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Physical disability in Late Antiquity Milan: slipped capital femoral epiphysis with severe secondary joint disease in the Basilica of San Dionigi

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With 3 figures

Abstract: The paper presents the skeletal remains of an adult male of 30–40 years with bone lesions and deformity on the left hip, recovered during the archaeological excavation below the former Basilica of San Dionigi, dated to Late Antiquity (3^{rd} – 5^{th} century AD) Milan. Biological profile and paleopathological analysis were performed following standard references and the bones underwent radiological examination. Differential diagnosis included congenital anomaly, active rickets, infectious diseases, femoral neck trauma, Legg-Carvé-Perthes disease, Slipped Capital Femoral Epiphysis (SFCE), osteogenesis imperfecta and osteoporosis. While the lesions were highly consistent with Legg-Calvé-Perthes disease, they were typical of SFCE, complicated by an avascular necrosis and secondary osteoarthrosis. The alteration of the femoral head led to a 7.8% leg-length discrepancy, causing gait alteration with partial compensation though increased muscular activity on the right leg, reduced mobility of the joint and potentially hip pain, difficulty in walking and running and even limping. This paper explores a case of physical disability from the Roman era found near a Christian place of worship and represents a rare case of SFCE in the paleopathological record.

Keywords: slipped capital femoral epiphysis; cripple; osteonecrosis; late antiquity; physical disability; Roman era

Introduction

Today, Slipped Femoral Capital Epiphysis (SFCE) is the most common hip disorder affecting adolescents, characterized by posteroinferior displacement of the capital femoral epiphysis on the metaphysis (or rather, an anterosuperior displacement of the metaphysis while the epiphysis remains set in the acetabulum) (Lehmann et al. 2006). The incidence varies between 0.2 (in Japan) and 10/100,000 (in the United States of America) with a boy to girl ratio of 1.43:1 and a seasonal variation in latitudes north of 40° with higher frequencies in summer and autumn. SFCE is most frequent Pacific Islanders and people of African descent compared to those of European descent, and least frequent in Indonesian-Malay and Indo-Mediterranean populations (Aronsson et al. 2006). Age of onset is about 12 years in boys and 11 years in girls but a possible trend showing a younger age of onset over time has been identified, potentially due to children maturing earlier today, suggesting that the condition may have developed at an older age in the past (Aronsson et al. 2006; Lehmann et al. 2006). The etiology of the condition is not completely understood but recognized factors that may influence the development of the condition include mechanical (e.g., femoral, or acetabular retroversion, coxa profunda), endocrine, and metabolic (e.g., obesity) disorders at puberty. Indeed, factors that reduce the resistance to shear and/or increase the stress at the physis may weaken it and cause it to fail mechanically (Aronsson et al. 2006). Obesity is a major risk factor as it increases mechanical loading on the hip, and obese children tend to present a reduced femoral anteversion and a more vertically oriented physis. Typically, the lesion is observed in overweight adolescent boys presenting with pain in the groin, thigh or knee and limping. Long-term effects include loss of function and varying degrees of deformity, and complications such as osteonecrosis and degenerative joint disease may occur as the disease progresses. SFCE

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is bilateral in 20–80% of cases, the second slip occurring within the year following the first. Clinical diagnosis requires an anteroposterior or frog-leg lateral pelvis radiograph and treatment focuses on preventing the progression of the slip though fixation (Novais & Millis 2012).

There are few cases of SFCE in the paleopathological literature: Ortner (2003: 349) described two cases from Chiacama, Peru (NMNH 265331) and the Historical Museum in Chur, Switzerland (HMCS GR 1582), Wasterlain & Umbelino (2014) reported a case from medieval Sintra (Portugal) and Knüsel et al. (1992) published a medieval case from North Yorkshire (United Kingdom) exhibiting entheseal and degenerative changes in the upper limbs potentially suggestive of the use of crutches.

In this paper, we present a rare case of physical disability from Late Antiquity (3rd–5th century AD) Milan (Italy) found near a Christian place of worship, specifically, a SFCE with severe secondary osteoarthrosis and osteonecrosis.

