Frequency of Costovertebral and Costotransverse Osteoarthritis in the Schroeder Mounds Site

Brian A. Keeling
Illinois State University, USA

Abstract: Schroeder Mounds (11HE177) is a late Late Woodland mortuary site (AD 900-1100) located on the bluffs of Henderson County, Illinois. There is little contextual information available about the site, therefore skeletal analysis is critical to understanding the health and behavior of the people buried there. The Schroeder Mounds osteological sample is exceptionally well preserved and is well-suited to a paleopathological assessment of costovertebral and costotransverse joint surfaces. Osteoarthritis (OA) was identified by reactive changes to the joint surfaces (pitting, osteophytic remodeling of joint margins) on adult individuals (N = 28) classified by sex and age group and scored by severity. Out of this sample, 96% (27/28) had costotransverse and/or costovertebral osteoarthritis. There were no sex differences in the prevalence of osteoarthritis and severity was not consistent with simple age-related degenerative changes. There was a pattern of extensive osteoarthritis on the 6th, 7th, 8th, and 11th and 12th ribs and the 1st, 11th, and 12th thoracic vertebrae. Based on clinical data, respiratory stress may have been a factor involved in the prevalence of osteoarthritis, but a previous assessment of the visceral surfaces of the ribs does not support a population experiencing such stress. An alternative cause, supported by previous examinations of vertebral degenerative changes and the presence of cases of os acrominale, Cervical osteoarthritis, and Baastrup's disease suggest load bearing activities (e.g., tump line) and labor-related postures may have contributed to this osteoarthritis. However, more comparative osteoarchaeological research and clinical research is needed to assess the causative or synergistic role(s) of bronchial infection and mechanical stress.

Keywords: Osteoarthritis, Costovertebral, Costotransverse, Schroeder Mounds, Ribs

Introduction

Schroeder Mounds (11HE177) is located on the bluffs overlooking the Mississippi River Valley in Henderson County, Illinois (Figure 1) (Kolb 1982). The Late Woodland is a period of socio-economic change from mobile horticulturalists to village sedentism and maize-intensive agriculture (Emerson et al. 2000). The time precedes the Mississippian period (~ AD 1000-1500) when agriculturalization, population density, and large aggregated settlements (e.g., Cahokia) begin to develop. Due to an unfavorable archaeological recording and documentation, despite Kolb's (1982) thorough report, the Schroeder Mounds site (11HE177) lacks archaeological documentation concerning subsistence-settlement strategies. What is known is that the Schroder Mounds is a mortuary site with burials scattered throughout the site (Kolb 1982). The limited pottery assemblage at Schroeder Mounds resembles the Maples Mills culture, which is largely known in the central Illinois valley and largely consisted of forager-farmers (Kolb 1982). Additionally, with a lack of published archaeological information on subsistence-settlement strategies on Schroeder Mounds, only research on the osteological assessment of the site has shed light on these patterns. This means that any information gained from the skeletal assemblage will help shape a larger picture on who these people were and their habitual behaviors.

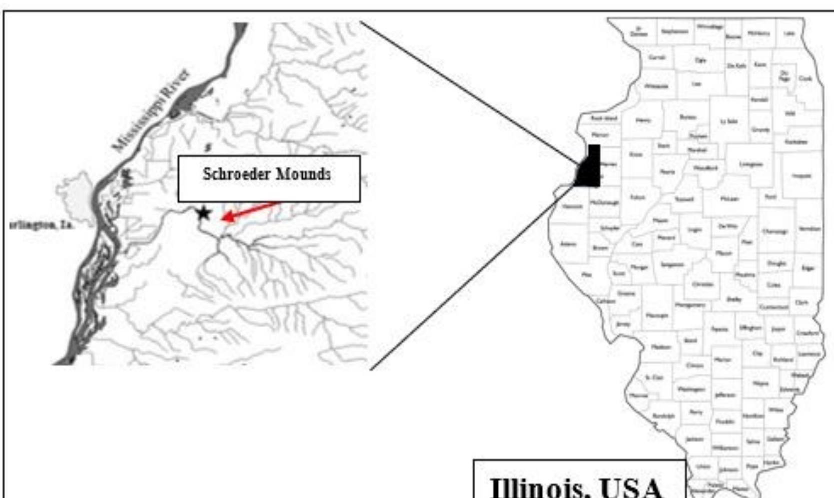

Figure 1: Displaying the geographic location of 11HE177 located in Henderson County, Illinois.

Preliminary paleopathological evaluations (Mosher et al. 2013; Nicosia et al. 2016; Smith et al. 2016) and evidence of maize consumption (Durchholz 2017) support the archaeological interpretation (Benn and Lee 2005; Hedman and Emerson 2008; Trader 2011) that the Schroeder Mounds peoples were forager-farmers living in a somewhat sedentary settlement pattern. Examinations of the pattern on treponemal disease and tuberculosis (Mosher et al. 2013), frequency of growth stunting (Nicosia et al. 2016), and the presence of linear enamel hypoplasia (LEH) (Smith et al. 2016) all reflect the Schroeder Mounds peoples as forager-farmers. For example, Mosher and colleagues (2013) linked treponemal disease at Schroeder Mounds to sedentism, and growth stunting at Schroeder Mounds was linked to a poor diet which was connected to more intensive agriculturalization (Nicosia et al. 2016). Smith and colleagues (2016) determined that the prevalence of LEH and its connection to both poor dieting and stress related to maize agriculture is further evidence that the Schroeder Mounds people were forager-farmers. In addition to these paleopathological assessments, the frequency and degree of Osteoarthritis (OA) can also impart important knowledge of subsistence-settlement strategies. By isolating the multiple factors contributing to OA (i.e. obesity, age, trauma, comorbidly, previous injuries), frequencies and meanings to biomechanical stress can be detected. By examining specific forms of OA, new information on subsistence-settlement activities of the Schroeder Mounds peoples can be understood. Additionally, any more information on the Schroeder Mounds individuals is important as these individuals are being relocated away and/or in the process of repatriation and may not be studied. Thus, it is essential that any information on these individuals be gathered to better understand who these people were. Therefore, this study uses a new method, Stages of Severity, to examine OA of the ribs, and further examines how this OA may reflect a pattern of habitual activities that the Schroeder Mounds peoples engaged in.

Osteoarthritis is the reactive change of the joint surface and joint margins that is progressive and has a wide variety of causes such as overuse injuries, acute trauma, age, and obesity. It is also one of the most commonly assessed reactive processes in paleopathology because of the informative role it has on answering questions of subsistence/behavioral strategies. Although OA has been well researched in recent years, paleopathological studies specifically on costovertebral/costotransverse (CV/CT) OA have been lacking (Figure 2) (Plomp and Boylston 2016). Almost all research on these articulation points only appear either in osteological diagnostics (i.e. White 2005), or in association with clinical literature (Erosa et al. 2018; Sales et al. 2007; Susmarski and Helm 2017). Additionally, although there have been some bioarchaeological literature on CV/CT osteoarthritis (Arden and Nevitt 2006; Mays et al. 2017; Waldron and Willoughby 2016), none of them have effectively linked CV/CT osteoarthritis to any etiologies. Despite this, Waldron and Willoughby (2016) suspected that besides OA from everyday respiration, OA of the CV/CT joints may be affected by external factors. In the current paleopathology literature (Buikstra and Ubelaker 1994; Rogers and Waldron 1995; Waldron and Willoughby 2016), the reactive change of these joints was noted when eburnation was present, which is a final bone-to-bone contact (i.e., loss of joint cartilage) that results in a smooth, polished surface (see Rogers and Waldron 1995), but its etiology has not been connected nor fully addressed. Although it has been understudied in bioarchaeological literature, some medical journals report the effects of CV/CT OA (e.g., Brown et al. 2008; Sales et al. 2007). In cadaver loadbearing studies, the left second through fifth rib and the tenth and eleventh thoracic vertebrae routinely exhibit the most reactive change (Brown et al. 2008). They also note that the causative factors are widely variable, with possible etiologies from age, weight, trauma, and habitual activities such as loadbearing. This study employs a different method to comprehensively quantify CV/CT OA to better understand habitual activities of the people at Schroeder Mounds. A novel approach, including a three-stage scale that documents and classifies common reactive changes (Arden and Nevitt 2006; Buikstra and Ubelaker 1994; Rogers and Waldron 1995; Waldron and Willoughby 2016) that occur with OA was used because it can better quantify the severity of reactive changes that occur and better determine the extent of OA affecting these individuals. By using this method, the frequency of CV/CT OA may be recorded and thus found to correlate to habitual activities such as loadbearing that the Schroeder Mounds peoples engaged in as previous clinical cadaver loadbearing studies (Brown et al. 2008) have demonstrated.

