International Journal of Paleopathology 13 (2016) 91–95

Contents lists available at ScienceDirect

International Journal of Paleopathology

journal homepage: www.elsevier.com/locate/ijpp

Tiptoeing through the rest of his life: A functional adaptation to a leg shortened by femoral neck fracture

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ARTICLE INFO

Article history:
Received 17 November 2015
Received in revised form 8 February 2016
Accepted 22 March 2016

Keywords:
Paleopathology
Hip fracture
Trauma
Disability
Roman Empire

ABSTRACT

Salvage excavation of a Roman cemetery (1st–2nd century CE) at the site of ancient Erculam (region of Campania), Italy, yielded the skeleton of an older male with a healed fracture of the femoral neck that reduced the femoral neck angle and resulted in leg shortening. The right foot shows bony alterations that appear to have developed as a consequence. The distal joint surfaces of the first and second metatarsals extend dorsally for articulation of the proximal phalanges in hyper-dorsiflexion. I argue that, in order to compensate for the shortened leg, the man lengthened it functionally by bearing weight primarily on his toes when he walked, rather than striking the heel first and then pushing off from the toe. The severity of degenerative joint disease in the right knee and in the metatarsophalangeal joints suggests that the injury occurred years before the man's death. This case adds to the bioarchaeological record of individuals who adapted to impaired mobility in the past, and it may be of interest to scholars who study the bioarchaeology of impairment and disability.

1. Introduction

The ancient cemetery of Erculam (also known as Herculia) is located in the modern town of San Marco di Castellabate on the western coast of southern Italy (Salerno province, in the region of Campania), roughly 400 km south of Rome (Fig. 1). The cemetery was discovered in 1983 (Fiammenghi, 1992) and dates to the 1st or 2nd century CE. This report focuses on the skeleton of an older adult male from one of the primary burials recovered at Erculam during salvage excavations by Italian archaeologists in 2004 and 2005 (Di Paola, 2006). He had sustained a fracture of the femoral neck that reduced the femoral neck angle and resulted in leg shortening. Three aspects of this case are described in this paper: the probable mechanism of injury, the consequences of the injury, and the implications for mobility impairment.

The mortuary treatment of this individual was no different from the others buried in this cemetery. Each adult skeleton had been interred in an extended supine position within a rectangular earthern pit covered with terracotta tiles (*a cappucina* style), indicating that they were of limited financial means and low social status. Libation tubes or the upper portions of amphorae may have marked the graves (e.g., Prowse and Small, 2009; and Toynbee, 1971), but none were in place at the time of the cemetery's discovery. Most burials did not have grave goods, but a few bronze coins and small terracotta vessels and glass bottles were recovered.

Historical data indicate that the ancient community had a maritime-based economy, so it is likely that many of the men who lived there made their living as fishers. Some, however, could have been merchants, worked a trade, or been engaged in agricultural activities related to the cultivation of grain and the maintenance of orchards and vineyards (Carré, 1993; Kolendo, 1993; Meijer, 1986: 218, Morely 2002).[1]

2. Materials and methods

The human remains from the Erculam cemetery are stored at the site of Velia, located in the Italian town of Marina di Ascea, some 35 km south of San Marco di Castellabate on the Tyrrhenian coast. The skeletons of 29 individuals were studied at Velia in the summer of 2013. Many of the skeletons were incomplete, and the bones were fragmented. This individual, however, was sufficiently complete to determine that he was a male, based on skull morphology and the size of long bones and joints. The pelvis was damaged postmortem, but the morphology of the greater sacroiliac notch

[1] Although diet and subsistence activities have not been reconstructed for Erculam itself, I refer interested readers to the comprehensive reviews of diets, water-related occupations, and agricultural activities for the nearby Imperial Roman coastal site of Velia by Craig et al. (2009) and Crowe et al. (2010).

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http://dx.doi.org/10.1016/j.ijpp.2016.03.001
1879-9817/

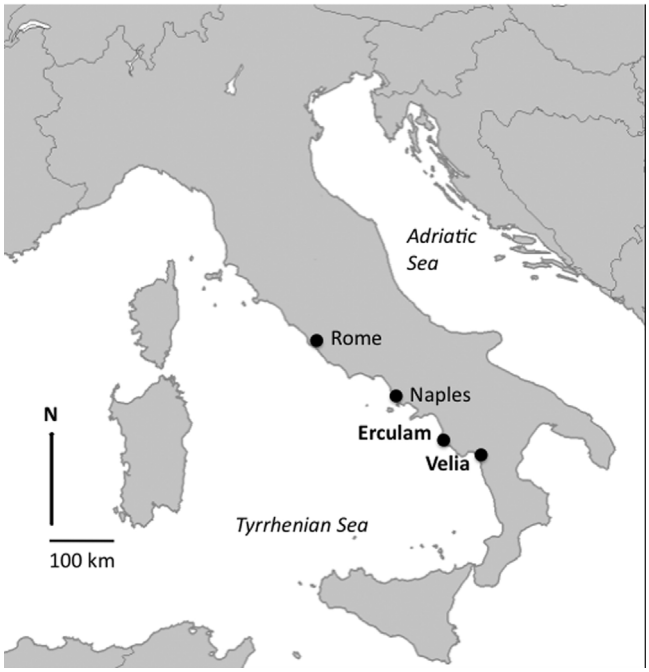

Fig. 1. Map of Italy showing the locations of the archaeological sites of Erculam and Velia, with Rome and Naples included for reference.