Material and methods

The marked imprint of Christianity in Milan, one of the capitals of the Roman Empire, can be traced to St. Ambrose. Since 374 AD, year of the start of his episcopate, his interventions aimed at the monumentalization of the urban center and the suburbs with the creation of places of worship intended for the devotion to martyrs. Ambrose drew a cross on the city through the construction of four basilicas with the episcopal pole at its center: *San Nazaro* (*b. Apostolorum*), *Sant'Ambrogio* (*b. Martyrum*), *San Simpliciano* (*b. Virginum*), and *San Dionigi* (*b. Salvatoris* et *sanctorum veteris testamentis* from the 13th century). The latter, located on the street of the eastern gate (today's *Porta Venezia*), was dedicated to a Milanese bishop of probable Eastern Greek origin, who died in exile in Cappadocia in 360 AD.

The most important restructuring of San Dionigi Basilica was promoted by Bishop Ariberto, who, in the 11th century, annexed both a monastery and a hospital. After its first destruction in the 16th century, the basilica was rebuilt in smaller dimensions, but it was eventually demolished a few centuries later and is now replaced by the *Indro Montanelli* gardens.

The 2019 archaeological excavation of the basilica was divided in four sections (A, B, C, D), where a total of 11 tombs were identified. It is important to note that the archaeological investigations are not completed as of yet and so the full planimetry is not available. We know that the burials were not in the basilica but in its vicinity. Section B was composed of four burials, including Tomb 6, a pit dug directly in the soil containing two individuals in supine position without any associated material culture. This was the only double burial of the site. The first skeleton recovered, skeleton A, is a female subadult individual of 14 to 16 years, buried in an E/W orientation. The skeleton was buried with the upper limbs placed behind the head and the lower limbs bent parallel to the side, suggesting that she may have been buried tied at the wrists and ankles. Skeleton A was covering skeleton B, an adult lying with the upper limbs crossed over the pelvis and the lower limbs outstretched. The tomb was stratigraphically dated back to 3rd – 5th century AD. Skeleton B is the object of the present study.

Macroscopic anthropological analyses were performed for the construction of the biological profile of skeleton B. Tooth nomenclature followed the FDI World Dental Federation notation or ISO 3950 nomenclature. Sex was assessed based on the morphological features of the pelvis (Phenice 1969; Walker 2005) and post-cranial measurements (Purkait 2003; Spradley & Jantz 2011). Age-at-death was estimated from the analysis of the pubic symphysis (Brooks & Suchey 1990), the auricular surface of the ilium (Lovejoy et al. 1985; Buckberry & Chamberlain 2002), the auricular surface combined with the acetabulum (Rougé-Maillart et al. 2009), and the sternal end of the fourth rib (Işcan & Loth 1986). Stature was estimated using regression formulae based on maximum length of the left tibia and ulna (Trotter 1970). Pathological analysis was performed following standard references (Aufderheide & Rodríguez-Martín 1998; Ortner 2003; Buikstra 2019; Biehler-Gomez & Cattaneo 2021) and by confrontation with the clinical literature. The femoral neck-shaft angle was measured as the angle between the femoral neck axis (the line connecting the femoral head center and the center of the femoral neck) and femoral long axis (determined by two points in the center of the femur at the anatomical neck and proximal center of the femoral shaft) using ImageJ. Differential diagnosis was formulated following the modified Istanbul Terminological Framework (Appleby et al. 2015). Entheseal changes were recorded following Mariotti et al. (2007).

Radiographic analysis was performed using a Poskom PXM-40BT and X-DR L WiFi at 73 kV and acquired via the Examion® software.

