CHAPTER XXVI-2

INTERNAL STRUCTURE OF THE HUMERI

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Abstract

Cross-sectional properties of long bones are commonly used for reconstructing mechanical loading histories related to locomotion, subsistence strategies, and manipulative behaviour. In this respect, a significant degree of functional bilateral asymmetry of the arm, likely related to unilateral activity levels, has been reported for Neandertals.

The two adult Neandertal partial skeletons Spy I and Spy II preserve both incomplete right and left humeri (Spy 5A and 5B; Spy 14B and 14A). We used techniques of CT-based virtual 3D modeling in order to quantitatively characterise their endostructure and to assess their degree of functionally-related bilateral asymmetry.

Spy I and Spy II show distinct patterns of topographic cortical distribution along the shaft and of endostructural degree of asymmetry. Compared to Spy I, Spy II is absolutely and relatively more robust and reflects a significantly higher degree of inner heterogeneity in mechanical loading patterns, with marked right dominance (14B).

INTRODUCTION

Evidence from the human fossil record proves that marked functionally-related structural changes in diaphyseal morphology of the upper limb (general robustness and related geometric properties) occurred through the Pleistocene (e.g. Ruff *et al.*, 1993). Compared to the morphostructural condition shown by the early anatomically modern humans, the Neandertal arm is characterised by a degree of robusticity revealing higher levels of habitual manipulative loads (Trinkaus, 1996; Churchill & Schmitt, 2002). Also, likely in relationship to unilateral activity levels and preferences, the Neandertal humerus shows marked bilateral asymmetry, with usual right side hypertrophy (Trinkaus *et al.*, 1994; Trinkaus, 1996; Volpato *et al.*, 2011). In terms of cross-sectional geometric properties, the extent of Neandertal functional asymmetry approximates the pattern currently shown by professional tennis-players (Trinkaus *et al.*, 1994).

The two adult Neandertal partial skeletons from the cave of Betche aux Rotches, near Spy (Fraipont & Lohest, 1886, 1887), currently referred to as Spy I and Spy II (Rougier *et al.*, 2004), preserve both incomplete humeri, labeled Spy 5A and 5B (right and left from Spy I, respectively), and Spy 14B and 14A (right and left from Spy II, respectively). Spy 5A, 14A and 14B miss the proximal end, while both extremities are not preserved in 5B.

Despite evidence from a previous study on the cross-sectional properties of the Spy II humeri (Trinkaus *et al.*, 1994), the polarity and comparative amount of functional asymmetry and handedness of the upper arm of these two Neandertal individuals are not yet reported.

By using advanced techniques of (µ)CT-based three-dimensional (3D) virtual reconstruction-modeling and quantitative structural analysis of long bone shafts already successfully applied to the Neandertal fossil record (Volpato *et al.*, 2005, 2006, 2007, 2011; Mazurier & Macchiarelli, 2006; Macchiarelli *et al.*, 2007; Volpato, 2007), here we present the volumetric endostructural characterisation of Spy I and II humeri and the assessment of their degree of functionally-related bilateral asymmetry.