The CV/CT joints are located on the ventral surface of the ribs (Figure 2). The CV joint is the articulation of the head of ribs

1-12, and their connection with the vertebral body of the thoracic vertebrae. The costotransverse joint connects the ribs to the transverse process or the lateral edges of the thoracic vertebrae. On the ribs, the CT joint of the ribs are located a few centimeters from the head of the rib on ribs 1-9. These rib joints function to both protect the body by forming the ribcage and are given slight mobility due to the nature of the inflation of the lungs and other respiratory processes (Brown et al. 2008). Due to a large multifactorial range of etiologies (i.e. age, trauma, infection, loadbearing, stress), the CV/CT joints are susceptible to the development of OA just like every other joint in the body. However, this particular OA is challenging given the functional co-association of respiration making this OA which adds another potential etiology to the multi-factoring range of causes. This makes it very difficult to quantify and draw definitive etiological conclusions on this type of OA. Therefore, determining the etiology, or causes of CV/CT OA can prove difficult to distinguish a pattern in behavioral or habitual activities from the rib joints since these joints are also involved in respiration (rib movement from lung expansion). In addition, the ribs of the body do not preserve well and can appear fragmented in archaeological samples. Post-mortem abrasion of the rib joint surfaces can also make it difficult to properly quantify assemblages as well as determining OA within individuals (Rogers and Waldron 1995).

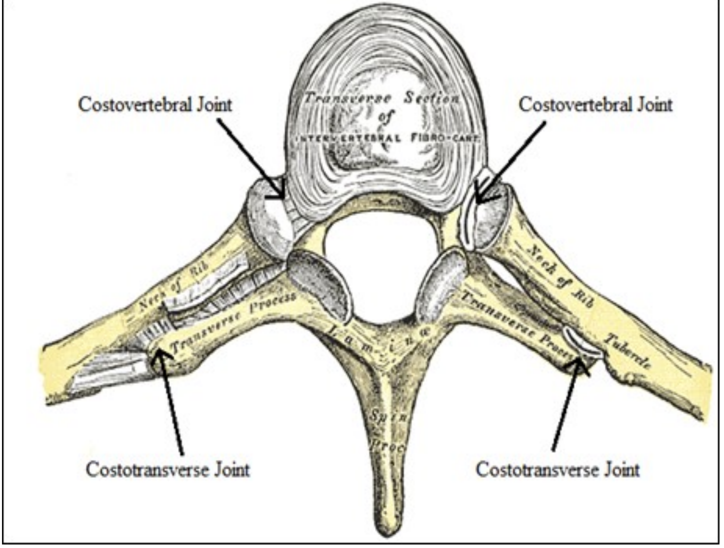

Figure 2: The rib articulation joints with the thoracic vertebrae.

In this study, reactive changes (porotic pitting, osteophytic remodeling of the joint margins, and eburnation), or changes to the bone due to the degeneration of the joint cartilage and bone-to-bone contact, were examined on the CV/CT joint surfaces of a later Late Woodland (AD 900-1100) osteoarchaeological sample from Illinois and assessed against clinical and experimental data (e.g., Brown et al. 2008; Sales et al. 2007) to study the frequency of OA in the articulation joints of individuals from Schroeder Mounds. The Schroeder Mounds individuals are excellent candidates to examine OA of these joints due to availability and the good preservation of the rib articulation facets. In concert with a previous paleopathological assessment of the ribs (Smith 2017), the results of the CV/CT OA assessment of the ribs can appropriately determine a more accurate range of etiology based on the frequency and pattern of the rib OA with corroboration of other paleopathological literature on the Schroeder Mounds individuals. This study aims to understand the habitual patterns of the Schroeder Mounds people through the utilization of a new method to identify the frequency and severity of osteoarthritis.

Materials and Methods

The Schroeder Mounds site (11HE177) adult age-at-death skeletal sample assessed for OA of the rib articulations was previously aged and sexed (Mosher et al. 2013; White 2005). Adulthood was determined by the presence of at least three third molars in occlusion. The sample was divided into three age-at-death categories: Group one was young adult (18-29 years), Group two were middle age (30-39 years), and Group three were mature (40+ years) adults. These group intervals were created to best classify individuals with diverse age ranges and best classify age group types (e.g. middle aged, mature). These categories also commonly match group intervals from other literature (Domett et al. 2017; Schrader 2012; Smith et al. 2016; White and Folkens 2005). These intervals were classified to best represent young adults (Group one; n=8), middle aged adults (Group two; n=11), and mature adults (Group three; n=7) based on the sample variety. Individuals were grouped conservatively by their minimum age to avoid overlap into multiple group categories and to avoid age-spread bias since each individual has a skeletal age range rather than definitive age. Individuals included in the study each possessed at least one well-preserved articulation of a CV joint and a CT joint. Twenty-eight adults (15 female, 12 male) were preserved enough for this examination. Ribs were sided and sequenced from an identified and sided comparative collection using Mann's (1993) methodology. Due to problematic preservation, not all ribs with articular surfaces could be assigned a rib number. The joints are nevertheless able to be numbered by a corresponding vertebral articulation in the event a rib cannot be numbered. If the rib numbers were still unidentifiable, they were categorized as 'unidentified'. Vertebral identification was identified using White and Folkens (2005) methodology and by comparative collection. Any unidentifiable thoracic vertebrae will be categorized as 'unidentified'. To assess the presence of OA, ribs and thoracic vertebrae were examined macroscopically and by a hand-held magnification lens.

Methods to Quantifying Costovertebral/Costotransverse Osteoarthritis

Prior to this study, only the presence of eburnation was used to define CV/CT OA. This is because eburnation is a well-known indicator of OA (Aufderheide et al. 1998; Rogers and Waldron 1995). However, more processes are involved in this joint degenerative process. Additionally, as noted in osteoarthritic literature (Aufderheide et al. 1998; Arden and Nevitt 2006; Buikstra and Ubelaker 1994; Mays et al. 2017; Rogers and Waldron 1995), there are more degenerative processes (osteophytosis, lipping, porosity) that can be used to diagnose OA besides the presence of eburnation. In this study, the presence of OA was determined by osteoporosis and/or eburnation on the joint surface, and osteophytic activity at the joint margins (Brown et al. 2008; Cohen et al. 1978; Plomp and Boylston 2016; Rogers and Waldron 1995).