Results

The skeleton under analysis was almost complete and well-preserved. The cranium was only represented by two fragments of the maxillary bones (allowing the recovery of four teeth: 21, 22, 23 and 24), the mandible, right humerus and first four cervical vertebrae were absent. The remainings of the bones were present although sometimes fragmented and only a few bones of the hands and feet were missing (Fig. 1). The anthropological analysis revealed a male individual, aged 30 to 40 years with an approximate stature of 181 to 187 cm. Schmorl's nodes were present on the vertebral bodies of T9 through L3. Two calluses constituted of lamellar and woven bone were found on the medial surface of the mid-diaphysis of the right tibia, corresponding to two potentially coeval traumatic injuries, still in healing at the time of

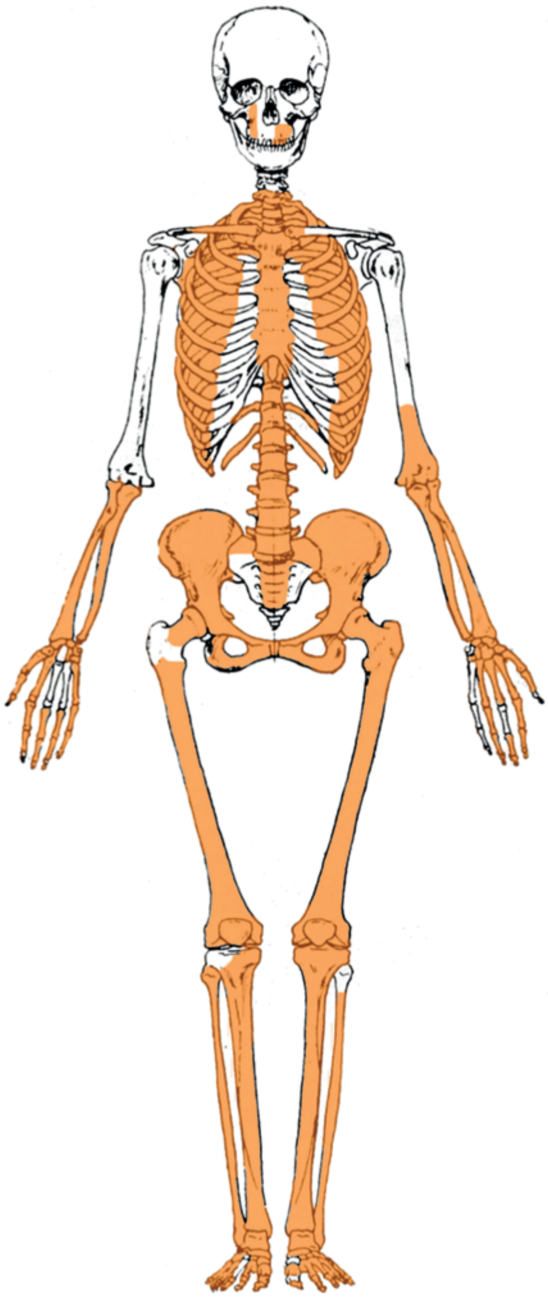

Fig. 1. Schematic representation of the skeletal remains of skeleton B. The bones present during anthropological examination are colored.

death. In addition, the first metacarpal of the right hand presented an abnormal curvature suggestive of an antemortem fracture in its last phase of healing. Regarding stress markers, linear enamel hypoplasia was observed on the labial surface of teeth 22 and 23, and Harris lines were noted on the distal end of the right tibia.

The pathological lesion subject of study in this paper is located on the left hip (Figs 2 and 3). The proximal epiphysis of the femur is displaced inferiorly and is deformed: the round head of the femur now assumes a cylindrical form inclined medio-inferiorly, with a femoral neck-shaft angle of 67° (Fig. 2a), corresponding to a severe *coxa vara* deformity. The femoral neck-shaft angle of the right femur could not be measured given that only the femoral head was recovered in the proximal epiphysis. The surface of the articulation is remodeled (with new bone apposition) and presents microporosity. The corresponding coxal bone also evidences pathologic alterations: large osteophytes border the acetabulum, the articular surface shows remodeling and *coxa profunda* (abnormally deep acetabular socket where the acetabular fossa is medial to the ilioischial line) as well as *protrusio acetabuli* (femoral head is medial to the ilioischial line) are noted; the medial wall of the acetabulum was broken postmortem. The dry bone articulation of the femoral head in the acetabulum shows that cartilage space was considerably reduced at the time of death to the point of almost complete absence. Indeed, rotation of the hip joint induced contact and friction between the bones, evidencing cam (alteration of the shape of the head of the femur interfering with the normal mechanical movement of the articulation) and pincer impingements (excessive coverage of the femoral head by the acetabulum).

