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Structural analysis of the femoral diaphyses of an early modern human from Tianyuan Cave, China

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ABSTRACT

The Tianyuan 1 skeleton is among the oldest fossil specimens of our species from East Asia. Important in the original assessment of the skeleton as belonging to a modern human was its femoral structure, particularly its well-developed pilasters. Also noteworthy were its large femoral diaphyseal second moments of area, which were interpreted as evidence of a physically demanding lifestyle, and pathological bone growths on the posterior femoral shafts. Here, we build on previous studies of femoral morphology in Tianyuan 1 by analyzing its diaphyseal structure using micro-computed tomography coupled with a novel method of visualizing cortical bone thickness distributions along the shaft with color maps. Additionally, we calculate diaphyseal second moments of area in Tianyuan 1 with and without its pathological bone additions in order to evaluate whether these growths are the cause of its apparently high diaphyseal robusticity. Diaphyseal color maps and second moments of area of Tianyuan 1 femora are compared to those of three recent (Holocene) human comparative samples, as well as samples of Pleistocene humans. The results show that in terms of cortical thickness distribution, Tianyuan 1 femoral diaphyses are strikingly similar to those of recent humans, as well as Pleistocene early modern humans, yet distinct from the diaphyses of Neandertals. This provides additional support for the modern human status of Tianyuan 1. Analyses of second moments of area reveal that Tianyuan 1 is best classified as a Pleistocene early modern human rather than as a member of any of the recent samples when pathological bone additions are included in area moment calculations. Interestingly, however, once pathological growths are virtually removed, Tianyuan 1 cannot be assigned with confidence to any comparative group. This suggests that the relatively high anteroposterior femoral diaphyseal strength mid-distally in Tianyuan 1 is to some degree a product of its pathological condition.

1. Introduction

The Tianyuan 1 partial skeleton discovered in 2003 at Tianyuan Cave, Zhoukoudian, China, represents a critical source of information about the anatomy and paleobiology of early modern humans in East Asia (Shang et al., 2007; Trinkaus and Shang, 2008; Hu et al., 2009; Shang and Trinkaus, 2010; Fu et al., 2013). Dated to 42,000–39,000 years before present (BP), Tianyuan 1 is among the earliest partial skeletons of *Homo sapiens* in this region subsequent to our species' spread out of Africa (Shang et al., 2007). The age at death of this individual has been estimated to be between 40 and 60 years, but its sex is unknown (Shang and Trinkaus, 2010). A large suite of modern human-like mandibular and postcranial features support the assignment of Tianyuan 1 to our species (Shang et al., 2007; Shang and Trinkaus, 2010). Nevertheless, in the original morphological assessment of Tianyuan 1, a limited number of archaic traits were identified, which suggested possible ancestry from earlier hominin forms (Shang et al., 2007). The modern human status of Tianyuan 1 was recently confirmed by an analysis of its nuclear genome that demonstrated that the individual derived from a population

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ancestral to many present-day East Asians and Native Americans, though it was also found to carry a limited number of archaic alleles (Fu et al., 2013).

Important in the morphological appraisal of the Tianyuan 1 skeleton as belonging to a modern human were its femora (Shang et al., 2007; Shang and Trinkaus, 2010). The right femur (PA1302) preserves much of the neck and trochanteric region plus a complete diaphysis (Fig. 1A), while the left femur (PA1301) is the proximal two-thirds diaphyseal section extending on its anterior surface to roughly midshaft and on its posterior surface more distally (Fig. 1B). Taxonomically, the most telling characteristics of the femora are their well-developed pilasters and distinct gluteal buttresses, both of which are features that firmly align Tianyuan 1 with the derived morphology of modern humans (Trinkaus, 2006). In addition to traits relevant to species assignment, noteworthy biomechanical features of the femora include their large diaphyseal second moments of area (a measure of shaft bending strength), which the describers of Tianyuan 1 interpreted as evidence of a physically active lifestyle typical of Pleistocene hunter-gatherers (Shang et al., 2007; Shang and Trinkaus, 2010). Also apparent on the mid to distal posterior diaphyseal surfaces of the femora are pronounced crests extending through the linea aspera muscle lines, which in all probability represent pathological alterations, but the precise etiology has not been determined. There are also irregularities of soleal lines on the proximal tibiae, which may be related to the femoral pathological abnormalities (Shang and Trinkaus, 2010).