Table 1: Stages of Severity. Each stage corresponds with a requisite that corresponds to the stage of Costovertebral (CV) and Costotransverse (CT) Osteoarthritis (O.A.).

Stages of Severity	
Stage Number	**Description of Stage**
Stage one: Slight	Slight (≤1/5) porosity on joint surface, elevated joint margins.
Stage two: Moderate	Moderate (≤ 2/5- 3/5) porosity on CV or CT and/or osteophytic remodeling (lipping) of the joint margins.
Stage three: Advanced	Most (≤3/5-5/5) of the joint surface is porotic; osteophytosis changed the original contour of the joint margin and/or polish is present.

This study developed a three-stage scale (Stage of Severity) of reactive change (Table 1). These stages are also illustrated in Figure 3 (see below). The purpose of this new method was to effectively record the presence of reactive changes and clearly categorize them in a way that distinguishes more severe reactive changes from others. These stages can then be efficiently used to determine severity and frequency of OA in individuals. Other standards to diagnose OA such as the standards developed by Buikstra and Ubelaker (1994) and Rogers and Waldron (1995) have been considered in the development of this methodology. Although such methods are useful in determining the presence and absence of OA on the joint surfaces, the scoring system more effectively highlights OA as a progression, ranked by severity, where certain reactive bone changes (e.g. osteophytosis, porotic pitting, elevation of joint surface) occur as a result of this degenerative process as the joint cartilage breaks down from bone contact and friction. However, to objectively distinguish the degree of reactive change, this study did adapt Buikstra and Ubelaker (1994)'s measurement of the degree of reactive change that covered a joint surface into each stage. For example, stage one requires at least 1/5 of the joint surface to have porotic pitting and remodeling of the joint surface. The breaking into fifths (1/5-5/5) measurement was determined to be the best fit for the classification of slight (Stage One), moderate (Stage Two), or advanced (Stage Three) reactive change. However, since reactive changes don't always occur simultaneously and widely vary depending on the development of the OA, Stages two and three contain and/or parameters so that bones with less porosity and more severe reactive changes such as larger osteophytic activity can properly be placed in more advanced categories. This allows the method to be more flexible in identifying reactive changes, but at the same time keeping distinguished categories. By breaking down reactive changes to these stages, this method better distinguishes individuals with OA by the severity of reactive changes present on the joint surfaces of the CV/CT joints. It also effectively categorizes and ranks reactive changes that often occur in OA and better distinguishes more severe reactive changes by the presence and degree of one or multiple reactive changes simultaneously occurring on the joint surface.

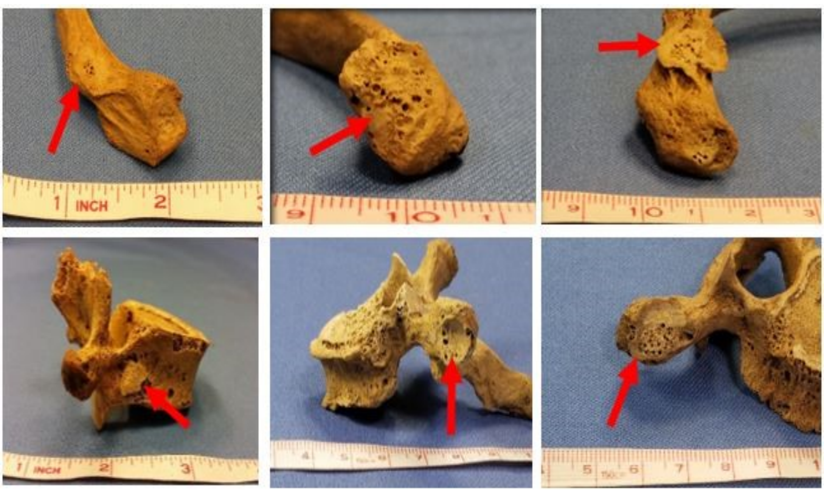

Figure 3: (Top Left) unidentified right rib, Stage one Severity. (Top Middle): 12th left rib, Stage two Severity. (Top Right): 8th right rib, Stage three Severity. (Bottom Left): 11th thoracic vertebrae, Stage one Severity. (Bottom Middle): unidentified middle thoracic, Stage two Severity. (Bottom Right): Burial 21, 12th Thoracic vert, Stage three Severity.

Furthermore, each reactive change that is noted in the scoring process is contained within changes known to occur during the degenerative process of OA and are well-noted in previous studies (Roberts and Manchester 2005; Rogers and Waldron 1995). However, since CV/CT OA often has differential manifestations, associating this OA with a specific set of etiologies is very difficult. When examining OA of the ribs or any other bones that don’t preserve well, eburnation of the bones has been previously determined to be the best way of determining OA. Moreover, post-depositional processes (i.e. acidic soil, environmental disruptions, faunal manipulation) that overtime cause erosion on the CV/CT joint surfaces can be difficult to distinguish from early signs of OA. These processes can often erode the joint surfaces, change their color, and texture so distinguishing early OA from depositional processes can be difficult. Therefore, this methodology helps better distinguish post-depositional processes from OA. To be considered a stage one level of OA, the joint margins must have evidence of reinforcement or remodeling.

Three stages, progressing by the presence of severe reactive changes, were devised. The first stage consisted of reactive changes such as reinforcement or remodeling of the joint surface, evidence of porotic pitting (slight (or $<1/5$) on the bone surface) on the joint surface, elevated joint surface? due to remodeling. Stages two through three exhibit progressive changes to the joint surface and margins. Stage two reactive changes must demonstrate moderate ($\leq$ 2/5- 3/5) porosity on CV or CT articulations and/or osteophytic remodeling of the joint margins. Stage three reactive changes demonstrate advanced OA where $\leq$3/5-5/5 of the joint surface is porotic; osteophytosis changed the original contour of the joint margin and/or eburnation is present Also, in order for a rib or thoracic articulation joint to be categorized under a specific stage of severity, the articulation surface needs to meet at least one or more of the requisites listed in Table 1. Additionally, Table 2 was constructed to define the processes that occur through OA of the joint surface. For the purposes of this study, this method can also better distinguish more advanced cases of CV/CT OA despite a lack of eburnation in the study sample. Individuals were scored based on the presence of OA in the CV, CT, and the corresponding thoracic vertebral column.

Table 2: Definitions of bone remodeling/degenerative changes that occur through osteoarthritis.

Remodeling/Degenerative Changes to the Bone	
Osteophy-tosis	The process of new bone formation through the buildup of osteophytes (nodules of new bone).
Porosity/ Porotic Pitting	Due to the healing process, the resorption of bone, after new bone formation on the articular facet, gives a pitting effect or the morphology of many pits in the bone.
Osteopo-rosis	The noticeable depletion of the total bone mass without affect-ing the total ratio of bone.
Eburna-tion	The most advanced stage of osteoarthritis where bone-to-bone contact has completely reshaped the articulator facet which then gives off a smooth and polished look.

