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Metric and morphological study of the upper cervical spine from the Sima de los Huesos site (Sierra de Atapuerca, Burgos, Spain)

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Abstract

In this article, the upper cervical spine remains recovered from the Sima de los Huesos (SH) middle Pleistocene site in the Sierra de Atapuerca (Burgos, Spain) are described and analyzed. To date, this site has yielded more than 5000 human fossils belonging to a minimum of 28 individuals of the species *Homo heidelbergensis*. At least eleven individuals are represented by the upper cervical (C1 and C2) specimens: six adults and five subadults, one of which could represent an adolescent individual. The most complete adult vertebrae (three atlases and three axes) are described, measured, and compared with other fossil hominins and modern humans. These six specimens are associated with one another and represent three individuals. In addition, one of these sets of cervical vertebrae is associated with Cranium 5 (Individual XXI) from the site. The metric analysis demonstrates that the Sima de los Huesos atlases and axes are metrically more similar to Neandertals than to our modern human comparative sample. The SH atlases share with Neandertals a sagittally elongated canal. The most remarkable feature of the SH (and Neandertal) axes is that they are craniocaudally low and mediolaterally wide compared to our modern male sample. Morphologically, the SH sample shares with Neandertals a higher frequency of caudally projected anterior atlas arch, which could reflect greater development of the longus colli muscle. In other features, such as the frequency of weakly developed tubercles for the attachment of the transverse ligament of the atlas, the Sima de los Huesos fossils show intermediate frequencies between our modern comparative samples and the Neandertals, which could represent the primitive condition. Our results are consistent with the previous phylogenetic interpretation of *H. heidelbergensis* as an exclusively European species, ancestral only to *H. neanderthalensis*.

Keywords: Atlas; Axis; Cervical vertebrae; Middle Pleistocene; Sima de los Huesos

Introduction

The Sima de los Huesos (SH) site is approximately 0.5 km from the Cueva Mayor entrance, well inside the Cueva Mayor–Cueva del Silo cave system in the Sierra de Atapuerca in northern Spain (Arsuaga et al., 1997b). To date, more than 5000 fossil human remains have been recovered from the site (Arsuaga and Martínez, 2004) in the excavations directed by one of us (JLA). Based on dental evidence, these remains belong to a minimum number of 28 individuals (Bermúdez de Castro et al., 2004) of both sexes and diverse ages. In addition, thousands of carnivore bones have been recovered mixed with and stratigraphically above the human fossils (García et al., 1997; García, 2002). All anatomical parts of the skeleton are represented among the human remains, suggesting that

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complete corpses were accumulated at this site. The age-at-death distribution suggests that a nonattritional demographic event affected this living population (Bocquet-Appel and Arsuaga, 1999; Bermúdez de Castro et al., 2004). The origin of the human accumulation is most likely to be anthropogenic (Arsuaga et al., 1997b). A recently discovered handaxe has been interpreted as evidence of symbolic behavior in these early humans (Carbonell et al., 2003).

A recently found in situ speleothem (SRA-3), which seals the human-fossil-bearing sediments throughout the site, has been dated. There is a hiatus in the speleothem growth at about 4 cm below the top. This upper portion shows a linear growth rate of about 1 cm per 32,000 years. Ten dates have been obtained in the lower 10 cm of speleothem below the hiatus, all of which indicate a minimum age of 350 ka, although this thickness could represent a significant amount of time beyond this date. Thus, a range of 400–500 ka has been proposed for the human remains (Bischoff et al., 2003). These dates are compatible with both the micro- and macromammalian assemblages (Cuenca-Bescós et al., 1997; García et al., 1997; García, 2002). Bischoff et al. (2006) recently published a reanalysis of six samples of SRA-3 using inductively coupled plasma-multicollector mass-spectrometry (ICP-MS), which yielded new dates that cluster around 600 ka, with an estimated minimum age of the speleothem, and thus of the underlying human fossils, of 530 ka.

The human remains from this site have been assigned to *Homo heidelbergensis*. This species, in our view, is exclusively European, and is ancestral only to the later Neandertals (Arsuaga et al., 1991, 1997c; Carretero et al., 1997; Martínez and Arsuaga, 1997).

