Extracapsular fracture of the femur in an elderly male from the Church of *Nossa Senhora da Anunciada* (Setúbal, Portugal)

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ABSTRACT

In modern populations, hip fractures in older people are associated with high morbidity and mortality. Their incidence is rising; notwithstanding, fractures of the proximal femur are still relatively uncommon in archeological contexts. This case study represents a well-healed hip fracture in an aged male skeleton from Church of *Nossa Senhora da Anunciada* (16th – 19th centuries AD) in Setúbal (Portugal). The individual was also diagnosed with diffuse idiopathic skeletal hyperostosis. Fractures of the proximal femur are usually associated with bone loss but in this case other causes are proposed, including the anatomy of the proximal femur, and the potential combined effect of diffuse idiopathic skeletal hyperostosis, cardiovascular disease, diabetes mellitus and falls.

Keywords: hip fracture; trauma; DISH; bone formers; paleopathology

INTRODUCTION

Fragility fractures are a major cause of morbidity and mortality, eliciting significant social and economic costs (Ström et al., 2011). Hip fractures account for less than 20% of all osteoporotic fractures but yield the most tragic consequences, including increased morbidity and mortality (Johnell and Kanis, 2006). In general, hip fractures are a consequence of osteoporosis, aging and augmented probability of falling among the elderly, affecting aged individuals of both sexes, but typically older women (Cauley et al., 2008; Johansson et al., 2009). Intracapsular fractures occur within the hip joint capsule, above the trochanters; and extracapsular fractures take place distally from the hip joint capsule (Nolla and Rozadilla, 2004).

Hip fractures undoubtedly affected individuals in past communities, but they were a comparatively

infrequent health problem (Curate, 2014). Examples from historical contexts provide a clearer picture of the complications caused by these fractures, including disability, community support and death (e.g., Bartonícek and Vlcek, 2001; Curate et al., 2010; Dequeker et al., 1997; Lovell, 2016; Mays, 2006). The frequency of hip fractures in the past is still unclear (Curate et al., 2011; Ives et al., 2016); but the prevalence of osteoporotic fractures in historical communities show geographical and chronological variations instead of homogeneous patterns of low frequency (Curate, 2014). Previous studies have confirmed the occurrence of hip fractures in Portuguese archaeological samples since at least the Late Neolithic (Curate et al., 2010; Curate et al., 2011).

In this case study, we describe and contextualize an extracapsular fracture of the femur in an older man, also diagnosed with diffuse idiopathic skeletal hyperostosis (DISH), from the Church of *Nossa Senhora da Anunciada* (16^{th} – 19^{th} centuries AD) in Setúbal, Portugal.

MATERIALS AND METHODS

Nossa Senhora da Anunciada was located outside the medieval defensive walls of Setúbal (Portugal) and inhabited by a population of low socioeconomic status, particularly fishermen. The associated churchyard was used between 1531 and 1839 AD (Neto, 2010). Individuals were usually inhumed in dorsal decubitus (supine) position with a NE–SW orientation. Each grave contained more than one individual: the constrained funerary space pressed grave reutilization. Coffin use was only detected in the burials of two adult males, including the case presented here (Antunes-Ferreira, 2015). Ninety-three individuals were exhumed: 82 adults (26 males, 47 females and 9 of unknown-sex) and 11 non-adults.

The focus of this case study is the skeleton of individual 8. The skeleton was almost complete and well preserved (Figure 1). Sex was estimated from the morphological features of the skull and pelvis (Buikstra and Ubelaker, 1994; Bruzek, 2002), and femoral bone dimensions (Curate et al., 2017; Table 1), suggesting a male. The individual was probably older than 50 years: the analysis of the sternal end of the 4^{th} rib points to an age interval of 54– 64 years (Isçan and Loth, 1984), and the estimation based on the auricular surface metamorphosis points to an age above 50 years (Lovejoy et al., 1985). The physiological length of the left femur (477 mm) indicates an estimated height of 174 cm (Mendonça, 2000). Digital radiographic analysis of both femora (35 kV, 10.9 mA) and the left second metacarpal (28 kV, 20.0 mA) was performed. The cortical index (MCI) at the second metacarpal midpoint was estimated according to Ives and Brickley (2004) and the Z-Score was calculated comparing the obtained value with the sample mean for older individuals provided by Umbelino et al. (2016). Diagnosis protocol for osteoarthritis followed Buikstra and Ubelaker (1994), and Rogers and Waldron (1995). The general paleopathological analysis followed the recommendations provided in standard textbooks (Buikstra and Ubelaker, 1994; Ortner, 2003; Roberts and Manchester, 1995).