Both femora were fragmented, the left was separated in two pieces and the right was missing the neck fragments. Considering these limitations, the length of left femur was estimated at 44 cm and the right femur at 51 cm. Although no asymmetry of the pelvis was recorded, entheseal changes were slightly more robust (one score higher) on the right lower limb (scores 1b–2) with respect to their contralateral sites (scores 1a–1c). For instance, the M. gluteus maximus was scored 2 on the right femur and 1c on the left, the M. vastus medialis of the femur and the quadriceps tendon of the patella were scored 1b on the right side and 1a on the left, and on the tibia, the quadriceps tendon was scored 2 on the right and 1c on the left whereas the M. soleus was evaluated at 1c on the right and 1b on the left.

Discussion and conclusions

The extent of the deformation and bone remodeling of the bones involved in the articulation (in particular, the proximal femoral epiphysis) indicate that the lesion probably initiated in childhood or adolescence, that is, close to the time of skeletal maturity preventing the remodeling of the bones in their original shape. The residual deformation altering the mechanics of the hip movement leads in adulthood to secondary degenerative disease.

Several hypotheses may account for the pathological alterations observed in this case, including a congenital anomaly, active rickets, an infectious disease (i.e., tuberculous arthritis and septic arthritis), femoral neck trauma, Legg-Carvé-Perthes disease, SFCE, osteogenesis imperfecta and osteoporosis.

Fig. 2. Left proximal femur (**a:** anterior view; **b:** posterior view; **c:** medial view) and innominate bone (**d:** lateral view).

