Hip fractures in the Portuguese archaeological record

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Abstract　Fractures are ubiquitous in the archaeological record but the majority of these are the consequence of a traumatic incident and do not reflect any loss of strength inherent to the bone. So-called fragility fractures, particularly hip fractures, are considered uncommon occurrences in skeletal populations from the past. Nevertheless, evidence of this type of fracture in the archaeological record is increasing. A methodical search for possible hip fractures in the excavation reports, theses and monographs housed in the Department of Anthropology of the University of Coimbra presented an occasion to describe six hip fractures, previously unpublished, from different Portuguese archaeological sites and to challenge the widespread assumption that hip fractures were nearly non-existent in the past.

Key words: hip fracture, proximal femur, palaeopathology, Portugal

Introduction

The overall fracture pattern in the population is bimodal, with peaks in the younger and geriatric groups. The fractures responsible for the late peak are often considered 'osteoporotic fractures,' 'fragility fractures,' or 'J-Type fractures' (Melton, 1995; Strømsøe, 2004). These fractures are distinguished epidemiologically by representative characteristics, specifically: connection with moderate trauma at sites containing significant quantities of trabecular bone; incidence rates that increase with age; and prevalence is higher among females than males (Melton, 1995). Osteoporotic fractures are usually associated with a fall to the floor from a standing height (Kannus et al., 1996).

It is widely accepted that osteoporosis is the main cause of reduced bone strength, and epidemiological data indicate that low bone mineral density (BMD) values are related with an increased risk of fraction at the population level (Melton, 1995; Marcus, 1996; Grynpas, 2003; Strømsøe, 2004; Sievänen et al., 2007).

The worst complications resulting from osteoporosis are fractures of the hip, or fractures of the proximal femur, which contribute disproportionately to the cost, morbidity and mortality attributable to osteoporosis among the elderly (Melton et al., 2003; Nurmi et al., 2003; Mukamal et al., 2007). Such a medical incident can promote a succession of detrimental health consequences including infection, pneumonia, depression, heart failure, and functional dependency (Magaziner et al., 2000; Roche et al., 2005; Lenze et al., 2007; Radley et al., 2008). Between 12% and 32% of all individuals who suffer a hip fracture will perish within 1 year

(Cummings et al., 1985; Nurmi et al., 2003; Roche et al., 2005), but the excess mortality due to hip fracture varies with age and sex (Melton, 1995). Increasingly, people who experience hip fracture become institutionalized after acute treatment in hospital (Radley et al., 2008).

Hip fractures were clinically recognized in the 16th century by Ambroise Paré (1575). His account of a patient with an intracapsular fracture of the neck of the femur was the earliest case ever to be published in a medical textbook. Although Paré was the first to describe fractures of the hip, it was Sir Astley Cooper (1822) who added the classic discussion of its main problem, the circulation of the femoral head and the condition of what subsequently became recognized as its vascular necrosis. During the 19th century, textbooks by Malgaigne (1842), Smith (1847), Hamilton (1860), and Stimson (1883) made significant advances in the description of the pathological appearance of hip fractures and provided the first statistical data with reference to this type of fracture in the clinical literature.

Fractures are omnipresent in paleopathological reports (e.g. Lovejoy and Heiple, 1981; Grauer and Roberts, 1996; Lovell, 1997; Judd and Roberts, 1998; Alvrus, 1999; Jurmain, 1999; Neves et al., 1999; Domett and Tayles, 2006; Djurić et al., 2006; Mitchell, 2006) but the majority of them are the result of a traumatic episode and do not reflect any frailty intrinsic to the bone itself (Dequeker et al., 1997). Fragility fractures, specifically hip fractures, are regarded as unusual occurrences in archaeological skeletal material (Ortner, 2003; Agarwal et al., 2004). A few years ago, Brickley (2002) stated that there were only two published cases of hip fracture in archaeologically derived bone, one from Roman Britain (Roberts and Manchester, 1995) and another from 12th dynasty Egypt (Dequeker et al., 1997), but evidence of fracture of the proximal femur in the archaeological record is growing (e.g. Stroud and Kemp, 1993; Bartonícek and Vlcek, 2001; Campillo, 2001; Ibáñez, 2001; Ferreira and Silva, 2002; Mays, 2006; Buzon and Richman, 2007; Salter-Pedersen, 2007; Ives, 2007; Curate et al.,

