CERVICAL ARTHRITIS, C3-C7, FROM AN IDENTIFIED OSTEOLOGICAL COLLECTION

ARTRITIS CERVICALES, C3-C7, EN UNA COLECCIÓN OSTEOLÓGICA DOCUMENTADA

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KEY WORDS osteophytic marginal lipping, porosity, eburnation, degenerative bone disease, William M. Bass Donated Skeletal Collection

ABSTRACT Osteoarthritis on the cervical vertebrae, C3-C7, accumulates as a function of age, life style, diet and severity of long-term skeletomuscular stress. However, the degree to which age (older adult and elderly) and sex differences impact on the manifestation of osteoarthritis remains difficult to assess because of the variability of biological aging and the lack of discrete post-reproductive age categories. The aim of this investigation was to score the degree of osteophytic marginal lipping, porosity and eburnation on the cervical vertebrae of identified individuals from the William M. Bass Donated Skeletal Collection of the Forensic Anthropology Center of the University of Tennessee, Knoxville, USA, to address whether the expression of osteoarthritic features differs (1) between older adults, 50-55 years, and elderly adults, 70-76 years, within each sex; (2) between both sexes of the same age category; and (3) between the sexes regardless of age. Osteological remains included were accessioned between 2000 and 2010 to reflect contemporary variation, and only C3 to C7 were scored given the distinctions in morphology and function of the atlas and axis. The vertebrae were separated by number and analyzed using Mann-Whitney U tests. Osteoarthritic features are generally more severe in males compared to females although eburnation is elevated in older females (50-55 years) compared to their elderly counterparts (70-76 years). Both sexes show an accumulation of osteoarthritic features as a consequence of advancing age. However, sex differences between elderly adults (70-76 years) are less extreme compared to when all females and males are considered regardless of age. Rev Arg Antrop Biol 21(1), 2019. doi:10.17139/raab.2019.0021.01.04

PALABRAS CLAVE osteofitos, porosidad, eburnación, enfermedad degenerativa del hueso, Colección William M. Bass

RESUMEN La osteoartritis en las vértebras cervicales, C3-C7, se acumula debido a la edad, el estilo de vida, la dieta y la gravedad del estrés esqueletomuscular a largo plazo. Sin embargo, el grado en que la edad (adultos mayores y ancianos) y las diferencias sexuales afectan la manifestación de la osteoartritis sigue siendo difícil de evaluar debido a la variabilidad del envejecimiento biológico y la falta de categorías discretas de edad postreproductiva. El objetivo de esta investigación fue evaluar el grado de inflamación osteofítica, porosidad y eburnación en las vértebras cervicales de individuos identificados de la Colección Osteológica William M. Bass del Centro de Antropología Forense de la Universidad de Tennessee, Knoxville, EE. UU, para determinar si la expresión de las características osteoartríticas difiere (1) entre adultos mayores, de entre 50-55 años, y ancianos, de 70-76 años, dentro de cada sexo; (2) entre ambos sexos de la misma categoría de edad; y (3) entre los sexos, independientemente de la edad. Los restos osteológicos incluidos fueron seleccionados entre 2000 y 2010 para reflejar la variación contemporánea, y solo se analizaron las vértebras cervicales C3 a C7, dadas las distinciones en morfología y función del atlas y del axis. Las vértebras se separaron por número y se analizaron mediante la prueba Mann-Whitney. Las características osteoartríticas son generalmente más serias en hombres que en mujeres, aunque la eburnación es elevada en mujeres mayores (50-55 años) en comparación con sus contrapartes mayores (70-76 años). Ambos sexos muestran una acumulación de rasgos osteoartríticos como consecuencia de la edad avanzada. Sin embargo, las diferencias en función del sexo entre los adultos mayores (70-76 años) son menos extremas en comparación con las diferencias observadas al considerar hombres y mujeres con independencia de la edad de los individuos. Rev Arg Antrop Biol 21(1), 2019. doi:10.17139/raab.2019.0021.01.04

Osteoarthritis is one of the most common pathological lesions seen in clinical, forensic and archaeological populations and is studied by both physicians and biological anthropologists (Jurmain, 1977; Listi and Manhein, 2012; McGonagle, Tan, Carey, and Benjamin, 2010; Ortner, 2003; Tersigni-Tarrant and Zachow, 2012; Weiss and Jurmain, 2007). Due to different academic approaches, researchers have used terms such as osteoarthritis, osteoarthrosis or degenerative joint diseases to describe this group of deteriorating conditions that radically alter the morpho-

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logical composition and mechanical properties of articular surfaces, resulting in joint pain and stiffening (Weiss and Jurmain, 2007; Woo and Pak, 2014). We follow Ortner (2003) and Weiss and Jurmain (2007) in identifying marginal lipping, porosity and eburnation on the cervical vertebrae as osteoarthritis. The etiology of osteoarthritis is unknown and is likely to be multifactorial, although it seems to be directly related to increasing age (Ortner, 2003; Weiss and Jurmain, 2007). Characteristics associated with the presence of osteoarthritis in a clinical setting include loss of cartilage, thickening, and tears in cartilaginous tissues (Bennell, Hall and Hinman, 2016; Loeser, 2009, 2010; Menkes and Lane, 2004; van der Kraan and van den Berg, 2007, 2008).