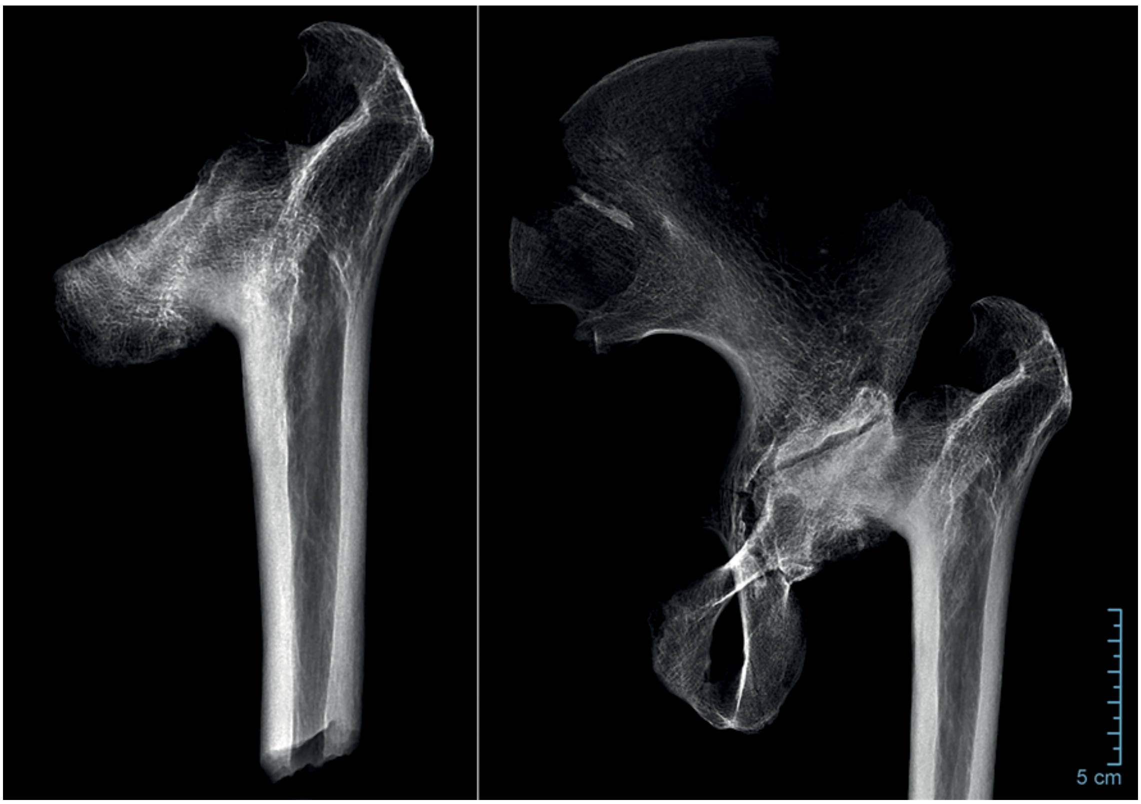

Fig. 3. Radiographs of the left femur and innominate bone.

The young age of the individual and the lack of any sign of osteopenia on radiographs exclude osteoporosis as a likely candidate from the differential diagnosis. Similarly, the absence of bending deformities renders the diagnoses of osteogenesis imperfecta and active rickets improbable (Brickley & Ives 2010). While the presence of a congenital anomaly is conceivable, the extent and severity of the deformation and bone remodeling suggest a local insult to the bone and an attempt at healing, inconsistent with an anomaly from birth. Therefore, the lesions observed were not consistent with osteoporosis, osteogenesis imperfecta, active rickets and a congenital anomaly.

Starting from a young age, tuberculous and septic arthritides can cause deformations and atrophies in the articulations (in particular the hip joint), not unsimilar to the present case. Unlike the case presented here however, they often terminate in bony ankylosis when left untreated (Ortner 2003). In addition, joint tuberculosis operates by creating cancellous sequestra and/or cavitation, with a destruction of the bones of the hip leading to upward subluxation or complete dislocation (Ortner 2003), none of which was observed here and no lesion suggestive of tuberculosis was noted on the rest of the skeleton. Although neither of these conditions can be categorically excluded from the differential diagnosis, they are less likely possibilities. The lesions are hence consistent with tuberculosis and septic arthritis.

Given the extent of capital epiphysis displacement, a traumatic component is probable. Femoral trauma such as femoral neck fracture and intertrochanteric fractures are uncommon, especially in young adults, but they can occur after a fall. No macroscopic or radiological sign of fracture on the femoral neck or intertrochanteric region was noted. Nonetheless, avascular necrosis and non-union are the most common complications of these types of fractures and the severe pathological changes observed are consistent with a complicated femoral neck fracture during growth (Dedrick et al. 1986; Hwang et al. 2001; Roshan & Ram 2008).

Legg-Carvé-Perthes disease is a childhood osteochondrosis of unclear etiology leading to aseptic necrosis, complicating fractures and acetabular and femoral changes including "mushroom-shaped" femoral head deformation (Ortner 2003; Smrcka et al. 2009; Wasterlain & Umbelino 2014). SFCE is characterized by a stress fracture between the metaphyseal side of a weakened growth plate and the neck of the femur causing a postero-inferior displacement of the femoral capital epiphysis, which can lead to aseptic necrosis of the epiphyseal bone as well as dislocation toward the femoral neck with healing (Salter 1999; Ortner 2003; Wasterlain & Umbelino 2014). Both conditions are multifactorial in etiology, are most commonly unilateral, occur in childhood, cause deformities of the hip joint and may be indistinguishable once the appearance of the joint is modified by degenerative disease in adulthood. However, flattening of the acetabulum and femoral head, and "mushroom-shape" of the proximal femoral epiphysis, two characteristic features of Legg-Carvé-Perthes disease, were not observed. Moreover, an inferior displacement of the left femoral head with respect to the neck was noted, suggestive of slipped capital epiphysis. Consequently, the lesions are highly consistent with Legg-Calvé-Perthes disease and typical of SFCE.

While a traumatic component is probable given the extent of capital epiphysis displacement, femoral neck trauma seems unlikely, given the absence of any macroscopic or radiological sign of fracture on the femoral neck and the restriction of the pathological changes to the head of the femur and acetabular socket.

