Biological Profile & Differential Diagnoses for Teaching Skeleton A-16

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Abstract

The examination of the human skeleton can present information about a person, such as age, sex and disease, long after the individual's death. A paleopathological analysis in the biological profile is instrumental to identifying disease, antemortem and perimortem modifications or postmortem changes and with this information, we can build a biological profile for the individual. This research examines the spinal pathology and vertebral trauma for a skeleton from the Department of Anthropology's teaching collection (A-16). Further examination of the vertebral profile provides more information in order to create a differential diagnosis. Although a definitive diagnosis is not made in this article, evidence suggests that subject A-16 suffered from a vertebral compression fracture, transverse process fracturing and characteristics of porosity throughout the axial skeleton that are consistent with severe osteoporosis. This research offers insight into the conditions that lead to various vertebral trauma and those insights provide an opportunity to discuss environmental, cultural or lifestyle circumstances of the case study individual.

Introduction

The creation of a differential diagnosis of pathology on skeletal samples can unveil a catalog of information pertaining to the individual's health, lifestyle, culture and history of trauma. From skeletal remains we can see the potential effects of physical labor (Gerszten et al., 2001) or over-use activity (Foster et al., 1989) and how that can translate in vertebral pathologies

(Lovell, 1994). We can also see osteopathic trauma, including healed and active injuries as well as disease. Disease and trauma of the vertebrae can be particularly influential during skeletal analysis, as the vertebral column displays a series of interesting reactions when faced with distress. The degree of reaction can be as minimal as slight osteophyte formation, which can be defined as bony outgrowth (van der Kraan & van den Berg, 2007), and as severe as complete vertebral fusion, known as Diffuse Idiopathic Skeletal Hyperostosis (DISH). The focus of this research is to conduct an initial visual diagnostic assessment for the subject A-16, catalog all osteological idiosyncrasies, and produce a differential diagnosis, concentrating on the subject's individual vertebrae.

Biological Profile

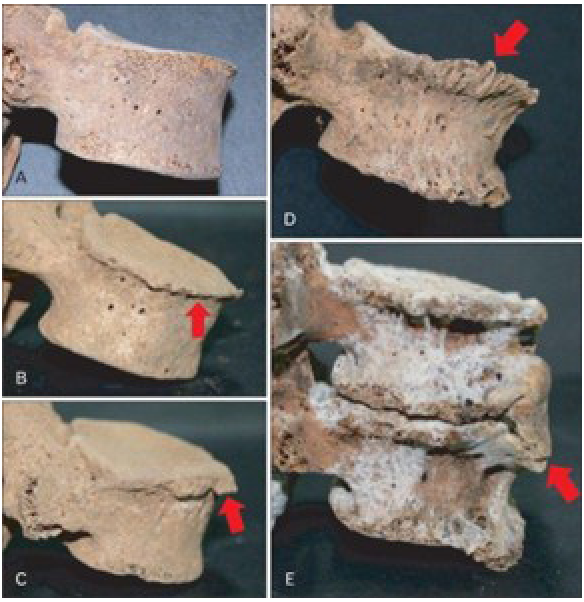
The study subject chosen for this analysis is part of a teaching collection at Florida Atlantic University. During a learning segment, this skeleton was recognized for having specific pathological anomalies that do not exist throughout the complete collection. This study will only provide a differential diagnosis for this specific individual. This subject will be known throughout this research review as A-16, due to the ethical obligation to respect the individual's nomenclature and pronouns used during their life. Efforts are being made to secure accurate information surrounding the acquisition of Florida Atlantic University's teaching skeletons. An ongoing master's thesis (Bunce, personal communication) intends to utilize various bioarchaeological processes, such as dental isotope analysis, to answer biological and ethical inquiries about the origins of these purchased teaching specimens. Because these questions are still being investigated, this research project will use standard methods to present a preliminary assessment for age and sex. The age range at death for subject A-16 is estimated to be 42-45 years using the Suchey-Brooks public symphysis scoring method (1990), and evaluation of the auricular surface of the ilium (Lovejoy et al., 1985a). The sex of A-16 is considered indeterminant based on fluctuating results using methods measuring landmarks of the os coxae, including the ventral arc, subpubic concavity and the ischiopubic ramus ridge (Phenice, 1969) and the greater sciatic notch and preauricular sulcus (Buikstra & Ubelaker, 1994). Additionally, measurements and grading of cranial landmarks, including the nuchal crest, mastoid process, supraorbital sharpness and ridge size and size of mental eminence as recommended in *Standards for Data Collection from Human Skeletal Remains* (Buikstra & Ubelaker, 1994) produced contradictory results. It is relevant to state that A-16 exhibits small skeletal features, inconsistent with the established standards. This type of disparity suggests that the sexual dimorphism of the population from which A-16 originated is inconsistent with the reference populations used to develop the standard techniques utilized in the American bioarchaeological context. Such disparities are suggestive of Asian ancestry (Schmitt, 2004) and while race or national origin is unnecessary to the biological profile, it could be an insight to the possible flaws in the standardized methods.