This study developed the Stage of Severity methodology (Table 1) and scoring procedures with a point-based scoring system to separate and distinguish more severe individuals with OA from each other. The scoring system will provide an appropriate scale to compare individuals with the same Stage of Severity from each other. Since the Stages of Severity methodology is ranked (Stage one< Stage two< Stage three) from slight to more advanced stages of OA, a point was given if a CV/CT articulation facet depending on the degree of OA that is present. One point was scored to an individual if an articulation facet had stage one severity, two points for stage two severity, and three points for stage three (see Table 1). Each individual was assigned an overall stage of severity based on the most advanced stage of severity present on either the ribs or articulating thoracic joints. Table 3 categorizes the individual's stage of severity and their individual score. The stage of severity assignment for each articulation facet and side (left or right) of both the ribs and thoracic vertebrae is shown in Tables 1.4 and 1.5. Unidentified ribs and thoracic vertebrae articulation joints were also included in this study as long as the articulation joint was preserved enough for study (see Tables 1.6 and 1.7). This sample's data on CV/CT OA were categorized into sex and age tables to identify any significant population-based differences. Furthermore, by utilizing the Stage of Severity methodology, the presence of OA in the Schroeder Mounds individuals were better defined, and the changes in severity of reactive changes could be noted. The scoring system in relationship with the reactive change stages can better determine the severity and frequency of OA in these individuals. This helped in determining possible etiologies that caused these severe cases of OA in the Schroeder Mounds individuals.

Table 3: Chart represents the age, sex, and associated burial number. Each individual is categorized with an individual stage of severity and an individual score based on the frequency of osteoarthritis.

Burial Number	Sex and Age by Burial Number	Presence of Severity by Burial Number	Individual Score
2	Female: 30-45	Stage three	76
3	Female: 25-35	Stage three	58
10A	Male: 30-45	Stage one	2
12	Female: 18-21	Stage two	7
21A	Female: 20-25	Stage three	14
22	Male: 30-45	Stage one	7
26	Female: 50+	Stage three	20
28	Female: 30-39	Stage two	24
37A	Female: 40+	Stage three	14
39A	Male: 40+	Stage two	23
46	Male: 30-48	Stage two	33
49	Male: 45+ 12	Stage two	10
50	Male: 35-45	Stage three	14
51A	Female: 25-40	Stage three	17
57	Male: 30-40	Stage two	30
66B	Female: Age Indeterminate	Stage two	34
69	Female: 45+	Stage three	48
76	Male: 30-45	Stage two	18
81	Male 50+	Stage two	40
103	Female: 20-25	Stage three	5
107	Female: 30-40	Stage two	50
110	Female: 25-35	Stage two	28
112	Male: 25-35	Stage two	9
114	Male: 35-50	Stage two	56
115	Female: 25-35	Stage three	33
116B	Unidentifiable	N/A	0
119	Male 50+	Stage three	37
121	Female: 34.7 + 7.8	Stage two	24

Table 4: Table is the collected data on the costovertebral and costotransverse articulation surfaces of the *left* ribs and the *left* side of the vertebral body in anatomical position. The table is organized by burial numbers and each articulation surface. Each number followed by a period and another number represents the rib or thoracic vertebrae number and the stage of severity the articulation surface has. For example, in the number '3.1' under the rib costotransverse column, the '3' represents the third rib's costotransverse articulation surface and the period is to separate and distinguish its stage of severity. The '1' following '3.' Represents that the third rib's costotransverse articular surface has Stage one osteoarthritic activity. UNID = unidentified. Commas after an 'UNID:' separate different unidentified ribs' stage of severity. For example, 'UNID: 1, 1.' Represents two unidentified stage one severity ribs or thoracic vertebrae articular surface. Semicolons and periods are used to break and separate different rib numbers and stages. CT = Costotransverse articulation. CV = Costovertebral articulation. 'T #' = total number of thoracic vertebrae for study per individual. 'Ribs #' = total amount of ribs for study per individual.

Burial #	**Ribs #**	**Left Ribs CV and stage**	**Left Ribs CT and Stage**	**T #**	**Left Thoracic CV**	**Left Thoracic CT**
2	9	4.1; 1.2; 10.2; 7.3; 6.2; 3.2; 11.2; 12.1	2.1; 1.2; 4.1; 6.2; 7.2	12	1.2; 4.1; 5.1; 7.2; 8.1; 9.1; 10.1; 11.1; 12.2	1.1; 14.1; 5.1; 7.2; 10.1; 11.1; 12.2
3	9	4.1; 8.1	8.1	12	1.1; 5.1; 6.1; 7.1; 8.1; 9.2; 11.1	3.1; 6.1; 7.3; 8.2; 9.2
10	3					
12	8	2.2;		12		
21	4	2.2	UNID: 2; 2.2	11	12.3	
22	0					
26	3			12	UNID: 2; 9.1; 11.3; 12.2	UNID: 2
28	8	5.1; 4.1; 7.1	5.1; 7.1	12	1.2; 4.1;8.1; 9.1; 10.1; 12.1	
37A	2	UNID: 2, 2	UNID: 2,2	8	11.3	

57 Frequency of Costovertebral and Costotransverse Osteoarthritis in the Schroeder Mounds Site

Burial #	Ribs #	Left Ribs CV and stage	Left Ribs CT and Stage	T #	Left Thoracic CV	Left Thoracic CT
39A	0			12	1.2; 3.1;4.1; 5.1; 9.1; 10.1; 11.2; 12.2	
46	8	8.1; 9.1; 11.1	7.2; 6.2; 9.1	12	4.1; 6.1; 8.1; 10.1	2.1; 4.1; 5.1
48	6			12	1.1; 6.1; 10.1; 12.2	7.1
49	0			1		
50	6	7.1; 8.1	7.2; 8.2	12	1.1; 10.2; 11.2; 12.3	UNID: 1
51A	8	UNID: 1. 11.1; 12.1	4.1;	7	12.2; 11.2	
57	2			7	1.2; UNID: 1, 1, 1, 1. 11.2; 12.2	1.2; UNID: 1, 1,
66B	9	UNID: 1, 1, 1; 1.1; 2.1; 6.2; 10.1; 11.3; 12.1	UNID: 1, 1; 6.1	7	1.2; 3.1; 9.2; 11.2; UNID: 1	1.1; 3.1; 9.2
69	9	1.1; 4.1; 6.1; 8.2; 10.1; 11.1		12	1.1; 3.1; 4.1; 5.1; 6.1; 7.1; 8.1; 9.1; 10.1; 11.2; 12.2	2.1; 4.1; 5.1
76	3			12	1.2; 7.1; 8.1; 9.1; 10.1; 12.2;	9.1;
81	12	UNID: 1, 1. 5.1; 6.1; 7.2; 8.3; 12.1	UNID: 1	12	2.1; 4.1; 5.1; 6.1; 7.1; 8.1; 9.1; 10.2; 11.2; 12.2	

Burial #	Ribs #	Left Ribs CV and stage	Left Ribs CT and Stage	T #	Left Thoracic CV	Left Thoracic CT
103	5	4.1;	7.2;	2	1.1; UNID: 1.	
107	6	8.1; 10.1	4.1; 3.2; 5.2	11	8.1; 9.1; 10.1; 11.2; 12.1	2.1; 4.2; 5.2; 7.1; 8.1; 9.1
110	2	1.1; UNID: 2		12	1.2; 6.1; 7.1; 8.1; 9.1	
112	6	7.1; 11.1	7.1			
114	12	5.2; 6.3; 4.1; 7.2; 8.1; 9.2; 10.2; 11.1	5.1; 7.2	12	5.1; 7.2; 8.2; 9.2; 10.1; 11.2; 12.2	4.1; 5.1
115	12	5.1; 6.1; 7.2; 8.2; 9.1; 10.1; 11.1; 12.2	6.1; 7.1; 8.1	9	12.2; UNID: 1, 1	3.1
116B	INCONCLUSIVE					
119	9	UNID: 1. 12.1; 8.3 (FUSED WITH 7)	UNID: 1, 1; 9.2			
121	12	3.1; 7.1; 8.1		12	1.1; 6.1; 8.1; 9.1; 11.2; 12.2	

Table 5: Table is the collected data on the costovertebral and costotransverse articulation surfaces of the right ribs and the right side of the vertebral body in anatomical position. The table is organized by burial numbers and each articulation surface. Each number followed by a period and another number represents the rib or thoracic vertebrae number and the stage of severity the articulation surface has. For example, in the number '3.1' under the rib costotransverse column, the '3' represents the third rib's costotransverse articulation surface and the period is to separate and distinguish its stage of severity. The '1' following '3.' Represents that the third rib's costotransverse articular surface has Stage one osteoarthritic activity. UNID = unidentified. Commas after

an 'UNID:' separate different unidentified ribs' stage of severity. For example, 'UNID: 1, 1.' Represents two unidentified stage one severity ribs or thoracic vertebrae articular surface. Semicolons and periods are used to break and separate different rib numbers and stages. CT = Costotransverse articulation. CV = Costovertebral articulation. 'T #' = total number of thoracic vertebrae for study per individual. 'Ribs #' = total amount of ribs for study per individual.