2010). These studies imply that this was undeniably an existing condition in past populations. In addition, Mensforth and Latimer (1989) and Curate (2009) showed that the prevalence of hip fractures in the older adults of the Hamman-Todd and the Coimbra skeletal collections, respectively, is fairly comparable to that found in modern epidemiological studies.

Previous studies by Ferreira and Silva (2002), Garcia (2007), Curate (2009), and Curate et al. (2010) confirmed the existence of hip fractures in Portuguese skeletal material since at least the 11th century, but had a limited scope of analysis, both geographically and chronologically. This study aims to collect original information on hip fractures in the Portuguese archaeological record through a careful revision of several previously unpublished palaeodemographic and palaeopathological reports and to challenge the common perception that hip fractures, related or not with bone loss, were nearly absent in past populations.

Materials and Methods

This investigation followed two complementary procedures: (1) excavation (field and laboratory) reports, theses, or unpublished monographs housed in the Department of Anthropology of the University of Coimbra were scrutinized with the purpose of identifying proximal femur fractures; and (2) potential hip fractures were confirmed (or not) by actually observing the affected bones.

Individuals suspected of having a hip fracture were subject to detailed macroscopical examination, and fractures documented according to clinical protocols (Riggs and Melton, 1986; Nolla and Rozadilla, 2004). Fractures that occurred above a point 5 cm underneath the distal part of the lesser trochanter up to the head of the femur were considered hip fractures (Gillespie, 2001; Nolla and Rozadilla, 2004). There are several categorization schemes for these fractures. Typically, they are classified according to anatomical location: intracapsular or extracapsular (Canale, 1998; Pervez et al., 2002; Brunner et al., 2003). Intracapsular fractures (also known as cervical fractures or fractures of the neck of the femur) occur inside the hip joint capsule, above the lesser and greater trochanters (Nolla and Rozadilla, 2004). Extracapsular fractures (also named as trochanteric or pertrochanteric fractures) occur distal to the hip joint capsule. They can be intertrochanteric or subtrochanteric. In intertrochanteric hip fractures, the fracture line commences at or near the lower part of the junction of the neck and shaft, and goes through the greater and the lesser trochanters. Subtrochanteric fractures occur at the region between the lesser trochanter and a point 5 cm distal (Gillespie, 2001; Nolla

and Rozadilla, 2004; Lee and Ertl, 2008). These fractures are also categorized according to severity and degree of stability; the Garden classification is an emblematic model (Canale, 1998).

When possible the crude prevalence (i.e. the proportion of fractures in the total number of individuals) and true prevalence rates (i.e. the proportion of fractures in the total number of femurs of the same side of the fracture) of hip fractures in the analysed samples were calculated (for adult individuals only).

Additional radiographic analyses were made in Coimbra University Hospital.

Results

A systematic search for potential fracture of the proximal femur in the excavation reports, theses, or unpublished monographs housed in the Department of Anthropology of the University of Coimbra provided an opportunity to describe seven hip fractures, previously unpublished, from six different archaeological sites.

Case 1: The *tholos* of Paimogo I (3000–2500 BC)

The *tholos* of Paimogo I (Lourinhã, central Portugal), a collective burial from the Late Neolithic, was discovered in 1968. The subsequent excavation of this vaulted chamber grave rendered at least 413 individuals, including 290 adults. Despite the fairly good state of preservation, the human bones were found highly disturbed, and without anatomical connections (Silva, 2002, 2003).