Diagnostic Data Set

A full skeletal analysis was performed and transcribed into a comprehensive data spreadsheet, with a particular focus on the vertebral column of A-16. The data has been compartmentalized to show bone cell response, state of activity, and condition that is visually displayed, based on a standardized format analysis presented by Owsley et al. (1995). The vast majority of vertebrae exhibited one or multiple osteopathic conditions, including osteophyte formation, as illustrated by Fig. 1.

Figure 1

Visual Example of Osteophyte Formation

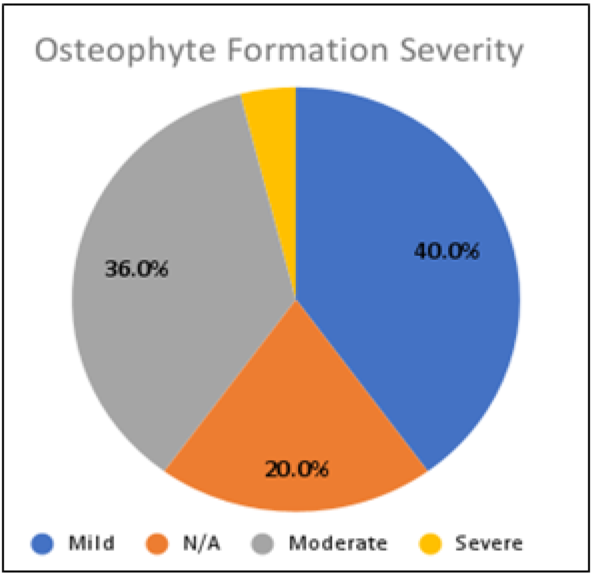


Note. (Kim et al., 2012): A) represents mild to no lipping and osteophyte formation, B) represents moderate formation, C) represents severe formation, D) represents severe formation with lipping and curving, and E) represents fusing of osteophytes of two or more adjacent vertebrae (No cases of D or E are present in subject A-16). This photo is approved to be distributed via Open Access article.

Osteophyte formation was assessed as mild for Cervical vertebrae 1, 2, 6, Thoracic vertebrae 2, 3, 6, 8, 9, 12 and Lumbar vertebra 2, moderate for Cervical vertebra 7, Thoracic vertebrae 1, 4, 5, 7, 11 and Lumbar vertebrae 4, 5, 6 (an additional lumbar) and severe for Lumbar vertebra 3, leaving only five vertebrae without evidence of bone abnormalities (Fig. 2). The osteophytes predominantly concentrated on the centrum with occasional growth on the superior facets of the arch. The centra on Thoracic vertebrae 4, 5, 6, 7, 8 suffer from extreme asymmetry, with the anterior body protruding right. This enigma is only displayed on the mid-late thoracic vertebrae.

Figure 2

Osteophyte Formation Severity of A-16



Note. Mild severity is most occurrent in A-16

Two vertebrae, Lumbar vertebrae 1 and 3, showed evidence of antemortem breaking of the transverse process, both on the right side. Lumbar vertebra 1 exhibited a clear absence of a transverse process with the site presenting as fully healed, indicating that it was broken with enough time to heal and build new cortical bone during the subject's life. Lumbar vertebra 3 exhibited evidence of possible regrowth in the transverse process, with signs of active healing surrounding the distal end of the process. Additionally, Lumbar vertebra 5 is without either transverse process; however, the break likely occurred postmortem; therefore, will not be assessed as pathogenic or traumatic.