Burial #	**Ribs #**	**Right Ribs CV and stage**	**Right Ribs CT and Stage**	**T #**	**Thoracic CV**	**Thoracic CT**
2	11	UNID: 2; 6.1; 10.1; 11.1; 12.1	1.1; UNID: 3; 6.1	12	5.1; 7.2; 8.1; 9.1; 10.1; 11.1; 12.2	5.1; 7.2; 8.1; 9.3; 10.1; 11.1; 12.2
3	8	UNID: 2; 1.2; 7.3; 8.3; 3.2	UNID: 1; 7.3; 8.3; 3.2	12	1.1; 5.1; 6.1; 7.1; 8.1; 9.2; 10.1; 11.1	3.1; 6.1; 8.3; 9.3
10A	2	7.1	7.1			
12	8	1.2;2.2; 12.1		12		
21	5	UNID: 1, 1		11	12.3	
22	6	UNID: 1, 1, 1, 1, 1, 1, 1				
26	1			12	UNID: 1,2; 9.1; 11.3	UNID: 2, ;8.1
28	7	UNID :2, 2		12	1.2; 4.1; 8.1; 9.1; 10.1; 11.1; 12.1	
37A	0			8	11.3	
39A	0			12	1.2; 3.1; 4.1; 5.1; 9.1; 10.1; 11.2; 12.2	7.1
46	10	8.1; 11.1; 12.1; 6.1; 7.2; 9.1	8.1; 6.1; 7.1; 9.2	12	6.1; 8.1; 11.2; 12.1	9.1;
48	9			12	1.1; 4.1; 12.2	
49A	0			1		
50	7	7.1; 11.1	8.2; 7.2	12	1.1; 10.2; 11.2; 12.3	
51A	9	11.1; UNID: 1.	UNID: 1, 1, 1	7	UNID: 2. 11.2	
115	11	4.1; 7.1; 8.1; 11.1	4.1; 8.3	9	12.2; UNID: 1.1.	UNID: 1. 3.1
116B	IN-CONCLUSIVE					

Burial #	Ribs #	Right Ribs CV and stage	Right Ribs CT and Stage	T #	Thoracic CV	Thoracic CT
119	12	1.1; 7.3; 8.3; 6.1	UNID: 2. 2.1; 7.3; 8.2; 3.2; 4.3; 6.1; 5.2; 9.2; 12.2			
121	12	UNID: 1, 1, 1. 12.1	UNID: 1.	12	1.1; 6.1; 8.1; 9.1; 11.2; 12.2	

Results

Osteoarthritis was identified on both the ribs and ---the accompanying thoracic vertebrae of the Schroeder Mounds individuals. Out of the 28 individuals examined, 27 individuals had at least stage one OA. Also, out of the 28 individuals, 25 individuals had at least stage two OA. Additionally, 11 individuals out of the entire sample had a presence of stage three OA on at least one of the rib or thoracic vertebral articulation joints (see Tables 6 and 7). Despite having a large proportion of individuals with stage three OA, there is a low frequency of stage three ribs and vertebrae in these individuals. However, even the prevalence of this advanced stage of OA, and its appearance in 11 individuals across different ages and sexes, warrants some explanation. Additionally, there is an even higher frequency of stage two OA among most of the study sample.

Frequency of Sex and Age Relative to Severity

The results by sex are shown on Table 6 (see below). The results show that males overall have a higher frequency of the most severe stage (4/12 [33%] vs 3/15 [20%]), but females have a higher frequency of stage two OA (66.7% versus 50%). Neither pattern is statistically significant.

Table 6: Table is based on individuals whether male or female expressing a specific Stage of Severity. Each individual was added based on their individual severity (Table 2).

Frequency of Severity by Sex				
Stage of Severity	**Male**	**Female**	**M vs F (p = <.05)**	**Total**
Stage one	2	2		4
Stage two	6	10	0.4259	16
Stage three	4	3	0.4605	7
Total	12	15		27

Regardless of the etiology, OA is generally known to be progressive and is age-related (Roberts and Manchester 2005). Therefore, the severity of OA was categorized by age. Two individuals were of indeterminate in age, so they were excluded from this analysis (116B; 66B). The results of Table 7 show that among the three adolescent/young adults (Group one), two of them have Stage three severity and only two of nine mature individuals do. This suggests that the Schroeder Mounds site's pattern of OA is not simply a geriatric condition. However, this result is tentative as the sample sizes are very small.

Table 7: Each individual was assigned an age group number based on their minimum age range. They were then further sorted by the individual's Stage of Severity. Each number represents one individual with Stage one on the bone. Individuals can have more than one stage represented in the skeletal sample as two different bone elements can have different progressions of osteoarthritis.

Frequency of Severity by Age Group				
Stage of Severity	**Group 1: (18-29)**	**Group 2: (30-39)**	**Group 3: (40+)**	**Total**
Stage one	3	7	2	12
Stage two	6	7	6	19
Stage three	5	5	2	12

Frequency of Severity Based on Ribs and Thoracic Vertebrae

Data was collected on the frequency of each rib and thoracic vertebrae in the sequence, and then was correlated to a stage level of severity. The results of can be found on Table 8 (see below).

Table 8: Each individual was assigned an age group number based on their minimum age range. They are then further sorted by the individual's Stage of Severity. Each number represents one individual with Stage one on the bone. Individuals can have more than one stage represented in the skeletal sample.

Frequency in Severity of Vertebrae, Left ribs, and Right ribs with Osteoarthritis														
Type/Severity	Thoracic vertebrae, Right rib, or Left Rib Number 1-12													
Thoracic	1	2	3	4	5	6	7	8	9	10	11	12	UNID	
Stage one	13	5	12	14	20	17	17	23	24	15	8	4	20	197
Stage two	12	-	-	1	2	-	6	3	7	8	22	21	4	88
Stage three	-	-	-	-	-	-	1	1	2	-	3	6	-	13
Total Vert:	27	5	12	16	22	18	24	27	33	24	33	33	24	**298**
Left Ribs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**UNID**	**Total**
Stage one	3	2	1	8	5	5	7	8	3	4	6	5	12	69
Stage two	2	3	1	1	2	4	8	3	2	2	1	1	6	36
Stage three	-	-	-	-	-	1	2	2	-	-	1	-	-	9
Right Ribs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**UNID**	**Total**
Stage one	3	2	2	4	3	10	8	6	2	1	7	7	32	87
Stage two	2	2	3	-	1	1	2	2	2	1	-	2	14	32
Stage three	-	-	-	1	-	-	4	4	-	-	-	-	1	10
Total Ribs	10	9	7	14	11	21	31	25	9	8	15	15	65	**240**

Overall, the most afflicted thoracic vertebrae (T) were T1, and T6-T12, with several of the articulation facets having stage three OA. T11-12 had the highest frequency of OA in the vertebral sample. As for the ribs, the 7th rib on both right and left articulation joints was the most common osteoarthritic rib having the highest severity, and the highest frequency of OA. Additionally, the seventh thoracic vertebrae also had a high frequency of OA. The eleventh and twelfth rib on both sides had many advanced osteoarthritic articulation facets. This matches with the frequency of the thoracic vertebrae as well. The highest frequency (32% including unidentifiable ribs) and the highest severity (stage three) of OA appears at mid-chest for the ribs and in the lower thoracic region. Almost all individuals within the sample had affected 7th ribs, and a large amount of OA in the ribs and thoracic vertebrae at the mid-low chest matches the noted frequency and severity of OA.