An incomplete, fragmented right femur (only the proximal third was recovered) exhibits an intracapsular fracture. The bone belongs to an adult, probably a female (Wasterlain, 2000). It was not possible to estimate age at death. The fracture (oblique, transcervical) is well remodelled. The femoral head shows signs of gross modification, with secondary development of osteoarthrosis. Eburnation of the proximal joint is visible. It is noticeable that fracture repair has occurred through the formation of new bone in the anteromedial surface of the neck of the femur. The true prevalence in the Paimogo I study sample for hip fractures in the right femur is 1.3% (1/78, Table 1).

Case 2: Paradela churchyard (12th–19th centuries)

During the excavation of the old churchyard of Paradela (Barcelos, northwest Portugal) 121 skeletons were recovered (100 adults). Historical and archaeological contexts suggest an occupation period between the 12th and the 19th centuries.

Table 1.   True prevalence of hip fractures in various skeletal samples

Study reference	Provenience	Chronology	n	Fractured	%
Curate (2009)	Identified skeletal collection, University of Coimbra, Portugal	19th–20th centuries	98	2	2.0
Curate et al. (2010)	Santa Clara, Coimbra, Portugal	14th–17th centuries	66	1	1.5
Ives (2007)	Several sites, UK	Post medieval	1180	7	0.6
Present study	São Julião, Constância, Portugal	14th–19th centuries	43	1	2.3
Present study	São Francisco, Santarém, Portugal	14th–17th centuries	103	1	1.0
Present study	Paradela, Portugal	12th–19th centuries	42	1	2.4
Present study	Paimogo I, Lourinhã, Portugal	Late Neolithic	78	1	1.3

Figure 1.   An extracapsular, intertrochanteric, fracture in an old male (Paradela, Barcelos).

Figure 2.   Increased opacity in the intertrochanteric region.

A hip fracture was observed in an old male (> 50 years old: Ferembach et al., 1980; Lovejoy et al., 1985; Wasterlain, 2000). The skeleton is fairly complete. However, the vertebra, the ribs, the upper limbs and the hip bones are fragmentary. The majority of the long bones from the lower limb are well-preserved. This skeleton shows degenerative lesions in the left shoulder, hip, and costal joints. Severe joint destruction is observed in the right hand and in the left feet. Degenerative focuses are also present in the vertebral fragments. Furthermore, a case of ankylosis is present between the 7th cervical and the 1st thoracic vertebrae, affecting both body and apophyseal joints.

The macroscopic study revealed a deformity in the intertrochanteric ridge of the left femur with bone mass deposition, creating an irregular folder. As a result, there is a shortening of the femoral neck (Figure 1). Radiographically, there is an increased opacity of the affected zone (Figure 2). Additionally, a fracture line is seen below the intertrochanteric crest. The lesions described are congruent with an extracapsular fracture, of the intertrochanteric type. At a biomechanical level, this traumatic event caused a visible limb asymmetry with acute involvement of the knee joint, with a

possible consequence to the individual's mobility. The crude prevalence of proximal femur fractures in this sample is 1.0% (1/100, Table 2). The true prevalence is 2.4% (1/42).

Case 3: Convent of São Francisco, Santarém (14th–17th centuries)

The convent of São Francisco of Santarém (central Portugal) was founded around 1242 and abandoned during the 17th century. During a partial excavation of the church, 132 individuals (103 adults), from both sexes and all age groups, were unearthed (Silva, 1999).