In addition to the broken transverse process, Lumbar vertebra 3 suffered a significant compression fracture, whereas the body of the vertebra has collapsed. The centrum indicates active healing surrounding the area with severe osteophyte formation. Thoracic vertebrae 4 and 5 display noticeable active wedging, likely in response to the fracture of Lumbar vertebra 3. The occipital condyles present as asymmetrical and do not align sufficiently with Cervical vertebra 1 with trauma present to the lateral part. This may be the most apparent indication for ongoing spinal distress.

In addition to the vertebral trauma and anomalies, subject A-16 presented a healed fracture on the left rib 12, moderate osteophyte formation on the acromial end of the left clavicle and slight osteophyte formation on the left patella.

Differential Diagnosis

Vertebral Fractures

Before discussing the type of fractures considered for a differential diagnosis, it is imperative to understand possible causes for vertebral trauma. Osteoporosis is a pathological disorder that affects the density and quality of bone and is often the contributing factor for fracturing (Curate et al., 2016). Because the cortical bone becomes thin and porous during the presence of osteoporosis, there is an increased risk of fracture, although the percentage of risk is variable (Ross et al., 1990). A variety of options exist to diagnose osteoporosis including, dual X-ray absorptiometry (DXA), radiogrammetry and ultrasonometry, which provides more qualitative results (Rinaldo et al., 2018). However, with limited access to medical grade technology, a visual assessment was used to determine the level of porosity in subject A-16. During the assessment of subject A-16, osteoporosis is evident throughout the entire vertebral column, concentrated in the thoracic and lumbar region, but not exclusively. Cervical vertebra 6 displays macroporosity, including through the osteophyte formations on the body, an unusual characteristic. Additionally, the weight of long-bones, particularly the tibia and femur, suggest bone density loss throughout the entirety of the body. Subject A-16 was originally hypothesized to be between the age of 42-45 at death and while osteoporosis is classified as a disease that perpetuates with age, the body will eventually reach a peak bone mass (Kralick &

Zemel, 2020), creating a plausible notion that A-16 could have experienced onset osteoporosis, even at an early age.

Figure 3

A-16 Crush Fracture

Note. A-16 Lumbar vertebra 3 with evidence of fracturing

Vertebral compression (crush) fractures are the most common in the archaeological record (Kralick & Zemel, 2020), and the most commonly treated throughout the extant human population. The fracture can occur under simple circumstances, such as hauling lightweight objects, or the trauma can occur under extreme duress, such as a fall. In the case of A-16, the sacrum is in near pristine condition with an intact coccyx lacking any visual irregularities. Sacral fractures and fracture of the coccyx would appear apparent, even as indirect trauma, if the individual suffered from a fall (Lovell & Grauer, 2018). If the fracture in Lumbar vertebra 3 of A-16 is a compression fracture, it is unlikely to have been due to an extreme fall landing on the buttocks or pelvis (Fig. 3).

Genant el al. (1993) created a visual and quantitative system to measure compression fractures for both validity and intensity (Fig. 4). The semiquantitative visual valuation provides comparative illustrations to grade wedge, biconcave and crush deformities: Grade 0: Normal, Grade 1: Mild, Grade 2: Moderate, Grade 3: Severe. A-16 is hypothesized to have a crush compression fracture and based on comparison, Grade 2, moderate, would be assigned. In addition, Genant et al. (1993) propose the collection of coordinates in the anterior, posterior and middle portion of the vertebra body. In their study, the coordinates were calculated digitately from X-ray imaging, then the results were plotted on a scatter graph. Due to the inability to capture images for A-16, a similar, crude, measurement system is used in conjunction with the original proposed formula. Measurements obtained for Lumbar vertebra 3 were performed with a standard manual sliding caliper. The threshold to identify a fracture, in this research review, is a 15% difference from the mean value in the general population (Ross et al., 1992; Genant et al., 1993). Results are as follows (Table 1):

Table 1

Calculations of Anterior, Posterior and Middle Portion of Centrum in A-16

Original Formula:
Anterior-posterior ratio (APR) = h_a/h_p
Middle-posterior ratio (MPR) = h_m/h_p

A-16 Lumbar 3 Dimensions:	**Population Mean (n=5):**
a=6.604cm, p=4.826cm, m=2.286cm	a=6.5024cm, p=6.604cm, m=6.4008cm
APR=1.368 MPR=0.47	APR=0.9846 MPR=0.9692