Most of the individuals appear to have a wide range of ribs affected with OA with the 7th-12th ribs being the most affected. The seventh rib manifests with the highest stage of severity. Stage three seventh ribs typically have very large osteophytic growth, with most of the joint surface being porotic. However, most of the skeletal sample appears to have a large frequency of Stage two CV/CT OA: 30% in thoracic vertebrae (including unidentified; 31% without), and 28% (including unidentified; 39% without) (see Table 4 and Table 5). Generally, among all the afflicted ribs with OA, the highest presence of advanced stages of severity (stages two and three) appears to happen throughout the 7-12th rib region. Within this range, there is a very high frequency of OA in the 6th-8th ribs (33% including unidentified ribs; 44% without), or at the mid-chest. Furthermore, it should be noted that percentages of these frequencies are included with and without the unidentified ribs and vertebrae because the frequency is much higher when considering only numbered ribs and thoracic vertebrae.

Discussion

By using the Stages of Severity method, new questions and answers could be derived from the data. First, CV/CT OA does exist in the Schroeder Mounds sample, despite the absence of eburnation. This is significant given that past literature

(Rogers and Waldron 1995) only could definitively identify this specific OA with the presence of eburnation. This study demonstrates that there is CV/CT OA present in a sample (the Schroeder Mounds) without the identification of eburnation through the use of the Stages of Severity methodology. Based on the assessment of Stage one and Stage two, there is a high case frequency of early OA on both the CV and CT joints. Typically, among the study sample, osteophytic activity accompanied by visible or severe porosity most commonly appears on the CT articulation (see Tables 1.4 and 1.5), and this also appears on the thoracic vertebrae as well. However, the only exception appears to be from Burial 119, in which a large osteoblastic growth occurred on the head surface articulation giving it an 'axe-like' appearance. This is due to malalignment with the CV joint surface. Based on the large frequency of cases of OA at the CT joint, and the afflicted region at mid-chest, there appears to be a pattern in the frequency and type of OA in the Schroeder Mounds sample.

Second, there is no sex difference in the basic frequency of CV/CT OA, but males have a slightly higher frequency of the most severe OA. This slightly higher frequency may be more individual related, as females also show signs of severe OA. This, in conjunction with the age-at-death data (Table 3), shows that progression of OA is not restricted by age or sex; all adult age groups are affected by various stages of OA. Of interest are two young adolescent females (burials 21A and 103) from Group one. Both had stage three CV/CT OA, in addition to three adults from Group two having stage three OA (Table 7). These adults are too young for the natural development of OA in the joints. This type of natural development usually becomes noticeable at general but numeric lower age cutoff needed here. Therefore, additional causes should be investigated in the presence of OA.

Furthermore, based on the absence of cases stated below in the Schroeder Mounds sample (e.g. Mosher et al. 2013; Nicosia et al. 2016), this study rejects other possible etiologies such as rheumatoid arthritis, ankylosing spondylitis, and Diffuse Idiopathic Skeletal Hyperostosis (DISH) of playing a role in the development of this type of degenerative joint disease. First, rheumatoid arthritis is a chronic inflammatory disease of the joints, has been found to be genetically associated, and usually is triggered by the onset of infection (Aufderheide et al. 1998). Signs of this arthritis would be the presence of cysts, porotic pitting, and the necrosis of the cortical bone (Aufderheide et al. 1998). Despite porotic pitting being found in the ribs, this is an overlapping reactive change in typical OA and previous studies (e.g. Mosher et al. 2013; Nicosia et al. 2016) have conducted assessment for these degenerative diseases and found none. If rheumatoid arthritis was a contributing factor, more signs of this type of OA would be present. Second, ankylosing spondylitis, is the condition in which the primary diagnostic criterion is fused vertebral bodies. Ankylosing spondylitis has many etiologies including trauma and infection to the vertebral column. Had this condition been observed in the thoracic vertebral column, the CV/CT OA could have been associated to ankylosing spondylitis that would have progressed OA of the rib joints from the spine. However, since there was no evidence of ankylosing spondylitis found in the vertebral column of any individual in the study sample, this etiology is also highly unlikely. Finally, Diffuse Idiopathic Skeletal Hyperostosis (DISH) is the condition caused by reactive bone growth to the transverse processes of the vertebrae that interlocks and fuses the vertebrae together. This reactive change usually happens along the side of the vertebral column and in the thoracic region can cover the CV/CT joints. If this was a causative factor of the noticed OA, other vertebral bodies would be fused and would be noticeable during examination. However, there were no signs of DISH in the study sample. Although DISH's etiology is still unknown, a study by Rogers and Waldron (2001) have linked a case study of DISH to a combination of type two diabetes and obesity in medieval monks. The Schroeder Mounds sample is very malnourished (Nicosia et al. 2016), thus making the likelihood of DISH playing any role in this samples OA very low. In terms of degenerative disease to the spine, it should be noted that with the severe cases of osteophytic activity of ruptured discs and other spinal trauma and disease (e.g., Boncal and Smith 2015; Wamsley et al. 2014), it may be likely that degenerative diseases might have a supportive cause if this activity should extend to the joint margins, progressing the development of CV/CT OA.

Respiratory infections can inflict rapid movement of the rib muscles and make fierce articulation movement (Zhang et al. 2016; Cohen et al. 1978). Rib muscles typically contract craniodorsally and medio-laterally when inhaling and exhaling, with the most movement between the upper and lower ribs. However, everyday respiratory processes only move the ribs a little and not enough to produce OA (Zhang et al. 2016). This means that the presence of long-term respiratory infection may be a direct cause of degeneration of the rib articulation facets, or its more likely that aggravated lung expansion is a cause of rapid rib movement and possible trauma that in effect, breaks down cartilage. If that is the case, then the upper and lower ribs would be greatly affected and have the highest cases of OA. In the present sample, there is little evidence of advanced OA in the upper ribs (ribs 1-4), but there is a high frequency in the CV/CT articulation points on the first thoracic vertebrae. This low frequency in the ribs may be from a lack of good preservation in the study samples. An earlier study thoroughly reviewed the same ribs and searched for signs of respiratory infection and found none (Smith 2017). No lesions related to respiratory infection such as cloaca (a result of blood borne infections that damage the inner table of the bone) or evidence of outer lesions such as osteomyelitis (damage to the outside wall) and periostitis (inflammation of bone due to infection) around the thoracic area could be found. Because of this, another explanation is more plausible.