Osteoarthritis increases substantially during the older adulthood period (+50 years) when the process of skeletal aging accelerates (Steele and Bramblett, 1988). Spinal arthritis is nearly ubiquitous after 40 years (Ortner, 2003), although only minimally developed (Snodgrass, 2004). Osteoarthritis occurs in 50% of people in western countries by the age of 60 years and essentially all individuals in an autopsy sample had some degree of osteoarthritic deformation by 65 years (Solomon, 2001). This process is characterized by bone remodeling which begins to accumulate in articular surfaces at an increased rate and is often coupled with decreases in bone density (Weiss and Jurmain, 2007). Osteoarthritis is the manifestation of secondary bone growth in the form of osteophytic marginal lipping and a reduction of bone density resulting in porosity, both of which stem from a disequilibrium between osteoblast and osteoclast activity, while eburnation is a severe manifestation of subchondral bone destruction (Ortner, 2003).

Osteoarthritis has received considerable attention by biological anthropologists (Bridges, 1992; Rothschild, 1997; Ortner, 2003; Snodgrass, 2004; Weiss and Jurmain, 2007). Systematic predisposition, mechanic functional influences, as well as age, sex, metabolism, nutrition, trauma and obesity have all been proposed as possible causes of osteoarthritis (Jurmain, 1977). Correlations between age and osteoarthritic features are reported, as well as descriptions of the development and degeneration of osteophytes (Andersson, 1998; Brennaman, 2014; Brennaman, Love, Bethard and Pokines, 2017; Listi and Manhein, 2012; Nathan, 1962; Stewart, 1958; Watanabe and Terazawa, 2006; Zukowski, Falsetti and Tillman, 2012). Listi and Manhein (2012) argued that osteoarthritic features in the vertebrae are related to age, but can only predict a general rather than specific range of ages. However, whether osteoarthritis is a normal function of aging has been challenged by evidence of the absence of expression in some joints even in advanced ages (Ortner, 2003). Stress from repeated use of articulations seems to be a generally accepted cause of the expression of osteoarthritis, particularly stress related to impact (Solomon, 2001), although heredity also appears to be an important factor.

Other studies have sought to reconcile activity patterns (Bridges, 1994; Chapman, 1972) and sexual dimorphism (Burr *et al.*, 1983; MacLaughlin and Oldale, 1992; Weiss and Jurmain, 2007) with the complexity of osteoarthritis expression. In the spinal column, osteoarthritis has been associated with marginal lipping or osteophytes (Lovell, 1994; Kim DK, Kim MJ, Kim YS, Oh and Shin, 2012; Knüsel, Goggel and Lucy, 1997; Snodgrass, 2004; Van der Merwe, Işcan and L'abbé, 2006), while features such as porosity and eburnation have been less often discussed (Buikstra and Ubelaker, 1994; Calce, Kurki, Weston and Gould, 2017; Rothschild, 1997). At the same time, controversial issues, such as whether marginal lipping is a pathology or an age-related transformation, have been examined (Weiss and Jurmain, 2007). According to Rothschild (1997), porosity is an enigmatic physiological trait seen in human bone and unrelated to osteoarthritis formation. Schultz (1998) argues that porosity is a poor indicator of osteoarthritis. Porosity arises from discontinuities in subchondral bone. This erosive disorganization emerges gradually over the life cycle unless some systemic condition accelerates the process (Rothschild, 1997). Marginal lipping may be a different process and more tightly correlated with age than eburnation and porosity (Weiss and Jurmain, 2007). Osteophytosis is a reactive response to osteoarthritis and is an indirect indicator of the disease rather than a manifestation of it (Weiss and Jurmain, 2007). Eburnation is the result of bone on bone contact in the absence of a cartilaginous layer between mating articular surfaces resulting in a complete destruction of a portion of the joint capsule, which may or may

not be painful (Rothschild, 1997), and is likely to be related to repetitious physical activities (Ortner, 2003).

Cervical arthritis has been extensively studied and treated by physicians (Hardin, 1992). In contrast, osteoarthritis of the cervical vertebrae has received little attention in biological anthropology. Two studies specific to the cervical skeleton include Taitz (1999) who noted population differences in bone mineral density and incidence of cervical osteoarthritis, and Haugen (1994), who examined the association between size and morphology of cervical vertebrae although without a focus on osteoarthritis. In the present study, osteoarthritic features on the cervical vertebrae (C3-C7), including the degree of marginal lipping, porosity and eburnation, were scored on recently deceased individuals (n=99) from the W.M. Bass Donated Skeletal Collection of the University of Tennessee, Knoxville, USA. Since these remains are of known age and sex, estimating these parameters was unnecessary thereby decreasing observer bias and increasing the validity of the results.