APR Differential Percentage=-39%
MPR Differential Percentage=51%

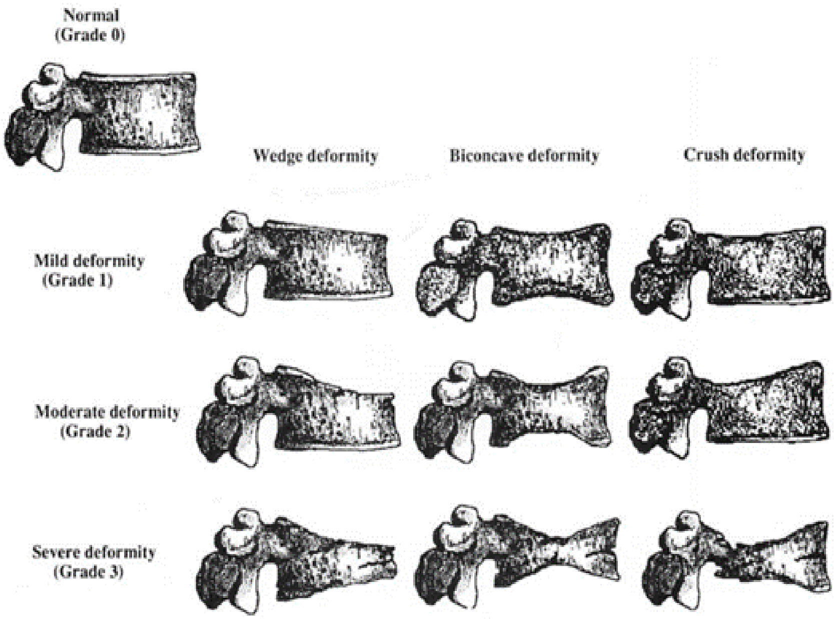
Note. Adapted from (Genant et al., 1993) in order to measure compression fracture.

Similar to the visual evaluation, Genant et al. (1993) provides a grading system [Grade 0: No reduction, Grade 1:

20-25% reduction, Grade 2: 25-40% reduction, Grade 3: 40%+ reduction]. The anterior measurement for the subject's Lumbar vertebra 3 is statistically a healthy range compared to the population surveyed. The posterior and middle region suffer a great deal of reduction due to the compression fracture. The middle-posterior ratio yields a 51% decrease from the population average (Appendix I), providing strong evidence to categorize the trauma as a severe, grade 3, fracture. An increased margin for error (15%) should be considered, due to the experience level of the observer. The measurable outcome differs from the original assessment and will be considered subsidiary information. Based on the analysis using the Genant et al. (1993) techniques, the fracture in Lumbar vertebra 3 of A-16 can be identified as a grade 2, moderate crush fracture.

Figure 4

(Genant et al., 1993) Semiquantitative Visual Grading of Compression Fracture



Note. Genant et al. (1993) Visual compression fracture guide to assess type of deformity and severity of deformity.

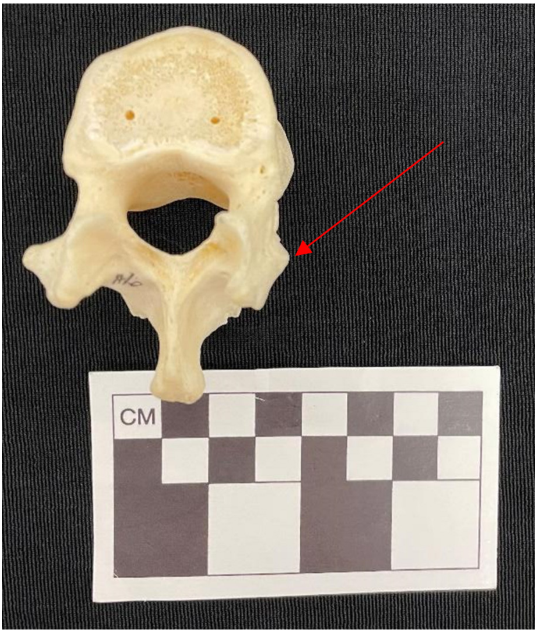
Transverse Process Fractures

Extreme forces are needed in order to fracture the transverse process of the lumbar vertebrae (Krueger et al., 1996). A significant collision, elevated fall, damage to the pelvis or other direct blunt trauma can cause transverse process breakage (Krueger et al., 1996; Miller et al., 2000).