Osteoarthritis of the rib/vertebral joints may have been caused from habitual burden-bearing using a chest and/or headband tump line. In recent case studies, such as studies of Nepalese porters using headband tumplines (Bastien 2005) or other groups using chest-level tumplines (Molleson 2008), these burden-bearing activities involve a single strap around the head (head-level tump line) or chest (chest-level tump line), and in a forward motion carry heavy loads in a sac by distributing the load's weight throughout the carrier's body. Each type of burden-bearing activity with a tumpline involves the sac resting on the thoracic vertebral column as the carrier moves the weight (Bastien 2005). The extremely high frequency and severity of the 7th rib, and the high frequency of OA in the 6th-8th ribs, may be the result of a type of strap that is wrapped around the body and some type of weight exerted on the body that could make gradual degeneration of the joint, especially if it is habitual behavior and if the person bends forward to press the burden on the spinal process and the articular facets of the CV/CT joints. Additionally, the corresponding 6th-8th thoracic vertebrae have a lower frequency of OA in this region despite a high frequency in the ribs. This may be because the ribs slightly project further than the vertebral column in the back. Therefore, the use of a neck/chest-level tumpline would mechanically constrict and further exert movement in these ribs and would explain the high frequency of OA in this region and not in the thoracic vertebrae.

Previous research has examined burden bearing signs in the Schroeder Mounds people. One research study on the Schroder Mounds sample linked intervertebral osteophytosis to tumpline use (Boncal and Smith 2015; Neidich and Smith 2014). In a Schroeder Mounds case study by Boncal and Smith (2015), the pattern of osteophytic reaction on the cervical vertebral body joint surface was demonstrated to be associated with the use of head-level tumpline. Boncal and Smith (2015) found Baastrup's sign or an enlargement on the spinous process of the vertebrae which was linked by the authors to burden bearing. They additionally examined os acromial or the condition of the distal end of the acromion on the shoulder not fusing together. This lack of fusion was argued to support the idea that burden bearing mechanical stress may have played a role in this lack of fusion. Furthermore, Neidich and Smith (2014) examined the robusticity of the Schroeder Mounds sample and a Tennessee River Valley sample and concluded that the robusticity of the upper body and cervical vertebral body is linked to habitual burden bearing activities. This study corroborates and further supports the idea of a tumpline as a causative factor in the rib and vertebral OA. The high frequency of OA, especially on the 7^{th}-12^{th} ribs, in both males and females, would have to indicate that whatever the technique was, both sexes employed it. Procuring and gathering for agricultural products may be one method that would involve such activity. Furthermore, the use of a tumpline to procure agricultural products would make sense with the evidence of maize agriculture (Durchholz 2017) at the Schroeder Mounds site, with previous research studies on burden bearing (Boncal and Smith 2015; Neidich and Smith 2014), and with comparative Late Woodland sites that demonstrated these people to be forager-farmers (Benn and Lee 2005; Hedman and Emerson 2008; Trader 2011).

In terms of the use of stages of severity to quantify CV/CT OA, the method worked well in this study. Prior to this study, researchers could only diagnose OA by the presence of eburnation on the joint surface. This study demonstrates that using the Stage of Severity methodology can determine populational habitual activities based on the pattern and severity of the OA present on the CV/CT surface. Using a Stage of Severity analysis allows the researcher to find frequencies and specific distributions of OA between different ribs and vertebrae (see Table 8). Additionally, it can be used to determine frequencies of OA between age and sex. This method also helps quantify OA despite the absence of eburnation in the sample.

This present study illustrates that CV/CT OA can provide a more comprehensive description of the degenerative changes in the vertebral column. This study demonstrated that porotic pitting, osteophytosis, and joint remodeling are all processes that can be used in understanding the habitual activities of the Schroeder Mounds people. The Stage of Severity methodology aid in the assessment of OA and to put weight to reactive changes on CV/CT joints on both the vertebral body/transverse processes and on the ribs. Hopefully, future studies will be able to compare these results with other sites and test the validity of the load bearing interpretation of the Schroeder Mounds site. Load bearing activities may be readily identified by the ribs in future research. The purpose of this study is to bring further research into frequencies of CV/CT OA. However, it needs to be noted that more experimental/archaeological research supported by clinical literature on load bearing studies and how load bearing techniques effect the thoracic region of the body is still needed.

Conclusion

The burial context of Schroeder Mounds belonged to a Late Woodland period population (Boncal and Smith 2015; Durchholz 2017; Kolb 1982; Mosher et al. 2013; Nicosia et al. 2017; Smith et al. 2016). This group would likely have had low residential mobility and subsisted on the cultivation of indigenous and exotic (i.e., maize) plants (Durchholz 2017; Emerson et al. 2000). The Late Woodland period populations were starting to be more involved in agricultural practices, as the Later Mississippian period would soon follow, and the intensification of maize agriculture would have dramatically increased (Pauketat 2004; Smith et al. 2016; VanDerwarker and Bardolph 2013). Therefore, the use of a tumpline would not only be plausible but beneficial to the Schroder Mounds people especially in maize agriculture collection. This study aimed to discover more about the Schroeder Mounds people through the frequency of CV/CT osteoarthritis. Based on the frequency of CV/CT osteoarthritis, this study further supports the idea that as the Late Woodland progressed into the Early Mississippian period, agricultural cultivation increased (Emerson et al. 2000; Pauketat 2004). With increased cultivation, the need for tumplines becomes even more apparent and is supported by the findings of this study. Previous research suggests the Schroeder Mounds people were forager-farmers (Mosher et al. 2013; Nicosia et al. 2016; Smith et al. 2016), and the use of a more efficient method of carrying such as a tumpline, would make carrying larger loads of products much easier. This study suggests, just like the Schroeder Mounds people, other late woodland sites in a similar context could have utilized tumplines as well. How is this suggestion made?

Moreover, this study is useful to future researchers concerned with Late Woodland peoples to examine more on the use of tumplines and other burden/bearing activities in other groups. This would additionally help understand the switch to maize agriculture and the material culture associated with burden bearing. Future clinical and biomechanical research can also use this study as a guide to further understand the effects of weight bearing on the ribs and thoracic vertebrae. By using a Stage of Severity methodological analysis, CV/CT OA could be identified by levels of severity and frequencies of age, sex, and rib/vertebral OA could be identified despite the lack of eburnation. Interestingly, the results of this study show that CV/CT OA was common in both men and women that were examined, and the severity was not confined to the older age groups. The 6^{th}-8^{th} ribs had the highest frequency of OA and the 7^{th} rib held the highest severity of OA. The middle to lower thoracic vertebra held the most frequent OA. This methodology can also be used in future studies that examine the possible use of tumplines to determine if the same osteoarthritic activity occurs in a similar frequency. Unfortunately, this study only involves a single site and a larger study involving the same methods and goal would help support and this study's interpretation on habitual activity and frequency of CV/CT osteoarthritis. Additionally, further examinations on the effects of respiration and respiratory infection on the CV/CT joints would further understanding of respiration's potential role in the frequency of CV/CT of the Schroeder Mounds people.

From the skeletal data, two possible interpretations were forwarded to explain the osteoarthritic phenomenon: respiratory infection or mechanical stress associated with burden-bearing. In the absence of any data suggesting chronic respiratory problems, particularly relative to the ubiquity of OA, the most likely cause is mechanical stress related to burden-bearing. Independent assessment of vertebral osteophytosis, the identification of kissing facets (Baastrup's signature), and the presence of multiple cases of *os acromiale* (e.g., Boncal and Smith 2015) lends support to this interpretation.

Acknowledgements

The author would like to thank Dr. Maria O. Smith (Professor, Dept. Sociology and Anthropology, Illinois State University) for access to the Schroeder Mounds collection and Brianna Durkin for the assistance during the recording process.