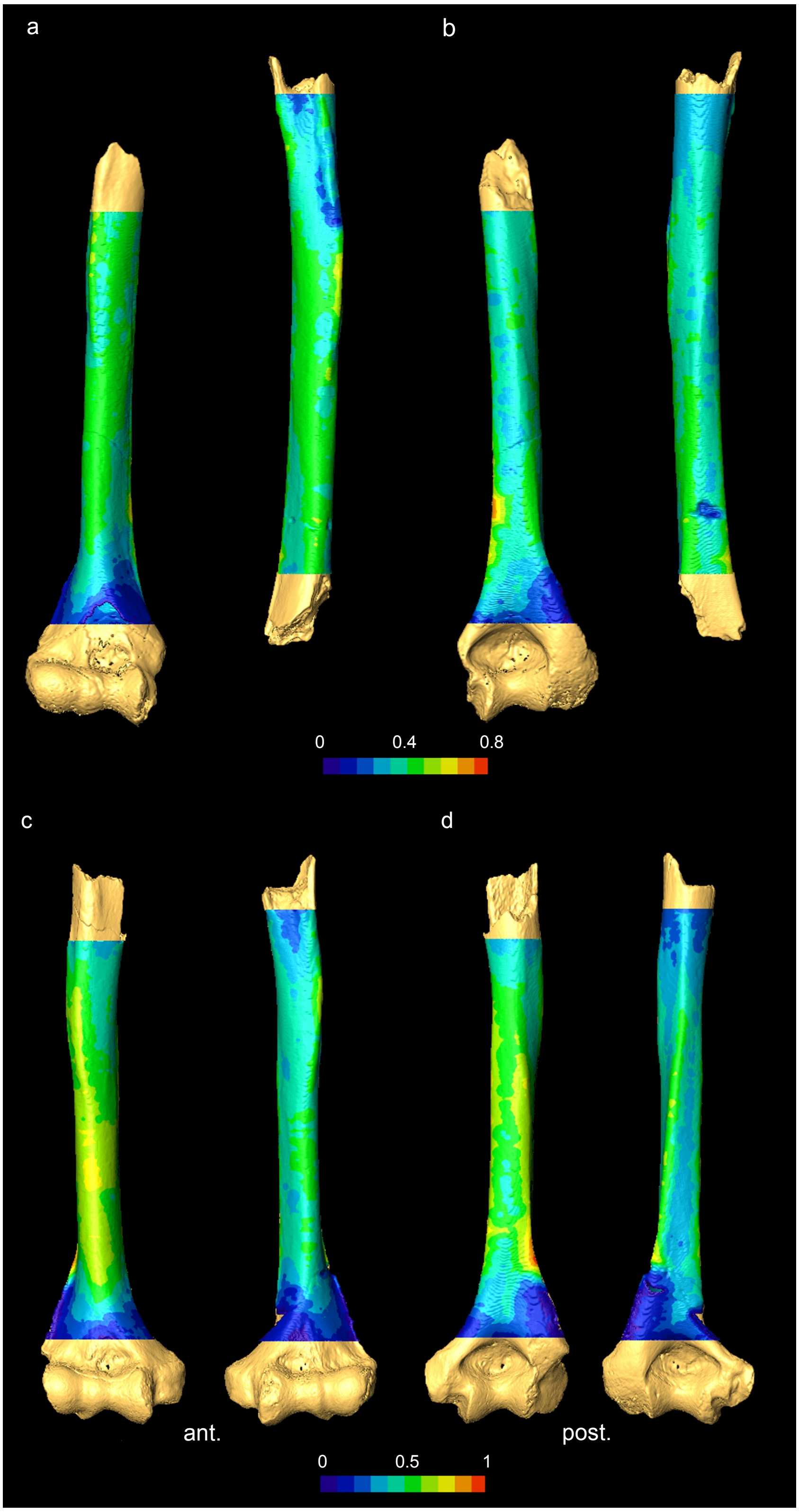

Figure 1. CT-based 3D mapping of the topographic distribution of the cortical bone thickness in Spy I (5A right and 5B left) and Spy II (14B right and 14A left) humeri. Upper row: 5A and 5B in anterior (a) and posterior (b) view. Bottom row: 14B and 14A in anterior (c) and posterior (d) view. Images, not to scale, rendered by means of a 10-stepped chromatic scale (in cm).

METHODS

While incomplete and partially filled by sediment, the four undistorted diaphyses are, as a whole, in relatively good preservation conditions (Hambücken, this volume: chapter XXVI-1), suitable for an inner structural characterisation.

The 3D virtual reconstruction and structural analysis of the adult humeral shafts from Spy (5A right and 5B left from Spy I, and 14B right and 14A left from Spy II) are based on a tomographic (CT) record performed in 2005 by means of a Siemens Sensation 64 CT model by researchers at the Royal Belgian Institute of Natural Sciences, Brussels.

Sections from the original record have been reconstructed and saved on Dicom format at a voxel size of 197.3 x 197.3 x 100 µm for Spy 5A and 5B, and of 195.3 x 195.3 x 300 µm for Spy 14A and 14B. The final volumes have been elaborated by means of AMIRA v4.0 package (Mercury Computer Systems, Inc.). The specimens have been oriented following the standardised protocol suggested by Ruff (2002).

The 3D mapping of the cortical thickness distribution along the diaphyses has been realised using a semi-automatic segmentation method, and the relative bone topographic variation has been rendered by means of a 10-stepped chromatic scale.

In the case of 5B, 14A, and 14B, the cortical and medullary volumes (CV and MV, in cm^3) have been respectively quantified for the shaft portions comprised between 35 % and 50 % (distal volume) and 50 % to 65 % (proximal volume) of the estimated biomechanical length. For Spy 5A and 5B, the former being incomplete above about 62.65 % of the shaft length, these variables have been assessed between 50 % and 62.65 % (restricted proximal volume). For each individual, the degree of bilateral asymmetry of the volumes (aV) has been quantified according to the formula: ([(max – min)/min] x 100) (Trinkaus *et al.*, 1994).

RESULTS AND DISCUSSION

The 3D virtual rendering of the four humeri in anterior and posterior views is shown in Figure 1. The quantitative assessment of the

	5A (r)	*5B (l)*	*14B (r)*	*14A (l)*	*aV Spy I*	*aV Spy II*
dCV (%)	7.47 (74.8)	7.37 (76.8)	13.01 (85.5)	9.38 (80.5)	1.36 %	38.64 %
dMV (%)	2.51 (25.2)	2.23 (23.2)	2.20 (14.5)	2.28 (19.5)	12.72 %	3.43 %
pCV (%)	-	7.49 (74.4)	12.16 (74.7)	9.32 (70.5)	-	30.58 %
pMV (%)	-	2.58 (25.6)	4.11 (25.3)	3.89 (29.5)	-	5.67 %
rpCV (%)	6.45 (74.6)	6.35 (75.5)	-	-	1.64 %	-
rpMV (%)	2.19 (25.4)	2.06 (24.5)	-	-	6.54 %	-