Age-based differences

One of the goals of the study is to identify whether the expression of osteoarthritic features differs between older adults, 50-55 years, and elderly adults, 70-76 years. The first age interval (50-55) represents the onset of older adulthood. Humans can be classified as young adults between skeletal maturation at 25 years and 49 years. Older adulthood can be defined as 50+ years when the skeleton begins to deteriorate at a more rapid rate (Brennaman *et al.*, 2017; Buikstra and Ubelaker, 1994; Steele and Bramblett, 1988). Fifty years is also a cross-cultural marker of the post-reproductive period demarcated by the universal cessation of menstruation in women (Hawkes, 2006; Fedigan and Pavelka, 2007). Observations on the identified Terry osteological collection showed that only individuals 50+ years had elevated composite scores for osteophytosis while these high values were virtually lacking in individuals younger than 35 years (Snodgrass, 2004).

The second age interval (70-76 years) can be considered the middle of the early elderly period, when more rapid skeletal degeneration of the vertebral system is noted to occur (Brennaman *et al.*, 2017; Steele and Bramblett, 1988). The Framingham Study offers further evidence for a breakdown of skeletal tissues after 70 years such that osteoarthritis of the knee was found in 15,6% of 598 individuals without any prior evidence of the condition, with a mean age of 70.5 years (Felson *et al.*, 1997). Ethnographic studies indicate that both sexes ≥70 years complain of back and joint pain, lethargy, frailty and difficulty walking long distances because of painful osteophytes (Gurven *et al.*, 2017).

Although post-reproductive ages lack any true biological divisions, the duration of the young adult period (25-49 years) is roughly equivalent in number of years to the difference between the two age groups (50-55 years and 70-76 years) investigated in the present study. Given that age appears to be the most important risk factor for osteoarthritis (Weiss and Jurmain, 2007), we expect elderly females and males (70-76 years) to exhibit greater severity of cervical arthritic features compared to their younger counterparts (50-55 years).

Sex-based differences

We also investigate whether differences are expressed between sexes of the same age category and between females and males regardless of age. Females have a greater reactivity of immune response than do males which contributes to increased longevity, and therefore the frequency of chronic diseases such as osteoarthritis (Ortner, 2003). Sex differences in osteoarthritis are likely to result from hormonal and physiological mechanisms rather than solely via occupational stress or cultural factors (Weiss and Jurmain, 2007). Females tend to exhibit more severe osteoarthritis in the lower limbs compared to the upper limbs (Weiss and Jurmain, 2007). Furthermore, overweight females exhibit more extreme osteoarthritis than their male counterparts because a greater amount of systemic and mechanical weight bears down on proportionally smaller joints. In fact, smaller individuals generally present more severe arthritis when age is taken into account, perhaps due to equal load bearing on proportionally petite articular surface (Weiss and Jurmain, 2007). Snodgrass (2004) found that females and males follow the same pattern of osteophyte formation in the thoracic and lumbar vertebrae, although females are more

variable (Snodgrass, 2004). However, the expression of osteoarthritis can be more severe in males (Solomon, 2001). For instance, Kim and colleagues (2012) examined an historic Korean population and found osteophytes were much more frequent in males than females, and this was attributed to the heavy physical labor observed in males. Van der Merwe *et al.* (2006) analyzed South African skeletal remains reporting the highest degree of osteophyte expression in the lumbar, followed by cervical and thoracic vertebrae, all of which were more pronounced in males than females. Given these sex-based differences, we expect males to exhibit greater severity in cervical arthritic features compared to females, both within age cohorts and regardless of age.

MATERIALS AND METHODS

Cervical vertebrae were examined from complete skeletons of the William M. Bass Donated Skeletal Collection of the Forensic Anthropology Center of the Department of Anthropology at the University of Tennessee, Knoxville, USA. Ninety-nine (n=99) self-reported "white" individuals, who died between 2000 and 2010 were scored using the 1-4 non-metric scoring method developed by Buikstra and Ubelaker (1994). The demographic trends within the body donation program of the Forensic Anthropology Center of UTK have been explored previously (Wilson, Algee-Hewitt and Meadows Jantz, 2007). A sample of 14% of past donors and 18% of future donors were primarily self-described as "white," from the Southeast USA, and included more males than females. A total of 60% of donors can be characterized as low to middle income and 40% of the sample are laborers and have a high school diploma (Wilson *et al.*, 2007). Although the exact demographic trends of the sample we examined are unknown, there is no reason to anticipate a departure from the patterns noted in Wilson *et al.* (2007). Our samples include 25 females who died between 50-55 years and 24 who died between 70-76 years. The male sample includes 25 individuals with age at death between 50-55 years and 25 individuals who died between 70-76 years.