In their study of 2,665 skeletons from the Hamann-Todd collection, Goodman et al. (1997) described five characteristics of the post-slip morphology, including loss of the normal concavity of the antero-superior region of the head-neck junction, increased concavity of the postero-inferior region of the head-neck junction, posterior location of the fovea with respect to a line through the axis of the neck, posterior tilt of the articular surface in reference to the axis of the neck and roughened surface of the exposed metaphyseal bone between the original position of the epiphysis and its displaced position. In the present case, all of these features could be verified, only the deformation was much more severe.

To assess leg-length discrepancy (LLD), the composite measurement of the femur (from the most superior point of the femoral head to the distal portion of the medial femoral condyle) and tibia (from the medial tibial plateau to the tibial plafond) (Sabharwal & Kumar 2008) was calculated: left leg length: 44 + 39 = 83 cm; right leg length: 51 + 39 = 90 cm. This resulted in an approximate 7 cm shortening of the left leg or 7.8% LLD. Reports vary on the extent to which LLD can affect gait and the degree of discrepancy required for such changes to occur (Gurney 2002). Nonetheless, Song et al. (1997) reported that an LLD of 5.5% or more created an increased vertical displacement of the center of gravity during gait, thus leading to a greater demand for mechanical work during ambulation. Importantly, younger persons tend to adapt to larger LLD than older persons and with time, individuals can compensate the discrepancy and reduce the energy and mechanical costs required (Gurney 2002). Given the young age of skeleton B and the length of time he lived with the discrepancy, he may have been able to minimize its effect on gait; yet, the large LLD must have caused gait asymmetry. In addition, compensatory strategies vary per individual, placing stress or requiring exaggerated motion in different areas of the lower extremities and spine (e.g., increased muscle activity, toe walking and pelvic obliquity) (Gordon & Davis 2019). In the present case, a higher degree of robusticity of the entheses was noted in the right leg with respect to the left. This may be the result of an increased muscle activity in the long limb to accommodate the discrepancy in the short limb, as reported in the literature (Song et al. 1997).

Consequently, the most probable condition responsible for the lesion observed in skeleton B is a slipped femoral capital epiphysis, occurring in late childhood to early adolescence, with osteonecrosis of the femoral head and severe degenerative disease in adulthood deforming the articulation, causing gait alteration, reduced mobility of the joint and potentially hip pain, difficulty in walking and running and even limping. Compensation for the LLD included increased muscular activity on the right leg.

The fact that skeleton B was buried simultaneously (the only occurrence in this site), and in the same tomb as skeleton A, whose unusual position suggests that she may have been tied at the wrists and ankles, may reflect their social consideration. No definitive explanation may be drawn for the burial with the limbs tied and hypotheses include disease, crime and even fear of return from the dead. In the case of skeleton B, this social consideration may or may not be related to the physical disability noted in the skeleton: the LLD must have led to gait asymmetry, which he may have partially compensated by increased activity on the long leg, but he must have also suffered from impaired mobility considering the severity of the alteration of the articulation, limiting his ability to work, and potentially causing constant pain and a noticeable limping, which may have subjected him to ridicule and labeled him as different. Nonetheless, mobility impairment would not have prevented him from being well-integrated into society, as he may have been able to walk using a wood cane (accessible to lower classes) and found income in sedentary trades (e.g., potter, shoemaker, craftsman, butcher, weaver of linen). In fact, the lower back disk hernias may have been caused by repetitive lifting, pulling, pushing, bending, and/or twisting from sedentary activity using back muscles instead of thigh muscles. Historical sources show that physical disability in antiquity often caused ridicule, shame, and lead to economic survival through craftsmanship or beggarhood (Laes 2018). Christian doctrine, particularly prevalent in Late Antiquity Milan, changed the perception of physical disability and suffering through the concept of charity, making the most unfortunate the objects of public giving, and skeleton B may have benefited from the support of his Christian community in accommodating his disability.

Conflict of interest

The authors declare no conflict of interest.

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