cultural reason that female scores increased while male degenerative disc scores continued to decline, especially since this trend began shortly after the sex-related dietary distinctions noted by Buikstra et al. (1987, 1994). Age alone cannot be used to explain these opposing trends since there is a larger sample of older remains during the Mississippian period than either the Middle or Late Woodland periods for both males and females (Table 3), yet this opposing directionality in degenerative disc trends. If age were the major contributing factor, one would expect to see increased DDD scores in both sexes given that the average age was higher for both males and females. An alternative interpretation of these data could be that the innovations the males had found during the Late Woodland continued to work with the intensification of maize agriculture while the innovations that the females were using were no longer viable. However, this has not been supported by any other analyses.

Future directions.—Future analyses of the vertebral regions (lumbar, thoracic, cervical) separately and an assessment of the asymmetry of the vertebrae would be beneficial. Analyzing vertebral regions separately would elucidate their differential responses to load bearing, stability, and biomechanical processes (Bridges 1994; Jurmain & Kilgore 1995). Evaluating the asymmetries of the vertebrae and their associated osteophytes may help to parse out which changes result from differences in activities and which are simply part of the aging process (Bridges 1994). In addition, future analyses of physical activity markers on the appendicular skeleton would be beneficial in determining what types of activities might help account for the differences seen here.

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