To increase comparability, only complete sets of cervical vertebrae from C3 to C7 for each individual were considered in the analysis. The first and second cervical vertebrae (atlas and axis) were excluded because these bones are distinct in the absence of a centrum (atlas), and in a centrum attached to the odontoid process (axis) (Steele and Bramblett, 1988). In humans, cervical vertebrae C3-C7 differ from one another in morphology and carry loads of increasing magnitude (Dawson and Trinkaus, 1997). Therefore, each vertebral element was examined separately, as were inferior and superior surfaces. Multiplying the number of individuals (n=99) by the number of vertebral elements in each (5) yields a total of 495 cervical vertebrae that were analyzed for this study (Table 1).

A non-metric scoring analysis was used to rank the degree of marginal lipping, eburnation and porosity (Buikstra and Ubelaker, 1994). In scoring the degree of marginal lipping, Buikstra and Ubelaker (1994) used scales from 1 to 4, where 1 is described as barely discernible, and 4 is described as ankylosis (Fig. 1). Porosity degree was analyzed using scales from 1 to 3, in which a score of 1 is represented as pinpoint perforations, and a score of 3 is described as both pinpoint and coalesced cavities being visible (Fig. 2). The degree of eburnation was scored based on a range of 1 to 3, in which a scale of 1 is considered as barely discernible, and a score of 3 is polished and with groove(s) (Fig. 3; Table 2). Areas on the cervical vertebrae which were scored included superior and inferior marginal lipping of the centrum, extent of marginal lipping of the centrum, superior and inferior porosity of the centrum, extent of porosity of the inferior centrum and degree of eburnation on articular facets (Buikstra and Ubelaker, 1994; Table 2). Prior to data collection at the University of Tennessee, Knoxville, a scoring error study was conducted at the Bioarchaeology Teaching Laboratory of the Department of Anthropology at Georgia State University, Atlanta, USA. There were no differences in the scores of the same vertebrae examined twice, with the two trials separated by one week.

Given that osteoarthritic features may be manifested at different intensities across the same articulation, it is possible that the scoring method chosen may have overestimated the values and as a consequence biased the true variability of the sample. Scoring provides a composite variable of an entire surface which serves as an estimate of the ex-

***TABLE 1**. Sample analyzed at the William M. Bass Donated Skeletal Collection of the University of Tennessee Knoxville, USA*

Category	Age (years)	Female	Male	Sub-total
Older adult	50	7	7	14
	51	6	6	12
	52	6	6	12
	54	5	5	10
	55	1	1	2
Sub-total		25	25	50
Elderly	70	3	3	6
	71	5	5	10
	72	4	4	8
	73	6	6	12
	74	2	2	4
	75	3	4	7
	76	1	1	2
Sub-total		24	25	49
Total		49	50	99

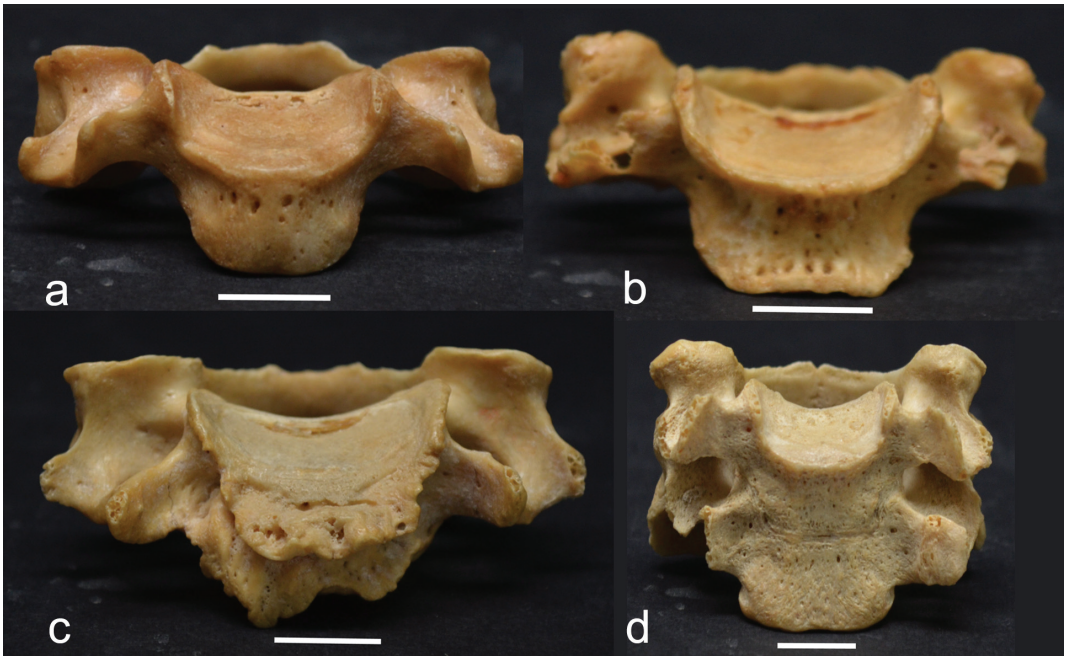

Fig. 1. Marginal lipping scoring system proposed by Buikstra and Ubelaker (1994). (a) barely visible, grade 1, on vertebra C3, GSU 3.260; (b) elevated ring, grade 2, on vertebra C4, GSU 3.8; (c) curved spicules, grade 3, on vertebra C7, GSU 3.170; and (d) fusion present/ankylosis, grade 4, on vertebrae C3-C4, GSU 3.237.