RESULTS

Individual 8 presented a well-healed fracture of the right proximal femur. Macroscopic observation revealed a lesion in the intertrochanteric ridge with new bone deposition, and shortening and posterior rotation of the femoral neck (Figures 2 and 3). The radiograph shows increased opacity in the intertrochanteric region. Secondary alterations include the overall shortening of the femur (a difference of 0.7 cm), extensive bone formation in the insertion site at the lesser trochanter and osteoarthritis in the right acetabulum. The described fracture is consistent with an extracapsular fracture of the hip, of the intertrochanteric type. There is no evidence of trauma in the remaining skeleton. MCI for individual 8 was 59.48 (Z-Score: 0.618).

In the appendicular skeleton, osteoarthritis was identified in the right shoulder, right acromioclavicular joint, both sides of the hip, and several vertebrae. The ossification of the anterior longitudinal ligament on the right anterolateral aspect of the thoracic spine involving four vertebrae and exuberant peripheral ossifications at entheseal sites (including bilateral lesions at the insertions of *triceps brachii*, *biceps brachii* and *soleus*, and also at the *rectus femoris*, *intermedius vastus*, *obturator externus*, *gluteus minimus*, *gluteus*

medius and *piriformis*) are compatible with a diagnosis of DISH (Figure 4) (Ortner, 2003; Waldron, 2008).

DISCUSSION

Hip fractures are frequently an outcome of bone loss and augmented risk of falling among the elderly, affecting aged individuals of both sexes (Cauley et al., 2008; Johansson et al., 2009). Other risk factors include abnormal bone geometry and quality, and stature (Navega et al., 2013; Sievänen et al., 2007). Osteoporosis and bone loss are major risk factors for hip fractures but, as suggested by metacarpal radiogrammetry, this individual did not show bone loss.

This individual was probably affected by DISH, a systemic disorder of indefinite etiology possibly related to metabolic, genetic, environmental, and endocrinological factors (Sarzi-Puttini and Atzeni, 2004). The main manifestation of DISH is ligamentous ossification of the anterolateral aspect of the vertebral column, sometimes leading to bony ankylosis, and probably epitomizes an extreme point of bone forming (Kiss et al., 2002; Waldron, 2008). DISH is more prevalent in males and older individuals, and people of higher status, which is congruent with the paleodemographic profile of individual 8. Interestingly, the disease is related with a higher prevalence of vertebral fractures, even if the values of bone mineral density in DISH patients are above the average (Diederichs et al., 2011).

DISH is associated with obesity, augmented incidence of risk factors for stroke and other cerebrovascular diseases (CVD), and diabetes mellitus (Coaccioli et al., 2000; Mader et al., 2004; Miyazawa and Akiyama, 2006), which in turn are associated with the risk of falling and hip fractures (Durão et al., 2018; Fan, 2016; Mitchell et al., 2015; Sennerby et al., 2009). The mechanisms accountable for the association between CVD, diabetes and hip fractures include an increased fall risk (Fan, 2016; Sennerby et al., 2009).

Stature and proximal femoral geometry have been identified as risk factors for hip fractures (Navega et al., 2013; Sievänen et al., 2007). Measurements of the proximal femur show that the length of the femoral neck (neck axis length, NAL) of individual 8 was significantly larger than the average values in two Portuguese reference skeletal samples (Curate et al., 2017). Some epidemiological studies have found that a larger NAL is associated with increased fracture risk (Gregory and Aspden, 2008).

Individual 8 was buried at a churchyard mostly used by fishermen and their families. Fishing is a hazardous occupation with a higher than average risk of injury, including fractures (Matheson et al., 2001). As such, occupational trauma cannot be discarded.

Extracapsular fractures involve females more often, but older males are also affected – as observed in other archaeological cases (e.g., Curate et al., 2011; Ives et al., 2016). In both epidemiological and archeological studies, intracapsular fractures are usually more common than extracapsular fractures (Ives et al., 2016; Zhang et al., 2000).

Fractures of the proximal femur motivate a series of harmful health consequences including pneumonia, heart failure, and poor functional outcomes (Durão et al., 2018; Lowe et al., 2010). Post-fracture mortality due to extracapsular fractures is higher, with one-year mortality rates reaching 30% (Cenzer et al., 2016; Nurmi et al., 2003). Mortality due to hip fractures in the past would be even greater (Brickley, 2002), but healing was not uncommon (e.g., Curate et al., 2010; Curate et al., 2011; Dequeker et al., 1997; Ives et al., 2016; Lovell, 2016). The extensive bone remodeling at the fracture site suggests that individual 8 survived for at least several months after the traumatic event. Hip fractures promote total or partial incapacity of the affected limb, enduring impairment, quotidian activity limitations, and prolonged institutionalization (Cenzer et al., 2016). As such, fracture healing and long-term survival are signs of community supportive care, at least during convalescence, as hip fractures are potentially disabling incidents that hinder the execution of basic daily-life activities. Caregiving behavior related to hip fracture is also recognized in other archaeological contexts (Curate et al., 2010; Curate et al., 2011; Ives et al., 2016; Lovell, 2016).

