The Progression of vertebral osteoporosis: the correlations between vertebral pathologies and sociodemographic risk factors

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INTRODUCTION

The identification of vertebral pathologies in human skeletonized remains is difficult. Most of the methods for identifying pathological conditions involve macroscopic assessment and ordinal scoring, or through the use of expensive and potentially destructive processes such as radiographs or genetic testing. However, little is understood regarding the etiology of osteoporosis (OP), osteoarthritis (OA), osteophytosis (VO), Schmorl's nodes (SNs), spondylolysis (SL), spondylolisthesis (SLT), and laminal spurs (LS).

Research on vertebral pathological conditions typically focuses on each pathology independently, or examines the pathologies in relation to one specific sociodemographic factor or related pathology (i.e., Genant *et al.* 1996; Jones and Doherty 1995; Kitahara *et al.* 2013; Knusel *et al.* 1997; Lovell 1994; Plomp *et al.* 2012; Mays *et al.* 2006; Merbs 2001, 2002; Nocak and Slaus 2011; Van Schoor *et al.* 2004; Weiss 2009). Osteoarthritis and VO are often examined together. For example, Van Schoor *et al.* (2004) found that individuals with OP have a higher risk for the development of OA. Additionally, Genant *et al.* (1996) found that postmenopausal women exhibit a higher prevalence for the development of OP; while Mays *et al.* (2006) showed that European populations are more at risk for developing OP than other ancestral groups, for example, African Americans. Jones and Doherty (1995) and Kitahara *et al.* (2013) conclude that OA is more prevalent in females, and that some types of OA are not seen in African Americans due to the high prevalence of bone mineral density in African Americans. Interestingly, Lovell (1994) did not find correlations between age and the frequency of OA or VO. However, Nocak and Slaus (2011) examined SNs, VO, and OA and documented their developmental correlations with age. Knusel *et al*. (1997) concluded that trauma, old age, disease, physical activity, and intrinsic factors cause SNs; while Plomp *et al.* (2012) observed that both sexes were equally likely to develop SNs. Merbs (2002) and Weiss (2009) conclude that SL has a higher prevalence in females, and in young-to-middle-age adults. Merbs (2001) also concluded that SLT is correlated with OA and VO, and that if untreated, SLT can lead to OA in individuals over 40 years old. While previous research has examined correlations between some vertebral pathological conditions as well as with some sociodemographic risk factors, many have produced conflicting results. Thus, this research assesses vertebral pathologies holistically in modern African and European American adults to further explore vertebral pathological etiologies (i.e., age, sex, occupation, and ancestry) and their inter-relationships.

Three hypotheses were examined: (1) that there is a positive correlation between OP and the other vertebral pathologies; (2) that a positive correlation exists between the vertebral pathologies and strenuous occupations; and (3) there are differences in the development of vertebral pathological conditions between African and European American individuals due to the higher level of bone density in African American individuals, and population differences in calcium (Aloia 2008; Stini 1990).

MATERIALS AND METHODS

The seven pathological vertebral conditions and their scoring systems used to explore their relationships to each other and to sociodemographic risk factors are presented in Figures 1-6. The Genant *et al*. (1985), Ubelaker (1999), Stewart (1985), and Merbs (2001; 2002) pathological scoring systems were applied to the vertebrae and compared to the documented sociodemographic records of 238 African (m = 43; f = 11) and European (m = 102; f = 82) American individuals from the William M. Bass Donated Skeletal Collection at the University of Tennessee, Knoxville. The individuals were placed into five-year age groups (20-99 years) and separated by sex for each ancestral group. Occupation was divided into four groups: unknown, labor-intensive (e.g., construction), non-labor intensive (e.g., office clerk and secretarial work), and unemployed. Each of these occupation and age categories, pathological conditions, and other sociodemographic risk factors (i.e., sex and ancestry) were analyzed with multiple Chi-square analyses to determine significant correlations.

Figure 1. Osteoporosis (OP) scoring following Genant *et al.* (1985).