and the absence of a ventral arc on the *os pubis* supported this assessment (Buikstra and Ubelaker, 1994). Age-at-death estimations are imprecise for adults, but this individual appeared to have been an older adult based on greater than 50% obliteration of the sagittal suture and a fine-grained pubic symphyseal face (Buikstra and Ubelaker, 1994), as well as an edentulous mandible with fully remodeled alveoli and one remaining maxillary molar with severe asymmetrical wear, scored according to Lovejoy (1985) and Smith (1984).

3. Results

The skeleton displays a well-healed fracture[2] of the proximal right femur (Fig. 2). When the femoral head is in anatomical position, the shaft segment distal to the neck is shifted superiorly and anteriorly, leading to a slight medial rotation of the femoral shaft. There is also a pronounced reduction (*coxa vara*) of the femoral neck angle that shortened the right leg. There is no evidence of avascular necrosis. Although the femoral head is not affected by arthritic change other than slight marginal lipping, the right distal femur and proximal tibia exhibit eburnation and grooving (Fig. 3); the right patella is affected by marked marginal lipping.

There are marked pathological alterations in several bones of the right foot. When the first metatarsal (MT) is articulated with its corresponding first proximal phalanx, it is clear that range of motion at this joint permits hyper-dorsiflexion (Fig. 4). This MT1 exhibits marked marginal lipping, erosive lesions, and eburnation of the distal subchondral surface, as well as a pronounced insertion site for *peroneus longus* on the plantar aspect of its proximal end. The MT2 and articulating proximal phalanx are affected to a lesser degree. Eburnation is visible on the distal subchondral surfaces of

[2] Congenital or developmental dysplasia (dislocation) of the hip was ruled out in the differential diagnosis due to the normal appearance of the acetabulum. A slipped capital femoral epiphysis was also ruled out since the abnormality of the neck in this femur occurs outside what would have been the limits of the fibrous capsule.

Fig. 2. Frontal aspect of left and right femora. Although partially obscured by post-mortem erosion, the right femur displays a healed fracture of the neck with reduced neck angle.

the first and second proximal phalanges (Fig. 5); unfortunately, the phalanges distal to these were not recovered during excavation.

Additional lesions that may be relevant to interpreting the mechanism of injury in this case are a crush fracture of the fifth lumbar vertebral body and Schmorl's nodes on the superior surfaces of the sixth through tenth thoracic and the first and second lumbar vertebral bodies, as well as extensive marginal lipping on the third through fifth lumbar vertebral bodies. The left distal femur, proximal tibia, and patella exhibit degenerative joint disease, although the lesions are not so pronounced as on the right side. Contrasting with the osteoarthritis in the lower limbs, the upper limbs display only slight marginal lipping at the shoulder and elbow joints. There is no evidence of trauma to the pelvis and there are no talar or calcaneal fractures. Two of the recovered 40 rib fragments (most of which are less than 10 cm in length) display evidence of trauma, although not necessarily from the same event. In one example the fracture is well healed and may have occurred at the time the femoral neck fracture was sustained, while in the other the fracture callus consists of unremodelled woven bone, indicating an injury only some weeks before death (Lovell, 2008).

4. Discussion

Three aspects of this case warrant discussion: the probable mechanism of injury, the consequences of the injury, and the implications for mobility impairment. Since the femoral neck is well protected by soft tissues, the fracture must have been caused by indirect blunt force trauma rather than a direct blow (for a discussion of mechanisms of injury, see Lovell, 2008), but how that indirect force was transmitted to the femoral neck is not entirely clear. The reduction in the femoral neck angle is consistent with a fall onto the feet from a height, with the force of impact transmitted upward. Supporting that scenario are the collapse fracture of a vertebral body and the Schmorl's nodes, although it cannot be determined if all of the injuries were sustained at the same time. Contradicting the scenario of a fall from a height is the absence of any evidence of trauma to the left leg or to the os coxae, tali, or calcanei. Indeed, the vertebral lesions could have resulted from lesser forces if the vertebral bodies had been weakened by a pre-existing condition such as osteoporosis.

Osteoporosis is strongly associated with fractures from low energy events (Bergström et al., 2008; Metcalfe, 2008), such as a fall from a standing height (Galloway, 1999: 251–252; and, for a review of preexisting bone loss and fragility fractures, see Beauchesne and Agarwal, 2014), particularly falling sideways (Anderson et al.,