Table 1. Absolute (in cm^3) and percent cortical (CV) and medullary (MV) volumes of the humeri from Spy I (5A and 5B) and Spy II (14A and 14B) assessed for the distal portion (d) comprised between 35 % and 50 %, the proximal portion (p) between 50 % and 65 %, and the restricted proximal portion (rp) between 50 % and 62.65 % of the relative estimated biomechanical length. Bilateral asymmetry of the volumes (aV; see Methods) is also given for each individual. r = right; l = left.

cortical and medullary volumes for different diaphyseal portions is reported in Table 1.

Spy 5A and 5B

With respect to the inner cortical bone topography of the humeri (Figure 1, upper row), Spy I shows a relative homogeneity in thickness distribution along the entire diaphysis, with only a modest distinction between right and left side, similarly to the modern human condition (Volpato, 2007). On both 5A and 5B, the thickest bone is found along the medial border of the shaft and in proximity of the deltoid tuberosity (anterior aspect).

Percent cortical volumes of the proximal (restricted proximal, i.e. 50-62.65 %) and distal (35-50 %) portions of the shaft are similarly distributed within and between the two specimens, with a slight relative prevalence of the left humerus (Table 1). A higher degree of absolute bilateral asymmetry is recorded for the medullary volume, mostly on the distal portion. Nonetheless, functionally-related endostructural asymmetry in this individual, which also shows weak muscular imprints on its external aspect, is extremely modest, with minor right dominance.

Spy 14B and 14A

In Spy II, the 3D-rendered cortical bone topography of the humeri (Figure 1, bottom row) shows a much more contrasted pattern in thickness distribution along both the anterior and posterior aspects of the diaphysis than observed in Spy I, with marked differences between the right specimen 14B, which is also much thicker (average cortical thickness on the mapped portion of the shaft = 3.1 mm) than its counterpart 14A (average = 2.3 mm). This result is particularly relevant also in the light of the quasi-identical preservation conditions (external and structural) shown by the two specimens. The thickest cortical values equal 9.5 mm and 7.8 mm, on the right and left shafts, respectively.

Although distinct quantitatively, in both humeri the greatest amount of bone is found at the level of the deltoid tuberosity, along the central anterior ridge, along the antero-lateral and antero-medial aspects, and along the lateral and medial parts of the posterior face. This pattern fits the topography of the muscular insertions of the *deltoideus*, the *brachialis*, and the *brachioradialis*, on the anterior aspect, as well as of the *triceps brachii* on the posterior part, i.e. of the muscles primarily involved in the flexion/extension of the arm.

In 14A and 14B, cortical volume is absolutely and relatively greater distally (35-50 %), to a proportional extent comparable to the figures reported for the Neandertal humeri of Regourdou, Dordogne (Volpato *et al.*, 2005, 2006, 2011). Also, similarly to the French specimen and differently from Spy I, Spy II shows strong right arm dominance.

CONCLUDING REMARKS

The humeri of the adult Neandertal individuals Spy I (5A and 5B) and Spy II (14A and 14B) show distinct patterns of cortical topographic distribution along the shaft and of endostructural degree of bilateral asymmetry. Compared to Spy I, Spy II is absolutely and relatively more robust and reflects a significantly higher degree of inner heterogeneity in mechanical loading patterns between the two sides, with marked right dominance (14B). As a whole, the model of relative cortical bone distribution found on Spy II is similar to the condition reported for Regourdou 1 (Volpato *et al.*, 2011), even if Spy II displays even stronger bilateral difference.

The Spy II amount of 3D (volumetric) cortical asymmetry assessed virtually (38.64 % distally and 30.58 % proximally) is comparable to the figures reported by Trinkaus and co-workers (1994) for its 2D geometric properties. In fact, the cross-sectional asymmetry on CA measured at 35 % and 50 % of the biomechanical length equals 45.9 % and 43.2 %, respectively (at the same locations, asymmetry of the medullary area corresponds to 23.2 % and 2.9 %; Trinkaus *et al.*, 1994).

Results from Spy I, which are rather unusual among adult Neandertals (Ben-Itzhak *et al.*, 1988; Trinkaus *et al.*, 1994; Trinkaus, 1996; Volpato *et al.*, 2011), testify to both a relative endostructural gracility and, mostly, to a much less heterogeneous loading pattern between the two arms, with only a slight right dominance, likely resulting from comparable levels of habitual manipulative activity.

While not conclusive, but only suggestive on this controversial matter, the differences recorded among the Spy I and Spy II humeri in terms of subtle endostructural organisation and degree of volumetric asymmetry of the cortical bone can be seen as reflecting both functional and sex differences (Ben-Itzhak *et al.*, 1988).

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