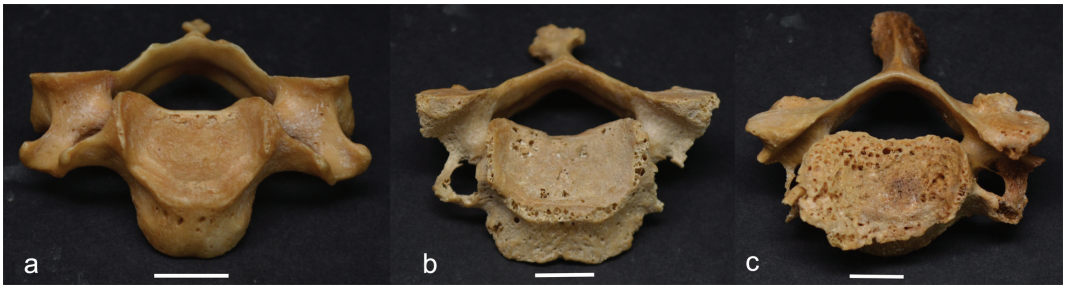

Fig. 2. Porosity scoring system proposed by Buikstra and Ubelaker (1994). (a) pinpoint, grade 1, on vertebra C3, GSU 3.260; (b) coalesced, grade 2, on vertebra C4, GSU 3.21; (c) both pinpoint and coalesced present, grade 3, on vertebra C6, GSU 3.41.

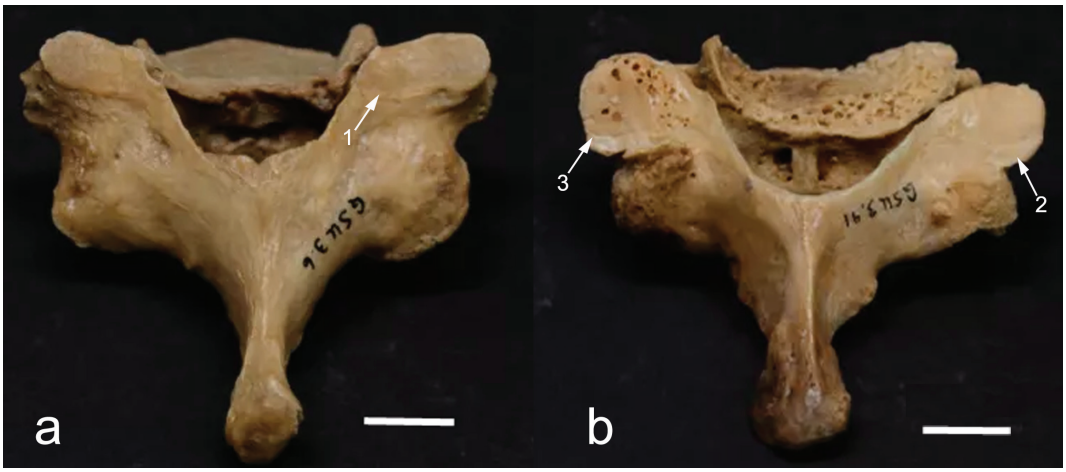

Fig. 3. Eburnation scoring system proposed by Buikstra and Ubelaker (1994). (a) barely discernible, grade 1 (identified by a white arrow=1), on the right superior facet of vertebra C7, GSU 3.6, (b) polish only, grade 2 (indicated by a white arrow=2), on the right superior facet; and polish/groove, grade 3 (shown with a white arrow=3), on the left superior facet of vertebrae C6, GSU 3.41.

***TABLE 2**. Cervical osteoarthritis score system described by Buikstra and Ubelaker (1994)*

Feature	Score	Extent	Description
Marginal lipping degree	1	<1/3	Barely visible
	2	1/3-2/3	Sharp ridge, at times coupled with spicules
	3	>2/3	Extensive spicule formation
	4		Ankylosis
Porosity	1	<1/3	Pinpoint
	2	1/3-2/3	Coalesced
	3	>2/3	Both pinpoint and coalesced present
Eburnation	1		Barely visible
	2		Polish only
	3		Polish with groove(s)

pression of osteoarthritis. A sampling technique could have been employed to avoid inflating the osteoarthritic scores, although such a procedure might possibly underestimate the severity of osteoarthritis. To err on the side of caution, we chose to use the Buikstra and Ubelaker (1994) method without the use of a sampling strategy. If indeed the severity of osteoarthritis has been overestimated in the cervical skeleton, at the very least it has been done so in a consistent manner as our intraobserver scoring study suggests.