References

Arden, N., & Nevitt, M. C. 2006. "Osteoarthritis: epidemiology". *Best practice & research Clinical rheumatology*, 20(1):3 -25.

Aufderheide, Arthur C., Rodriguez-Martin, Conrado.Langsjoen, Odin. 1998. *The Cambridge Encyclopedia of Human Paleopathology*. Cambridge, UK; Cambridge University Press.

Bastien, G. 2005. "Physiology of load-carrying in Nepalese por ters". Doctoral dissertation, Thesis, Université Catholique de Louvain.

Benn DW, Lee DV. 2005. "A late Louisa phase household in the upper Mississippi Valley, Henderson County, Illinois". *Illinois Archaeology* 14:1–40.

Boncal, S. and Smith, M.O. 2015. "Cervical pathol-ogies and case study from the Schroeder Mounds site of Woodland Period Illinois," Poster presented at the Midwest Archae ology Conference Meetings, Milwaukee Wisconsin (November).

Brown, K., Pollintine, P., & Adams, M. 2008. "Biomechanical implications of degenerative joint disease in the apophyse al joints of human thoracic and lumbar vertebrae". *Ameri can Journal of Physical Anthropology*, 136(3), 318-326.

Buikstra, Jane E., Ubelaker, Douglas H. 1994. *Standards for data* *collection from human skeletal remains*: Proceedings of a seminar at the Field Museum of Natural History, orga nized by Jonathan Haas (Arkansas Archeological Survey research series; no. 44). Fayetteville, Ark.: Arkansas Ar cheological Survey.

Cohen, M. J., Ezekiel, J., & Persellin, R. H. 1978. "Costovertebral and costotransverse joint involvement in rheumatoid arthritis". *Annals Of The Rheumatic Diseases*, 37(5), 473.

Domett, K., Evans, C., Chang, N., Tayles, N., & Newton, J. 2017. "Interpreting osteoarthritis in bioarchaeology: Highlight ing the importance of a clinical approach through case studies from prehistoric Thailand". *Journal of Archaeo logical Science*: Reports, 11, 762-773.

Durchholz, Aaron. 2017. "Candy Corn: Subsistence Strategy and Dental Decay at the West-Central Illinois Schroeder Mounds (11HD177) Site". Presentation at the Midwest Bioarchaeology & Forensic Anthropology Association conference, Milwaukee Wisconsin.

Emerson, Thomas E., McElrath, Dale L., Fortier, Andrew C. (Eds.). 2000. "Late Woodland societies: tradition and transformation across the midcontinent". Lincoln, NE : University of Nebraska Press.

Erosa, S., Erosa, S.C. and Sperber, K., 2018. "Costovertebral Pain Syndromes". *Musculoskeletal Sports and Spine Disor ders: A Comprehensive Guide*, pp. 369-371.

Hedman KM, Emerson TE. 2008. "The luthy alps site: AMS dates, stable isotopes, and maize consumption in the Cen tral Illinois River Valley at the Late Woodland-Mississippian interface". *Illinois Archaeology* 20:48–84.

Kolb M. 1982. *The Schroeder Mounds Site: A Preliminary Analy sis from a Spatial Perspective*. Master's thesis, Depart ment of Anthropology, University of Wisconsin, Milwau kee.

Mann, R. 1993. "A Method for Siding and Sequencing Human Ribs". *Journal Of Forensic Sciences*, 38(1), 151.

Mays, S., Watt, I. and Loe, L., 2017. "An unusual erosive ar thropathy from Medieval England". *International Journal of Osteoarchaeology*, 27 (4), pp. 693-699.

Molleson, T. 2007. "A method for the study of activity related skeletal morphologies". *Bioarchaeology of the Near East.*

1, 5-33.
Mosher, G., Smith, M., Albrecht, J., & Salaka, V. 2013. “Treponemal Disease, Tuberculosis and Subsistence-settlement Pattern in the Late Woodland Period West-central Illinois”. *International Journal of Osteoarchaeolo gy*, 25(5), 776-787.

Nicosia, Christopher, Dorsz, Jessica R., Smith, Maria O. 2016. “Subadult Growth Stunting at Schroeder Mounds (11He177): A Late Woodland Sample from Illinois”. *Field Notes: A Journal of Collegiate Anthropology* 8:104-120.

Neidich, Deborah L., and Maria Ostendorf Smith. 2014. "An in vestigation of Teres Minor insertional robusticity and its pattern in a Late Woodland Period sample from west-central Illinois," Paper presented at the Midwest Archaeol ogy Conference, Springfield, Illinois.

Pauketat, T.R., 2004. *Ancient Cahokia and the Mississippians*. Cambridge University Press, Cambridge, UK. Roberts, C. A., & Manchester, K. 2005. *The Archaeology of Disease*. Ithaca, N.Y.: Cornell University Press.

Rogers, J., and Waldron, T. 1995. *A Field Guide to Joint Disease in Archaeology*. John Wiley. New York.

Rogers, J., and Waldron, T. 2001. “DISH and the monastic way of life”. *International Journal of Osteoarchaeology*, 11 (5), 357-365.

Sales, J., Beals, R., and Hart, R. 2007. “Osteoarthritis of the cos tovertebral joints - The results of resection arthroplasty”. *Journal of Bone and Joint Surgery-British Volume*, 89B (10), 1336-1339.

Schrader, S. A. 2012. “Activity patterns in New Kingdom Nubia: an examination of entheseal remodeling and osteoarthritis at Tombos”. *American Journal of Physical Anthropology*, 149(1), 60-70.

Smith, Maria O. 2017. Personal Communication. November 1, 2017.

Smith, Maria Ostendorf, Kurtenbach, Katie J., and Jacqueline C. Vermaat. 2016. “Linear enamel hypoplasia in Schroeder Mounds (11HE177): A Late Woodland period site in Illi nois”. *International Journal of Paleopathology*.

Susmarski, A.J. and Helm, E.R., 2017. “Acute Facet Pain”. In *Musculoskeletal Sports and Spine Disorders* (pp. 411-

414). Springer, Cham.

Trader, PD. 2011. “Fragmented frontier: Examining a Late Woodland settlement in West-Central Illinois”. *Illinois Archaeology* 23:124–157.

VanDerwarker, A. M., Wilson, G. D., & Bardolph, D. N. 2013. “Maize adoption and intensification in the central Illinois River Valley: An analysis of archaeobotanical data from the Late Woodland to Early Mississippian periods (AD 600–1200)”. *Southeastern Archaeology*, 32(2), 147-168.

Waldron, T. and Willoughby, J., 2016. “The Use of Palaeo pathological or Historical Data to Investigate the Causa tion of Disease”. Papers from the I*nstitute of Archaeolo gy*, 25(2).

Wamsley, Brooke, Emily Blankenberger, Veronica Butterfield, and Maria Ostendorf Smith. 2014. "Sex differences in mechanical stress in aspects of the hip joint in the Late Woodland Sample from Schroeder Mounds," Paper pre sented at the Midwest Archaeology Conference, Spring field, Illinois.

White TD, Folkens PA. 2005. *The Human Bone Manual*. Aca demic Press: New York.

Zhang, G., Chen, X., Ohgi, J., Miura, T., Nakamoto, A., Matsu mura, C., & ... Hisada, T. 2016. “Biomechanical simula tion of thorax deformation using finite element ap proach”. *Biomedical Engineering Online*, 1518. https://doi.org/10.1186/s12938-016-0132-y.