The fracturing of the transverse process is closely connected to the suffering of internal abdominal damage, primarily targeting the liver, kidney and spleen. (Miller et al., 2000). In modern study, athletes who participate in contact sports, such as football, are often missing one or several transverse processes (Brynin & Gardiner, 2001). Subject A-16 displays two incidents of complete elimination of the transverse process, on Lumbar vertebrae 1 and 3. Both sites appear healed with new cortical bone in place. Lumbar vertebra 3 exhibits possible regeneration of the transverse process or indication that the break occurred more laterally, compared to Lumbar vertebra 1. Several case studies show the fracturing of the transverse process as a simple or greenstick fracture, which can be described as a bend on one side rather than a complete break, and the trauma appears to be isolated (Agrawal et al., 2009). A-16 clearly suffered a traumatic injury that caused an absolute removal of the transverse process in multiple areas (Fig. 5).

Figure 5

A-16 Missing Transverse Process

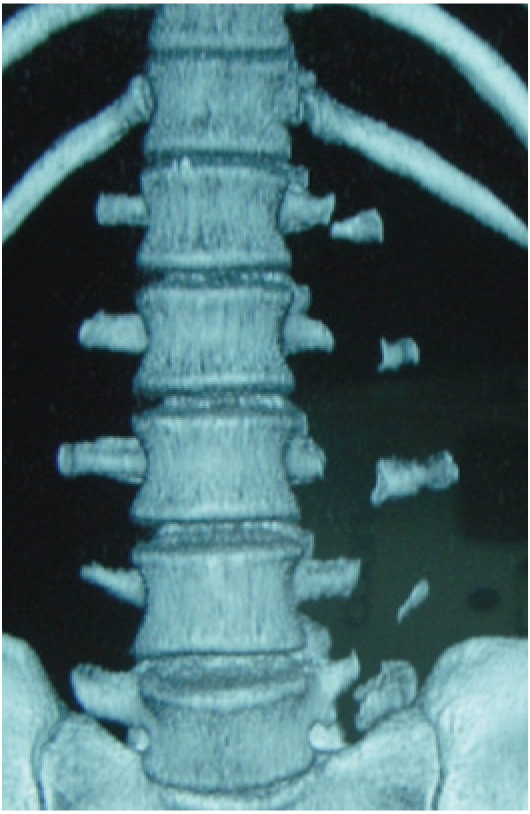


Note. A-16 Lumbar vertebra 1 without right transverse process.

A study of multiple level transverse process fractures has identified completed breakage, similar to A-16, in a young, active cricket player (Bali et al., 2011) (Fig. 6). The timescale and ancestry for A-16 is unknown, but A-16 is believed to be a modern individual and the suggestion for athletic participation is plausible. In archaeological record, examples of fractured transverse processes are often accompanied by the hypothesis for domestic or child abuse (Wheeler et al., 2013; Padgett & Jacobi, 2015), due to the increased and sporadic amount of trauma present on the population being studied. The overall trauma present in A-16 is minimal compared to the studies regarding abuse; therefore, it is believed to be incidental and in conjunction with other diagnoses.

Figure 6

Example of Transverse Process Fracturing



Note. (Bali et al., 2011): Anterior view of transverse process fracturing in a twenty-six-year-old cricket player. This photo is approved to be distributed via Open Access article.

Diffuse Idiopathic Skeletal Hyperostosis (DISH)

Diffuse Idiopathic Skeletal Hyperostosis is a condition, usually associated with joint disease, such as osteoporosis, that affects the anterior spinal ligaments and subsequently, the bone making up the vertebral column. If DISH is present, the vertebrae will display a "melting" or "dripping candle wax" appearance (White et al., 2012), due to the ossification of the individual vertebrae. Additionally, DISH most predominantly affects the mid-lower thoracic vertebrae, with little effect on the lumbar region (Rogers & Waldron, 2001). The extra bone formation can be severe, but the condition is recognizable as it does not affect the sacroiliac joints or articular facets (Verlaan et al., 2007), usually associated with other degenerative disorders. Subject A-16 displays no visual indication that DISH could be prevalent in the vertebrae or in the appendicular skeleton. The subject's vertebrae, while exhibiting osteophyte formation, does not appear to be fusing together. Additionally, the osteophyte formation is not solely concentrated toward the anterior portion of the centrum, a key marker for a DISH diagnosis. Finally, the vertebral trauma for A-16 is intensified in the lumbar vertebrae.