For the data collected at the University of Tennessee, Knoxville, descriptive statistics were compiled for each age and sex grouping. Mann-Whitney U tests were utilized to compare the scoring of each cervical osteoarthritic feature (marginal lipping, porosity and eburnation) across age cohorts for females and males separately to identify whether age impacted the sexes differentially. Differences were considered significant if the p value was ≤ 0.05. Other tests included whether older adult females and males (50-55 years) differed in the expression of osteoarthritic features and similarly whether the two sexes of elderly adults (70-76 years) were distinct. A Mann-Whitney U test was utilized to ascertain whether differences existed solely as a function of sex and therefore included all females and males (50-76 years)

RESULTS

Descriptive statistics for each age and sex category are depicted in Table 3. The means for older adult males are nearly universally higher than those of same-aged females with the exception of the extent of porosity and eburnation, where females exhibit higher average values. In fact, the older adult females (50-55 years) exceed all other age/sex categories in extent of porosity and eburnation. Besides these exceptions, elderly female and male means exceed those of their younger counterparts across comparisons. The standard deviation of the scores is highest for extent of marginal lipping, and lowest for eburnation, except for older adult females (50-55 years) which present a slightly higher dispersion of scores for this feature compared to the other age/sex categories (Table 3).

Differences in cervical osteoarthritis with respect to age among females (50-76 years)

When only females are compared with respect to age, only the porosity of the inferior surface, the extent of porosity of the inferior body and the degree of eburnation show significant values (Table 4). The older adult (50-55 years) category exhibits a greater extent of porosity on the inferior surface for C3 and C4 whereas eburnation is more severe in the older adult (50-55 years) category for C3. However, elderly adults (70-76 years) show a greater severity of inferior porosity than older adults (50-55 years) as expected. Inferior porosity and extent of marginal lipping superiorly and inferiorly do not differ between older adult (50-55 years) and elderly (70-76 years) females.

Differences in cervical osteoarthritis with respect to age among males (50-76 years)

When only males are considered, a greater number of osteoarthritic features and vertebrae shows significant values and these differences are primarily of the expected pattern consisting of elderly males (70-76 years) exhibiting greater severity than older male (50-55 years) adults (Table 4). These differences are found in marginal lipping of the superior body of C5, and marginal lipping of the inferior centrum and extent of marginal lipping in C3-C5. Degree of eburnation is found to be significantly greater in elderly males (70-76 years) compared to their older adult (50-55 years) counterparts across the cervical vertebrae, C3-C7. While inferior porosity also shows this pattern for C4, the opposite is seen in C7 (Table 4).

Sex differences in cervical osteoarthritis among older adults (50-55 years)

When female and male older adults (50-55 years) are compared, there is a lack of differentiation for most of the scored osteoarthritic traits (Table 5). Two exceptions include the extent of inferior porosity and degree of eburnation, both of which are greater in females

***TABLE 3**. Descriptive statistics for each age/sex group*

	Female					Male				
Older adults (50-55 years)	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD
Marginal lipping superior	125	1	3	1.32	0.587	124	1	3	1.41	0.570
Marginal lipping inferior	125	1	3	1.45	0.638	125	1	3	1.60	0.704
Extent of marginal lipping	125	1	3	1.53	0.736	125	1	3	1.75	0.815
Porosity superior	125	1	3	1.17	0.492	125	1	3	1.26	0.608
Porosity inferior	125	1	3	1.17	0.475	125	1	3	1.29	0.632
Extent of marginal lipping	125	1	2	1.54	0.501	125	1	3	1.30	0.568
Eburnation	125	1	3	1.33	0.55	125	1	3	1.03	0.218
	Female					Male				
Elderly (70-76 years)	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD
Marginal lipping superior	120	1	3	1.46	0.68	125	1	3	1.668	0.713
Marginal lipping inferior	120	1	3	1.67	0.763	125	1	3	2.07	0.764
Extent of marginal lipping	118	1	3	1.58	0.685	116	1	3	2.091	0.681
Porosity superior	118	1	3	1.25	0.558	120	1	3	1.271	0.471
Porosity inferior	118	1	3	1.31	0.577	120	1	3	1.388	0.592
Extent of marginal lipping	118	1	3	1.3	0.575	120	1	3	1.47	0.646
Eburnation	118	0	3	1.17	0.511	120	1	3	1.28	0.471

N:number of individuals;Min: minimum values; maximum values ; SD:standard deviation.