The record of the upper cervical vertebral column is relatively abundant for *Homo neanderthalensis* and late Pleistocene *Homo sapiens*, but with respect to the rest of the genus *Homo*, it is scarce or nonexistent.[1] The virtual absence of a fossil record of the upper cervical spine for the middle Pleistocene underscores the importance of the SH specimens described and analyzed here.

Regarding the Neandertals, the most conspicuous traits described for the atlas vertebra (C1) are (1) weakly developed tubercles for the insertion of the transverse ligament and (2) a caudal projection of the anterior tubercle (Boule, 1911–1913; Martin, 1923; Heim, 1976; Arensburg, 1991); for the Neandertal axis (C2) no trait or pattern has been highlighted except its great morphological variability (Piveteau, 1966). In his study of the cervical spine of the Kebara 2 Neandertal individual, Arensburg (1991) concluded that, except for the horizontal spinous process of the C6 and C7, the cervical column seemed to be within the range of variation of modern human populations. Nevertheless, the study of the middle Pleistocene SH upper cervical vertebrae (C1 and C2) may reveal some previously undocumented morphological features and/or patterns of variation within the Neandertal evolutionary lineage.

The first part of the study comprises the inventory of all the atlases and axes, with the determination (if possible) of the age at death (Tables 3 and 4) and the minimum number of individuals represented among the remains. A brief description of the most complete adult vertebrae is also provided. In the second part, we perform a metrical analysis of the adult vertebrae and compare the anatomical features present in the SH specimens with those found in other samples of *Homo*, especially *H. neanderthalensis* and *H. sapiens*.

Materials

The SH vertebral sample comprises 455 fossils that represent at least 180 vertebrae. The cervical sample consists of 116 fossils (Gómez-Olivencia, 2005), including 22 first cervical vertebrae (atlas) and 16 second cervical vertebrae (axis). The present study includes the atlas (C1) and axis (C2) remains recovered up through the 2004 field season. An inventory and photographic documentation of all the fossil material, as well as short descriptions and metrical data of the most complete adult vertebrae, are provided.

Descriptions of a few of the cervical vertebrae [including the atlas VC3 (AT-1554) and a general description of the SH cervical vertebrae] have been published previously (Carretero et al., 1999; Gómez et al., 2005). The present study provides a detailed analysis of the SH upper cervical spine. Appendix 1 provides information on the labeling of the SH vertebrae.

For comparative purposes we have studied a large sample of modern human skeletons and fossil hominin specimens from the following species: *H. antecessor*, *H. neanderthalensis*, and late Pleistocene *H. sapiens* (Table 1). Although remains of the atlas and axis are also known from the Mousterian site of Qafzeh (Vandermeersch, 1981), their fragmentary nature makes comparison with these specimens difficult. Data for the following specimens have been taken from the literature: Kebara 2 (Arensburg et al., 1990; Arensburg, 1991), Régourdou 1 (Piveteau, 1966), Shanidar 2 and 4 (Stewart, 1962; Trinkaus, 1983), Subalyuk (Pap et al., 1996), and Dolní Věstonice 14 (Sládek et al., 2000).

Methods

We used standard anthropometric techniques and instruments to take all measurements. The metric variables are illustrated in Fig. 1. Following Meyer (2005), the areas of vertebral canals were measured on scaled digital images and cross-checked for accuracy by comparing imaged linear measurements to physical dimensions measured with digital calipers. This method avoids the considerable error of area estimation by simply multiplying the dorsoventral and transverse diameters of the neural canal (Meyer, 2005). Vertebral-canal areas were measured on cranial (atlas) and caudal (axis) photographs using CAD software and cross-checked using the canal's maximum transverse diameter (M11). For the atlas, the photograph was taken in superior view.

[1] The exceptions are the specimens from Dmanisi (Meyer, 2005), Gran Dolina (Carretero et al., 1999), and Koobi Fora (KNM-ER 1808; Walker et al., 1982; Leakey and Walker, 1985) for the early Pleistocene and, for the middle Pleistocene, the atlas from the Zhoukoudian I1 individual (Boaz et al., 2004).