An aged female (> 50 years: Ferembach et al., 1980; Lovejoy et al., 1985; Brooks and Suchey, 1990) exhibits a remodeled extracapsular, intertrochanteric, hip fracture of the left femur. The skeleton is incomplete but reasonably well preserved. Moderate osteoarthrosis was noted in the tarsal bones. Although the left femur is broken and incomplete (the distal segment is absent), it is possible to observe the fracture repair in the intertrochanteric region. Several degenerative alterations are present, namely a severe secondary osteoarthrosis in the proximal femoral articulation and the closure of the acetabulum. The true prevalence for hip

Table 2.   Crude prevalence of hip fractures in various skeletal samples

Study reference	Provenience	Chronology	n	Fractured	%
Curate (2009)	Identified skeletal collection, University of Coimbra, Portugal	19th–20th centuries	98	2	2.0
Curate et al. (2010)	Santa Clara, Coimbra, Portugal	14th–17th centuries	71	1	1.4
Mays (2006)	Ancaster, UK	3rd–4th centuries	16	1	6.3
Mensforth and Latimer (1989)	Hamann-Todd Collection, USA	19th–20th centuries	938	23	2.5
Present study	São Julião, Constância, Portugal	14th–19th centuries	106	1	0.9
Present study	São Francisco, Santarém, Portugal	14th–17th centuries	103	1	1.0
Present study	Paradela, Portugal	12th–19th centuries	100	1	1.0

fractures in this sample is 1.0% (1/103, Table 1). The crude prevalence is also 1.0% (1/103, Table 2).

Case 4: Church of São Julião, Constância (14th–19th centuries)

In the years of 2002 and 2003, during the urban renewal of the historical centre of Constância (Portugal), 151 skeletons (106 adults and 45 non adults) were unearthed from the Church of São Julião, dated from the 14th–19th centuries (Assis, 2007).

Among the several pathological cases, an old female skeleton was observed (> 50 years: Ferembach et al., 1980; Lovejoy et al., 1985; Wasterlain, 2000), with an intracapsular fracture of the left femur. The skeleton is fairly well preserved but incomplete. The preserved joints display degenerative lesions, more conspicuous in the hip bone, and in the lumbar and sacrum vertebrae. The sacrum shows porosity and perforation of the upper body surface. Musculoskeletal stress lesions are present in the upper and lower limbs. In the right leg there is a severe periosteal reaction of unknown aetiology at the site of insertion of the tibia–fibular ligament.

An atypical neck angle in the left femur not present in the matched pair was noted. The alterations are characterized by a decrease in the neck length and by a slight medial-posterior rotation of the femoral head. A small bony ridge crosses the femoral neck in the anterior view. Moreover, a bone folder is present in the superior border of the femoral head. These bone abnormalities are compatible with a consolidated cervical (intracapsular) hip fracture. According to the Gardner classification, the head rotation suggests a valgus impaction fracture. The crude prevalence of hip fractures in this study-base is 0.9% (1/106), while the true prevalence is 2.3% (1/43). The crude prevalence in older females (> 50 years) is 8.3% (1/12, Table 1).

Case 5: Juncal necropolis (16th–20th centuries)

Juncal (Porto de Mós) is a small village located in the centre of Portugal. Its old necropolis, closed in the early 20th century, is contiguous to the S. Miguel Church which was built in 1780. In 2006, during an emergency archaeological survey, human bone remains were exhumed from an ossuary.

A left femur fragment with severe pathological alterations in the proximal joint was recovered. This femur probably belongs to an adult male (Wasterlain, 2000). The estimation of age at death was impossible due to the absence of the remaining skeleton. Macroscopically the bone lesions are characterized by a medial-posterior rotation of the femur head, levelled at the growth cartilage border, and subsequent reduction of the femoral neck angle. A slight bony callus is noted above the trochanteric fossa. The femur head shows acute degenerative lesions, or osteoarthrosis, with marginal lipping, sclerosis and eburnation. Severe bone growth is present at the site of insertion of the piriform, obturator internus and gemelli muscles. New bone deposition is present in the proximal quarter of the diaphysis. The alterations described are consistent with a subcapital neck fracture (an intracapsular fracture), with a varus rotation of the head. Alternatively, this case might represent a slipped capital femoral epiphysis (Brenkel et al., 1986; Ankarath et al., 2002). Slipped capital epiphysis is a Salter-Harris type 1 fracture