***TABLE 4**. Differences with respect to age assessed using probability (p) values from Mann-Whitney U tests for each element (C3-C7) comparing differences between older (50-55 years) and elderly (70-76 years) adult females and males*

	Marginal lipping superior	Marginal lipping inferior	Extent of marginal lipping	Porosity superior	Porosity inferior	Extent of inferior porosity	Eburnation degree
Females only							
C3	0.689	0.118	0.265	0.354	0.852	0.000 O>E	0.049 O>E
C4	0.557	0.160	0.641	0.732	0.543	0.008 O>E	0.124
C5	0.464	0.488	0.827	1	0.035 E>O	0.198	0.869
C6	0.367	0.134	0.527	0.249	0.046 E>O	0.315	0.057
C7	0.062	0.733	0.908	0.109	0.697	0.243	0.163
Males only							
C3	0.237	0.001 E>O	0.011 E>O	0.327	0.075	0.383	0.024 E>O
C4	0.125	0.001 E>O	0.001 E>O	0.37	0.015 E>O	0.13	0.018 E>O
C5	0.005 E>O	0.007 E>O	0.022 E>O	0.909	0.168	0.229	0.009 E>O
C6	0.200	0.068	0.579	0.76	0.413	0.223	0.035 E>O
C7	0.120	0.64	0.948	0.089	0.022 O>E	0.438	0.004 E>O

Significant values ($p \leq 0.05$); directionality of the relationship is given using O:older adult and E:elderly.

***TABLE 5**. Differences between females and males with respect to age assessed using probability (p) values from Mann-Whitney U tests for each element (C3-C7)*

	Marginal lipping superior	Marginal lipping inferior	Extent of marginal lipping	Porosity superior	Porosity inferior	Extent of inferior porosity	Eburnation degree
Older adults (50-55 years)							
C3	0.465	0.335	0.181	0.332	0.18	0.003 F>M	0.014 F>M
C4	0.783	0.314	0.423	0.668	0.668	0.006 F>M	0.005 F>M
C5	0.953	0.536	0.620	0.484	0.186	0.207	0.042 F>M
C6	0.167	0.480	0.121	0.177	0.105	0.266	0.010 F>M
C7	0.124	0.385	0.205	0.697	0.456	0.122	0.002 F>M
Elderly adults (70-76 years)							
C3	0.966	0.002 M>F	0.007 M>F	0.317	0.659	0.098	0.081
C4	0.195	0.003 M>F	0.000 M>F	0.408	0.137	0.148	0.306
C5	0.028 M>F	0.023 M>F	0.001 M>F	0.514	0.465	0.221	0.456
C6	0.306	0.540	0.064	0.537	0.56	0.261	0.176
C7	0.460	0.339	0.104	0.736	0.144	0.703	0.220
All adults (50-76 years)							
C3	0.583	0.006 M>F	0.004 M>F	0.177	0.665	0.158	0.591
C4	0.242	0.004 M>F	0.001 M>F	0.726	0.28	280	0.249
C5	0.107	0.035 M>F	0.009 M>F	0.333	0.181	0.957	0.536
C6	0.078	0.336	0.018 M>F	0.15	0.095	0.981	0.321
C7	0.092	0.186	0.045 M>F	0.478	0.973	0.376	0.278

Significant values ($p \leq 0.05$); directionality of the relationship is given using F=female and M=male.

than males. While eburnation is greater in females for all cervical vertebrae C3-C7, these patterns are only found in C3 and C4 for the extent of inferior porosity (Table 5).

Sex differences in cervical osteoarthritis among elderly adults (70-76 years)

When elderly females and males (70-76 years) are compared, a number of significant differences exist in the degree of marginal lipping but none in porosity and degree of eburnation. Males exhibit a greater extent of superior marginal lipping than females in C5, as well as a greater degree of inferior marginal lipping and overall extent of marginal lipping in C3-C5 (Table 5).

Sex differences in cervical osteoarthritis regardless of age (50-76 years)

When all females and males are compared (50-76 years), significant differences exist in marginal lipping of the inferior body for C3-C7, and the extent of marginal lipping for all elements examined, C3-C7 (Table 5). For all significant differences, it is males who show the greater degree of severity when compared to females of all ages. None of the other indicators of osteoarthritis show significant differences between the sexes (Table 5).

DISCUSSION

The goals of this study are to identify whether the expression of osteoarthritic features differ (1) between older (50-55 years) and elderly (70-76 years) adults within each sex; (2) between both sexes of the same age category; and (3) between the sexes regardless of age (50-76 years). Although the results are preliminary given the moderate sample sizes, Mann-Whitney U test results do indicate the existence of age and sex differences. Considering our first question regarding whether the severity of osteoarthritis on the cervical vertebrae C3-C7 increases as a function of age, it appears that elderly males (70-76 years) exhibit a much greater degree of expression than do older males (50-55 years), although for the degree of superior porosity of the corpus and extent of inferior porosity, no difference is observed between the age categories (Table 4). Distinctions in eburnation are particularly marked in elderly (70-76 years) versus older (50-55 years) adult males, observable throughout the cervical skeleton under investigation. For females, eburnation is markedly different only in C3, and older adults (50-55 years) actually exhibit a greater severity than their elderly (70-76 years) counterparts. Specifically, two older adult females (50-55 years) exhibit severe eburnation. One female exhibits evidence of polish/grooving on the inferior facets (grade -2-3) on C3, while on C4 the presence of polish and grooves on the superior and inferior left facets (grade 3) is discerned. Another female presents polish on the superior and inferior right facets with eburnation (grade 3) on C3 coupled with marginal lipping on the facets. In addition, this female exhibits polish in all facets (superior and inferior) with eburnation (grade 3) combined with marginal lipping on C4 and C5.