Ankylosing Spondylitis

Ankylosing spondylitis is a common rheumatic disease that primarily affects the joints and tendons of the spine (Braun & Sieper, 2007). Low bone density is typically concurrent with Ankylosing Spondylitis, especially in the lumbar region. Similar to the overreaction of the joint trauma found in cases of DISH, ankylosing spondylitis causes the vertebrae to fuse together. Although the reaction and initial appearance is similar to DISH, the sacroiliac joint and articular facets are not preserved in cases of ankylosing spondylitis (Schwartz, 2007). A-16 does not present severe vertebral fusion; therefore, Ankylosing Spondylitis can be dismissed as a reasonable diagnosis.

Schmorl's Node

Schmorl's node is the herniation of the nucleus pulposus, the inner core of the vertebral disc (Schmorl & Junghanns, 1971, as cited in Kyere et al., 2012). The herniation creates a depression in the vertebral body (Schwartz, 2007), visually akin to notches carved from Swiss cheese. Schmorl's nodes are generally common, asymptomatic and have been shown to resolve over time. The pathogenetic reason for the occurrence of herniation is unknown as many researchers theorize everything from degenerative disease to vertebral disc deterioration (Kyere et al., 2012).

Studies of Schmorl's node have found the occurrence to be most common in the lower thoracic region. (Kyere et al., 2012). Hilton et al. (1976) finds distribution of the Schmorl's node in the Dorsolumbar region but primarily in lumbar 1. Upon immediate view of subject A-16, the trauma displayed on Lumbar vertebra 3 could be interpreted as Schmorl's node. However, the indentation produced from a Schmorl's node is distinct and presents as "delicate", unlike the crude permeation from a compression fracture. Additionally, based on previous research studies, the condition is unlikely to be found as low as Lumbar vertebra 3 on the vertebral column.

Metastases

Vertebral trauma can be indicative of a multitude of ongoing ailments, including metastatic disease. Metastases are malignant growths that can occur in the skeletal system when internal organs, such as the breast, lungs or kidneys are affected by cancer. Fracturing of the vertebrae can be a subsequent reaction to the presence of metastases and, unfortunately, can appear identical to "spontaneous compression fractures'' in standard radiographic imaging (Cicale et al., 2013). Magnetic resonance imaging (MRI) technology is helpful to show the difference between benign fracturing and malignant trauma. A differential diagnosis from Cicale et al. (2013) concludes that MRI imaging can show specific characteristics for osteoporotic vertebral compression fractures, such as ordinary bone marrow signaling and the presence of split (retropulsed) fragments. Metastases can affect other areas of the body, including the pelvis and femur (Rybak & Rosenthal, 2001). The ability to determine whether the lumbar compression fracture present in A-16 is caused from metastases rather than an osteoporotic disorder or physical injury is futile without professional imaging, potential biopsy and further examination. Additionally, the os coxae and both femurs do not present visual cause for pathological concern in subject A-16. The potential hypothesis for metastasis will remain as indeterminate.

Tuberculous Spondylitis

Tuberculous of the spine, or Pott's disease, is the distribution and emergence of *Mycobacterium tuberculosis* into the vertebral column. Many times, Pott's disease is not considered in the initial diagnosis for trauma of the vertebrae as it can be difficult to decipher (Morse, 1978 as cited in Schwartz, 2007). The presence of Tuberculous in the spine can cause bone loss and collapse of the vertebra and the process of regeneration will not occur. Because A-16 demonstrates healing in the fractured areas, Tuberculous Spondylitis may be eliminated from possible diagnosis. However, access to MRI imaging would aid in determining the level of bone loss throughout the individual vertebra.

Other Pathology

Asymmetry of the Skull

A-16 presents explicit evidence of irregularity in shape of the skull, of occipital condyles, as well as bone degradation in the lateral part of the occipital region. The superior articular facets of Cervical vertebra 1 do not articulate with the occipital condyles comfortably. This deformity merits further consideration as the cause for the copious traumas to the vertebrae. Little research and few case studies have been presented for abnormal characteristics in the occipital condyles (Das et al., 2006), although the few that are offered indicate the hypothesis for developmental defects. The suggestion of a developmental abnormality certainly aligns with the evidence presented in A-16, specifically concerning the asymmetrical shape of the cranial vault and base. Many major deformities of the skull occur during subadult development and the severity of the asymmetry can denote a possible pathological condition (Russo & Smith, 2011).