Radiographs of the enlarged muscle attachment crests suggested that they consist primarily of new bone with little mineralization that was laid down over normal intact cortical bone (Shang and Trinkaus, 2010). Importantly, these pathological alterations were interpreted as not being associated with any loss of locomotor function since the large femoral and tibial diaphyseal second moments of area are consistent with the Tianyuan 1 individual having engaged in high levels of physical activity. However, the degree to which the high diaphyseal robusticity was itself a product of these pathological additions of new bone remains unclear.

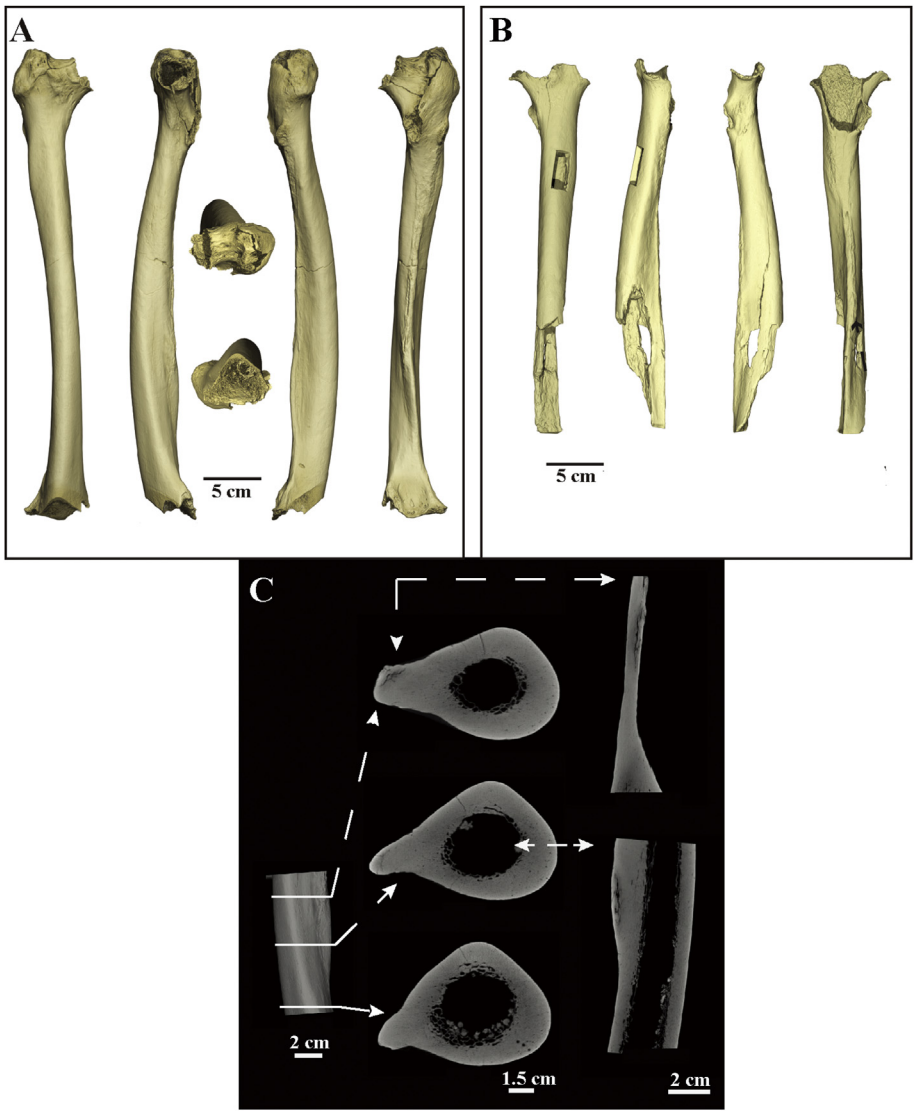

Fig. 1. A. Tianyuan 1 right femur (PA1302), left to right: anterior, medial, lateral, and posterior views. From top to bottom: proximal and distal views. **B**. Tianyuan 1 left femur (PA1301), left to right: anterior, lateral, medial, posterior views. **C**. Left, mid-distal section of Tianyuan 1 right femoral shaft. Middle, from top to bottom: three transverse cross sections. Shaft locations of cross sections are indicated with arrows. Right, from top to bottom: the mediolateral longitudinal section at the pilaster and the anteroposterior longitudinal section at the midsection of the transverse cross section, corresponding to longitudinal length at the mid-distal section on the left.

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