Although these two cases are extreme, they are part of a pattern in the sample. Nearly half of older adult females (50-55 years) present some polishing (grade 2) at least on one vertebra, and often on several. In comparison, only a single older adult male (50-55 years) exhibits a grade of 3 for eburnation for a single vertebra (C3) and a grade of 2 for C5 whereas all other males are described as a grade of 1 for eburnation. The extent of inferior porosity in older adult females (50-55 years) is also elevated relative to other age/sex classifications. To the degree that cervical osteoarthritis is an indicator of overall stress on the skeleton, it appears that women in the older adult category (50-55 years) led relatively demanding lives, or that secular changes were involved in the expression of eburnation.

The second goal is to investigate sex differences within age cohorts. When older adults (50-55 years) of both sexes are compared, females present a significantly greater severity of eburnation and extent of inferior marginal lipping when compared to males. When elderly adults (70-76 years) of both sexes are compared, males exhibit the greatest severity of marginal lipping. Degree of porosity does not differ between the sexes for either age category.

Considering our third objective, when all adults regardless of age (50-76 years) are examined, males again exhibit the greatest severity of marginal lipping on the inferior body of C3-C7, and extent of inferior marginal lipping of C3-C5 (Table 4). In this study, the sexes do not significantly differ in the degree of porosity and eburnation for either elderly adults (70-76 years) or all adults (50-76 years) suggesting similarities in the aging process between males and females (Snodgrass, 2004).

The cervical skeleton must simultaneously support the static weight and dynamic activity of the cranium. Some have reported a greater severity of osteoarthritis in the lower cervical vertebrae (C6 and C7) compared to the superior ones (Dawson and Trinkaus, 1997; Knüsel *et al.* 1997). However, we note that C3-C5 present a greater number of significant differences between age/sex classifications. Our results show that the expression of cervical osteoarthritis becomes increasingly pronounced over the latter half of the life cycle.

At least part of our sample is likely to derive from laborer-type occupations (Wilson *et al.*, 2007). Osteoarthritis does not seem to directly reflect the extent of loading an individual endures and does not have a good correlation with any particular set of activities (Ortner, 2003). However, stress that occurs early in the life cycle and is extreme for decades often does manifest into osteoarthritis (Weiss and Jurmain, 2007). It appears that farmworkers have

among the highest prevalence of osteoarthritis, perhaps because of an early onset of increased mechanical loading during childhood (Weiss and Jurmain, 2007). However, the individuals in our sample are not very likely to be farmworkers in any consistent fashion and therefore the osteoarthritis observed must be from other types of occupational stress. The degree to which the cervical vertebrae react to occupational stress must also be addressed. Excessive loads carried on the head may result in marginal lipping on the cervical vertebrae (Lovell, 1994). Although such stresses would not be expected in our sample, the differences between older (50-55 years) and elderly (70-76 years) males, and between these age categories in females, is likely to have resulted from loading stress or be a systemic effect of age.

CONCLUSIONS

This study corroborates that cervical osteoarthritis manifested by marginal lipping and porosity is related to the aging processes (Listi and Manhein, 2012; Maat, Mastwijk and van der Velde, 1995; Van der Merwe *et al.*, 2006; Weiss and Jurmain, 2007). Osteoarthritis is observed to occur with greater severity in elderly adults (70-76 years) of both sexes. However, males seem to have deteriorated substantially more between older adulthood (50-55 years) and the elderly period (70-76 years) compared to females. For example, across the cervical vertebrae (C3-C7), eburnation is scarcely observed in older adult males (50-55 years) whereas is significantly more frequent in the elderly category (70-76 years).

However, sex rather than age alone appears to account for the expression of eburnation in our sample. Older females (50-55 years) tend to exhibit moderate to severe eburnation compared to their male counterparts. These differences may derive from hormonal and life cycle differences between the sexes (Hawkes, 2006; Fedigan and Pavelka, 2007; Weiss and Jurmain, 2007) or could have arisen from secular changes introduced during the second half of the 20th century. Besides eburnation and inferior porosity, sex differences are not extreme between older adult females and males (50-55 years).

Among the elderly (70-76 years), males present more severe marginal lipping than do females, although the sexes do not differ in porosity. When adults of all ages (50-76 years) are considered, no sex differences are noted in eburnation and inferior porosity. Finally, cervical osteoarthritic marginal lipping is higher in males than females at all ages (50-76 years) which could be related to the division of labor and the heavy physical activity often observed in males (Van der Merwe *et al.*, 2006; Woo and Pak, 2014) or other factors related to the conditions of life.

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