Figure 3.   A comminuted fracture at the base of the neck of the femur in an old male (Church of Nossa Senhora da Conceição, Seixal).

through the proximal femoral physis and usually occurs in adolescents at about the growth spurt. There is a sheering force across the epiphysis at the hypertrophic zone that allows a slip, usually in the varus direction (Adler, 2008). Against this differential diagnostic is the fact that this fracture frequently results in osteonecrosis and chondrolysis because of the tenuous nature of the blood supply, which is clearly not the case.

Case 6: Church of Nossa Senhora da Conceição, Seixal (18th–19th centuries)

The church of Nossa Senhora da Conceição, Seixal (south Portugal), was built in 1500 and partially destroyed in 1755, during the Grande Terramoto de Lisboa (Great Earthquake of Lisbon). It was abandoned in the 19th century. The associated necropolis was used only for a short period, between 1755 and the end of the 19th century (Lopes, 2002). During an emergency excavation 30 adult individuals were recovered (11 females; 10 males). An elderly male (> 50 years: Lovejoy et al., 1985; Brooks and Suchey, 1990; Bruzek, 1991) exhibited a traumatic lesion in the right proximal femur (Figure 3). The total separation of the bone in three pieces is compatible with a comminuted fracture at the base of the neck of the femur (extracapsular fracture). The fracture had not healed although the abundant new bone production proves that some time had elapsed between the moment of the fracture and the death of the individual. A severe non-specific infectious disease affected the whole femur and the tibia. Osteopenia, i.e. generalized bone loss (González-Reimers et al., 2002), was not detected on plain radiological analysis. As such, this fracture is probably secondary to a harsh traumatic episode, like a violent fall or a sturdy blow to the right side.

Discussion

In this study we describe six previously unpublished cases of hip fracture, from various Portuguese archaeological sites dating from the Late Neolithic to the beginning of the 20th century. The individuals observed did not show signs of other fractures.

The few existing palaeopathological studies which documented hip fractures convey a true prevalence ranging from 0.6% (Ives, 2007) to 2.0% (Curate, 2009), and a crude prevalence ranging from 1.4% (Curate et al., 2010) to 6.3% (Mays, 2006). Intermediary values were reported by Curate et al. (2010), for the true prevalence (Table 1); and Mensforth and Latimer (1989) and Curate (2009), for the crude prevalence (Table 2). Therefore, the crude prevalence rates found in the different samples in the present study are usually lower than the ones reported in the available literature. The true prevalence rates observed in the study samples are similar to the rates found in the literature.

Fracture patterns within a population are highly informative, because age and sex influences the occurrence and nature of the trauma (Lovell, 1997). So-called fragility fractures are typically associated with moderate trauma at sites containing significant quantities of trabecular bone; incidence rates that increase with aging; and higher frequency among females (Melton, 1995).

In the described hip fracture cases, taken as a whole, males and females were equally affected (two females; two males; one possibly female, and one possibly male). Women display a significantly higher bone fragility, which is a consequence of their smaller-sized bony structures, inferior peak bone mass, rapid bone loss after menopause, thinner cortical thickness, and a greater trabecular disconnection (Orwoll, 2000). In addition, women may incur greater microarchitectural damage than men and adapt less effectively by periosteal apposition, a factor that further contributes to gender differences in bone geometry (Seeman, 2003).

Therefore, hip fractures are usually most common in women (Gillespie, 2001; Brunner et al., 2003; Nolla and Rozadilla, 2004) but some modern clinical studies found a higher incidence among males (e.g. Solomon, 1968; Zhang et al., 2000).

Four of the affected individuals were older adults (> 50 years), which is in agreement with the general epidemiological expectation that older individuals are more prone to this type of fracture (Anderson and Cooper, 1999; Brunner et al., 2003). With increasing age, modifications taking place in bone quantity, quality and microarchitecture influence the resistance of trabecular bone to local collapse, augmenting fracture risk (Nagaraja et al., 2007).