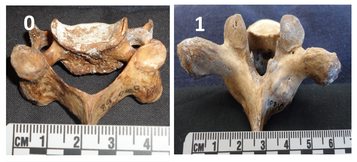

Figure 2. Osteoarthritis (OA) scoring following Ubelaker (1999).

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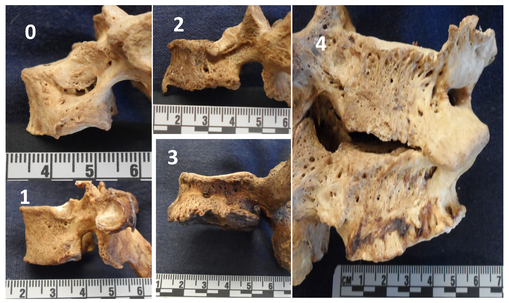

Figure 3. Osteophytosis (VO) scoring following Stewart (1958).

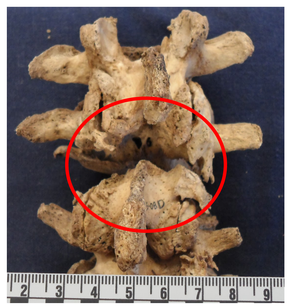

Figure 4. Spondylolysis (SL) scoring following Merbs (2002).

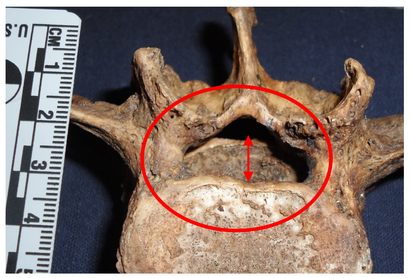

Figure 5. Spondylolisthesis (SLT) scoring methods following Merbs (2001).

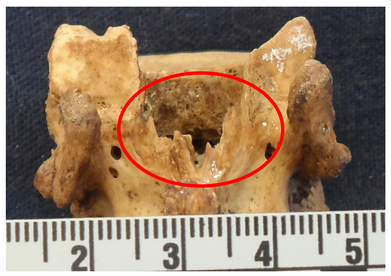

Figure 6. Laminal spurs (LS).

RESULTS

Table 1. Chi-square analyses of vertebral pathological conditions and sociodemographic risk factors (p-values).

	Age	Sex	Ancestry	Occupation
Osteoporosis	0.010 (L3) 40+ years	0.049 (T11) Males	0.000 (T12) European American	0.000 (L1) Labor-intensive
Osteoarthritis	0.001 (L5) 40+ years	0.001 (L4) Females	0.002 (T12) European American	0.014 (L5) Labor-intensive
Osteophytosis	0.000 (L4) 45+ years	0.039 (L4) Males	0.000 (T12) European American	0.001 (L2) Labor-intensive
Schmorl's Nodes	0.001 (T3) 45+ years	0.009 (T9) Males	0.023 (T12) European American	0.003 (T11) Labor-intensive
Spondylolysis	0.932	0.076	0.086	0.506
Spondylolisthesis	0.192	0.001	0.807	0.600
Laminal Spurs	0.008 (L1) 40+ years	0.005 (L3) Male	0.017 (T12) African American	0.032 (L3) Labor-intensive

Table 2. Chi-square analyses of vertebral pathological conditions (p-values).

	Osteoporosis	Osteoarthritis	Osteophytosis	Schmorl's Nodes	Spondylolysis	Spondylolisthesis	Laminal Spurs
Osteoporosis	--	0.000 (T12)	0.002 (T7)	0.002 (T12)	0.003 (T10)	0.007 (L5)	0.004 (T11)
Osteoarthritis	0.000 (T12)	--	0.000 (L5)	0.000 (L3)	0.004 (T1)	0.006 (T9)	0.000 (L3)
Osteophytosis	0.002 (T7)	0.000 (L5)	--	0.000 (L5)	0.269 (T12)	0.023 (T8)	0.017 (L4)
Schmorl's Nodes	0.002 (T12)	0.000 (L3)	0.000 (L5)	--	0.013 (L1)	0.042 (T5)	0.006 (L5)
Spondylolysis	0.003 (T10)	0.004 (T1)	0.269 (T12)	0.013 (L1)	--	0.821	0.009 (L5)
Spondylolisthesis	0.007 (L5)	0.006 (T9)	0.023 (T8)	0.042 (T5)	0.821	--	0.004 (T11)
Laminal Spurs	0.004 (T11)	0.000 (L3)	0.017 (L4)	0.006 (L5)	0.009 (L5)	0.004 (T11)	--

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Figure 7. Example of osteoporosis scores for T12 and ancestry.