CONCLUSIONS

Hip fractures are still considered uncommon in archeological samples, but recent paleopathological studies suggest that hip fractures were moderately frequent in past populations. Hip fractures are usually associated with aging and low bone mass but in this case other etiological factors could have been involved, including proximal femur geometry, and the possible synergistic association between DISH, cardiovascular disease, diabetes and falls.

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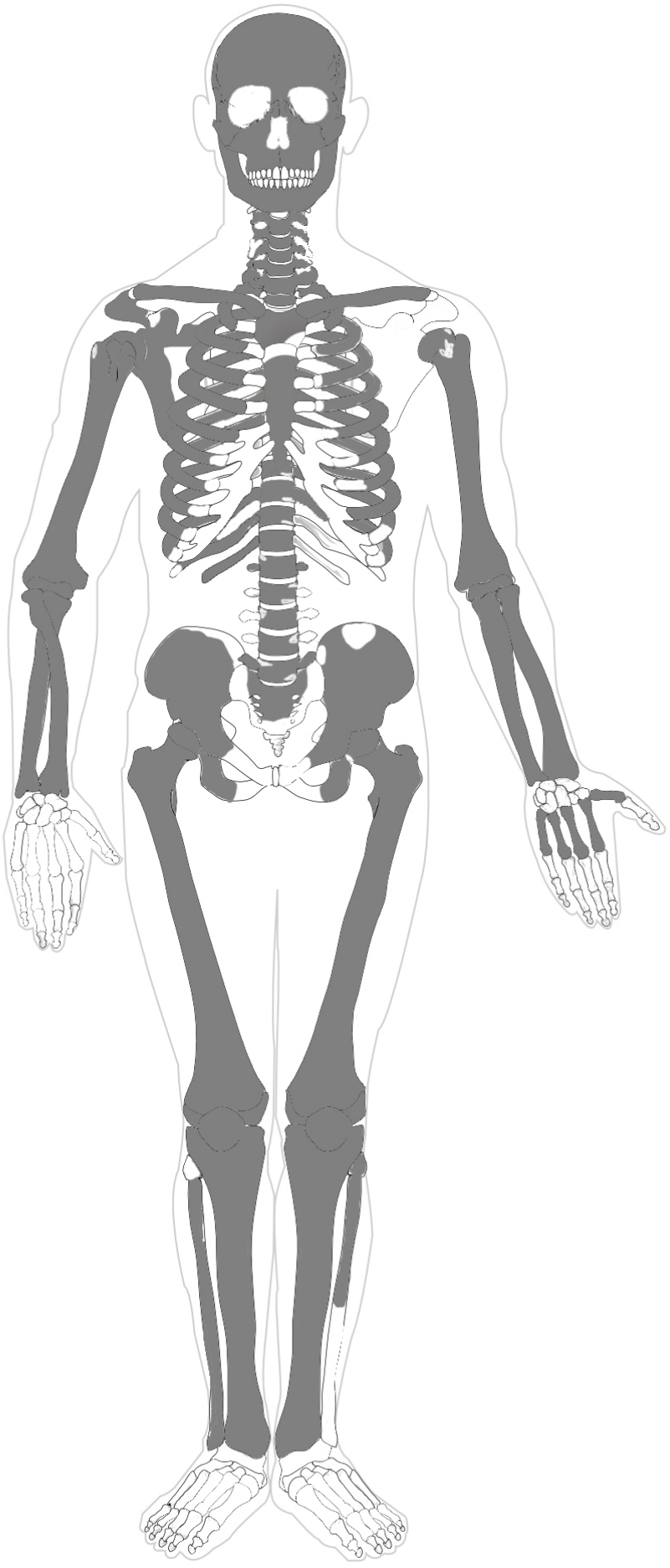
FIGURES CAPTIONS:

Figure 1: State of preservation of the skeleton of individual 8 (areas shaded in grey are present and complete).

Figure 2: Right femur of individual 8 with an extracapsular fracture (a, c) and left femur (b, d).

Figure 3: Plain radiograph of the right proximal femur. Note the augmented opacity at the intertrochanteric region.

Figure 4: Diffuse idiopathic skeletal hyperostosis in the thoracic vertebrae of individual 8. Note the amount of hypertrophic bone formation that led to ankylosis.




A
B
C
D

Table 1: Femoral measurements (in mm) of individual 8 (church of *Nossa Senhora da Anunciada*, Setúbal, Portugal).

Femoral measurement	Left femur	Right femur
Maximum length	479.0	472.0
Physiological length	477.0	469.0
Neck axis length	102.9	---
Biomechanical neck length	85.2	---
Neck height	33.0	---
Neck breadth	27.2	---
Vertical head diameter	47.4	---
Transverse head diameter	48.6	---
Anteroposterior subtrochanteric diameter	32.2	---
Mediolateral subtrochanteric diameter	33.4	---