According to anatomical location, three intracapsular and three extracapsular fractures were recorded. In modern epidemiological studies, intracapsular fractures are generally more common than extracapsular fractures (Kannus et al., 1996; Michaëlsson et al., 1999; Zhang et al., 2000), but not always (Maghraoui et al., 2005). These two types of hip fracture are usually considered together in aetiological studies (Michaëlsson et al., 1999). Nevertheless, individuals with a trochanteric fracture (i.e. extracapsular) are generally more osteoporotic than those with cervical hip fractures (i.e. intracapsular), and have higher postfracture mortality (Seeley et al., 1991; Kannus et al., 1996; Nurmi et al., 2003).

The elderly individual from the Church of Nossa Senhora da Conceição (Case 6) suffered an extracapsular, comminuted, fracture, and died shortly after, possibly because a secondary infection. Infectious pathogens are responsible for a high mortality rate after hip fracture (Sharma et al., 2003; Fenton et al., 2008). Mortality in past populations from hip fractures would unquestionably have been much higher (Brickley, 2002), but repair was possible (Stimson, 1883). Of the six described fractures, five were remodelled, suggesting long survival of the individuals after trauma. Furthermore, three of the affected individuals showed signs of eburnation in the head of the femur, which demonstrate the preservation of limb mobility (Stimson, 1883)—although eburnation could be present before the fracture. More than half of the patients who live autonomously before sustaining a hip fracture, face enduring disability and prolonged institutionalization as hip fractures promote total or partial incapacity of the affected limb (Melton et al., 2003; Physician's Guide, 2003). As such, the remodelling associated with the fractures and the long-term survival of some of these individuals are suggestive of a solid community support, at least during recovery.

Proximal femur fractures have been acknowledged as a sign of osteoporosis for more than 150 years (Cooper, 1822). Currently, nearly all hip fractures occur as an outcome of a fall by an individual with reduced bone strength (Melton et al., 2003; Physician's Guide, 2003; Di Monaco et al., 2006; Mukamal et al., 2007). As such, it is probable that at least some of the described hip fractures are a consequence of bone loss. However, one of the cases (Case 6) is probably the result of a high-energy trauma. Indeed, about one in six hip fractures result from severe trauma (Melton, 1995).

Conclusion

Hip fractures are regarded as unusual traumatic events in the archaeological record (Ortner, 2003; Agarwal et al., 2004). Notwithstanding, there are increasing numbers of palaeopathological reports that refer to this type of fracture (e.g. Stroud and Kemp, 1993; Roberts and Manchester, 1995; Dequeker et al., 1997; Bartoníček and Vlcek, 2001; Campillo, 2001; Ibáñez, 2001; Mays, 2006; Ives, 2007; Salter-Pedersen, 2007; Curate et al., 2010).

Although the proportion of the population that lived to over 70 years of age was certainly smaller in the past (Brickley, 2002), some people definitely lived into old age (Jackes, 2000), enough to experience osteoporotic fractures (Brickley, 2002). It is apparent from classic medical texts (e.g. Paré, 1575; Cooper, 1822; Malgaigne, 1842; Smith, 1847) and palaeopathological studies focused on identified skeletal collections (Mensforth and Latimer, 1989; Curate, 2009) that fragility fractures occurred with relatively high frequency in aged individuals from populations with lifestyles different from those found nowadays, who obviously did not benefit from modern medicine.

This review was intended to expand the information about hip fractures in the archaeological record. While this type of fracture was probably rarer in the past as compared to modern populations, it is increasingly evident that it indeed affected individuals in past communities. A careful revision of old, forgotten, archaeological reports and the directed study of large skeletal series will surely convey additional information about fractures of the proximal femur in the past.

Acknowledgments

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