Craniosynostosis is a prevalent disorder that causes asymmetry in the skull due to the premature fusion of cranial sutures (Tubbs et al., 2012). The degree of irregularity in the skull of A-16 could indicate mild and non-symptomatic craniosynostosis. Blunt force trauma to the skull could also result in cranial trauma and a possible domino effect along the vertebral column. A-16 lacks evidence of concentric fracturing or internal beveling of the skull, often correlated with blunt force trauma impact (Berryman & Haun, 1996). Because the cervical vertebrae, other than mild osteophyte formation, present as well preserved and without evident trauma, the abnormalities displayed in the occipital condyles and asymmetry of the skull may be a separate issue. There is no clear indication to postulate a conjunction between the idiosyncrasies of the occipital condyles and the trauma in the lumbar vertebrae.

Conclusion

Subject A-16 exhibits significant evidence of trauma, particularly throughout the vertebrae and calvarium. Although osteoporosis and age-based compression fractures are most commonly to blame for vertebral trauma in skeleton collections, a necessary differential diagnosis has been evaluated, as a result of ample and thorough research. I provide the following reasonable diagnosis: The asymmetry of the skull is not likely affiliated with the trauma present in the mid-lower vertebrae. The irregular shape likely comes from a developmental defect of abnormal fusion of the sutures. The occipital condyles may have incurred trauma due to the skull asymmetry as the weight would be unevenly distributed atop Cervical vertebra 1. Lack of evidence for blunt force trauma is indicative of a developmental diagnosis. A-16 has several areas of concern along the vertebral column. Two diagnoses are offered, as the circumstances of fracturing appear isolated. Nearly the entire collection of vertebrae suffers from mild to moderate osteophyte formation and severe osteoporosis. This is consistent with the general state of the rest of the appendicular and axial skeleton. The compression fracture located on lumbar 3 is likely due to the decreased density of the vertebral bones. In cases of noticeable osteoporosis, compression fractures are common and can occur even under low-impact circumstances. The subject was initially assessed to be between the age of 42-45, and although it is not unheard of for that age group to experience osteopathic disease, the level of porosity is concerning. During the original analysis, the cranial suture closures indicated an age of 42-60 based on the *Standards for Data Collection from Human Skeletal Remains* (Buikstra & Ubelaker, 1994). As a result, because A-16 displays heightened porosity, we may want to consider an age range of 42-60, although many factors can influence osteoporosis. Further research into the origin of this individual will allow for biocultural factors to be considered. The transverse process fracturing appears to be a separate pathological outcome from the compression fracture in Lumbar vertebra 3. Although the breakage takes place in the same region, the situation of association is improbable. It takes considerable force to incur a clean break of a transverse process, especially on the lumbar vertebrae. Because A-16 is in relatively healthy condition, with minor trauma in rib 12 and left clavicle, abuse or disenfranchisement as causes are unlikely. A-16 is a modern individual, however, and could be susceptible to an athletic lifestyle. Athletes, particularly participating in contact sport, are seemingly more prone to fracturing of the transverse process. The images provided by Bali et al. (2011) appear most similar to the condition of A-16. Because the processes are in a fully healed state, it may indicate reason to believe that the trauma is more mature, especially compared to the healing condition of the compression fracture. A-16 may have endured sports-related injuries during a young adult stage, providing an adequate timeline for the processes to undergo relatively refined mending. Finally, as mentioned in the review, X-ray and MRI imaging is suggested for the entire vertebral column in order to capture potential disease imperceptible through visual diagnosis. The results presented in this research only cover a fraction of potential pathological conditions affecting A-16. Many factors lead to a diagnosis; however, we can only draw some basic conclusions as there are many things still unknown. This study intends to provide insight into life history information and offer interpretations of pathological anomalies to aid in future academic analysis and understanding. Further biocultural analysis that draws on the social history of A-16 could benefit this case study, strengthening or adjusting the diagnosis.

Appendix I

	Anterior Measurement	Middle Measurement	Posterior Measurement
A-15	6.35cm	6.35cm	6.604cm
A-13	7.112cm	7.112cm	7.112cm
A-11	6.604cm	6.604cm	6.858cm
A-1	5.842cm	5.588cm	6.096cm
A-17	6.604cm	6.35cm	6.35cm

The population measured above includes individuals available to reviewer in an academic setting. The sex, age and ancestry for the above are unknown and may share no commonalities with A-16. The above population was measured for technical practice.

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