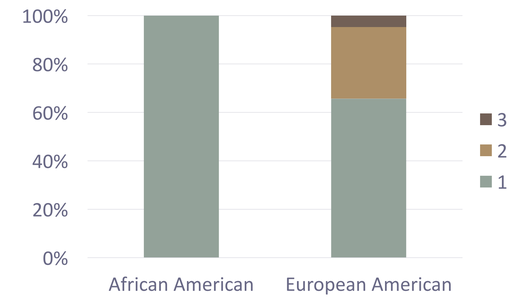
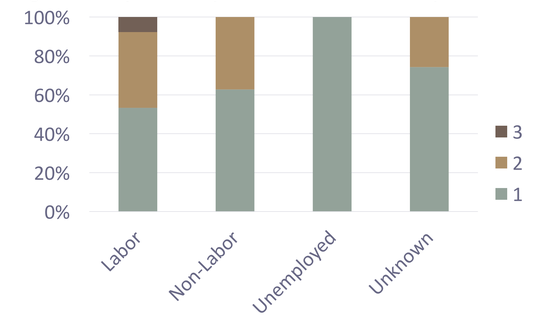


Figure 8. Example of osteoporosis scores for L2 and occupation.



DISCUSSION AND CONCLUSIONS

Overall, the results of this study support the three proposed hypotheses: that there are correlations between OP and other vertebral pathologies; that occupation influences their expression; and that there are ancestral differences in the expression of vertebral pathologies.

Specifically, the results of this study indicate that most of the vertebral pathologies are correlated with sex, age, ancestry, and occupation (Table 1; Figures 7 and 8). Generally, the conditions are more severe with advancing age, with laborious occupations, and in European males. However, SL and SLT are not correlated with increasing age, which is expected since these conditions are generally observed in younger, more active individuals (Merbs 2002; Weiss 2009). Interestingly, only females show an increased prevalence for OA, particularly in L4; however, VO, SNs, SLT, and LS show higher levels in males. Surprisingly, OP did not show a higher expression in females, which was observed in previous research involving postmenopausal women (Genant *et al.* 1996). However, the lack of OP in females in this study may be due to the low number of females in the sample. Additionally, OP, OA, VO, SNs, and LS show higher levels of development among European Americans compared to African Americans. This may be due to increased bone density in African American individuals and population differences in calcium intake (Aloia 2008; Stini 1990). All conditions except for SL and SLT are correlated with laborious occupations such as construction, mechanic, or laborer. However, individuals classified with non-labor intensive occupations still exhibited some level of development of these vertebral pathologies, particularly with advancing age. Moreover, the majority of the vertebral pathologies are correlated with each other (Table 2). Overall, these correlations indicate that many of the vertebral pathological conditions have a higher likelihood of development in individuals who have another vertebral pathology. These correlations additionally suggest that their expressions are influenced by many of the same processes (i.e., advancing age, physical activity and occupation, sex, and ancestry).

Despite the inclusion of 54 individuals of African American ancestry, the available sample was overwhelmingly European American, which is reflective of commonly studied skeletal collections. While the Bass Collection provides detailed records of sociodemographic data, the information is voluntarily provided by the donors and thus is not always complete or accurate. The authors hope to further this research with larger and more diverse collections, including a more equal representation of age, sex, and ancestries, along with sufficient antemortem data to indicate work history and habitual activity. This will provide more accurate results that can pinpoint correlations between vertebral pathological development and sociodemographic risk factors.

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