**SI2 Cross-sectional geometry (CSG)**

**I) Details of cross-sectional geometry analysis**

The study of the biomechanical competence of long bones analyzes the cross-sectional geometry (CSG) at specified percentages of bone length (mechanical length, as indicated in Ruff, 2002), using the polar moment of area as a measure of overall bending and torsional rigidity (Ruff, 2000). The method is based on the widely accepted notion that bone tissue optimizes to its mechanical environment so as to maintain physiological strains within the normal limits [“Wolff’s Law,”, better referred to as “Bone Functional Adaptation” (cf. Pearson and Lieberman, 2004; Ruff et al., 2006b)]. Bone tissue is deposited in the shaft’s cross-section where mechanical loads require it to prevent strains in excess of the elastic limit, whereas below a certain strain threshold, the bone tissue is reabsorbed.

In this study, we use mid-shaft and mid-distal cross sections for the humeri, mid-shaft and mid-proximal sections for the forearm, and mid-shaft sections for the lower limb (femur, tibia, and fibula). When available, cross-sections were reconstructed from both sides of the upper limb, in order to evaluate bilateral asymmetry (see below). Only one side of the lower limb was sampled, with preference to the right side. In the case of BT individuals, all measurements for the lower limb come from the right side elements.

By analyzing the cross-sections of the diaphysis, it is therefore possible to obtain variables that correlate with the bending moments (second moments of area: I) and overall torsional rigidity (polar moment of area: J or Ip) of the diaphysis. J is proportional to the torsional rigidity of a bone and is calculated as the sum of two perpendicular SMAs. The cross-sectional variable Zp (section modulus) is used here to evaluate overall bone rigidity, and is calculated by raising the polar second moment of area (J) to the power of 0.73 (Ruff 1995, 2000). Bending moments are influenced by body dimensions; in order to obtain measures of relative strength, or robusticity (*sensu* Ruff et al. 1993), which can aid the reconstruction of functional adaptations to patterns of activity, Zp needs to be scaled by bone length and the body mass of the individual (Ruff, 2000). For most individuals, body mass was estimated from the superoinferior diameter of the femoral head following the guidelines in Trinkaus and Ruff (2012). For some individuals in the comparative sample for which the femoral head was not preserved and could not be estimated via regression equations based on the rest of the Late Pleistocene sample, body mass was calculated using the cylindrical method (Holt, 1999; Ruff et al., 2006a).

In addition to overall strength, indices are used to characterize functional adaptations related to the asymmetric use of the dominant upper limb in various activities (Trinkaus et al., 1994; Churchill et al., 2000; Rhodes and Knüsel, 2005; Shaw and Stock, 2009a; Sparacello et al., 2011, 2015, In Press), as well as to evaluating the shaping of the cross-sections of the lower limbs in response to varying levels and types of mobility (Holt, 1999, 2003; Shaw and Stock, 2009b, 2013; Marchi and Shaw, 2011; Carlson and Marchi 2014). For the upper limb elements, asymmetry was computed as: (maximum J – minimum J) / minimum J, expressed as a percentage (Trinkaus et al., 1994), and hence it represents an absolute (non-directional) asymmetry. For the lower limbs, we calculated the cross-sectional shapes, i.e. the ratios of perpendicular second moment of areas. For the tibia, Imax/Imin (ratio of the maximum and minimum SMA) was used, while for the femur, Ix/Iy (ratio of SMAs calculated about ML and AP planes) was preferred (Sparacello et al., n.d.). Another index, the relative fibular robusticity was calculated as 100 × (J fibula/J tibia) (Marchi and Shaw, 2011; Sparacello et al., 2014, In Press a). Finally, the ratio of tibial vs humeral robusticity (average between sides; only invididuals with paired humeri were included) was calculated, given its correlation with mobility levels (Shaw and Stock, 2013). All indices and ratios are derived from unstandardized data.

The cross-sectional parameters were obtained, depending on the available technology, from CT scans of the humeri, subperiosteal molds plus biplanar radiography for cortical thickness, ellipse formulae employing external diameters and cortical thickness, and scaled photographs of fossilization breaks (O’Neill and Ruff, 2004). For some individuals, cross-sectional parameters were computed from subperiosteal contour modeled as a solid section, and the CSG measures were computed based on recent human regressions (Sparacello and Pearson, 2010). In addition, in order to include humeri with internal damage or for which cross-sectional data is not available, in some cases midshaft second moments of area were estimated from maximum and minimum subperiosteal diameters using a least squares multiple regression based on: 1) a pooled sample of Late Pleistocene individuals for the humeri (Sparacello et al., In Press) and femora (Trinkaus, personal communication); 2) a pooled sample of Pleistocene individuals and modern humans for the radius, ulna, and tibia (Pearson, 1997; Pearson et al., 2006; Pearson and Sparacello, In Press). The different techniques for obtaining cross-sectional parameters provide consistent results, well within the variation produced by the variable preservation of the fossil remains (cf. Macintosh et al., 2013; O’Neill and Ruff, 2004; Sparacello and Pearson, 2010; Stock, 2002).

**II) CSG properties for BT individuals and the comparative sample.**

Figure 1. Ulnar robusticity [section modulus Zp (mm3) standardized by dividing for body mass (kg) and bone length (mm)]. Values for BT individuals compared to the sample statistics of the Middle Upper (MUP) and Late Upper (LUP) Paleolithic specimens. Boxplots indicate the median (horizontal bar), the upper and lower quartiles (boxes), and the upper and lower non-outlier extremes (vertical bar).

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Figure 2. Radial robusticity [section modulus Zp (mm3) standardized by dividing for body mass (kg) and bone length (mm)]. For explanations, see figure 1.

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Figure 3. Ulnar bilateral asymmetry in diaphyseal rigidity [100 x (max J – min J)/ min J]. J: polar moment of area, mm4 . For explanations, see figure 1.

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Figure 4. Fibular robusticity [section modulus Zp (mm3) standardized by dividing for body mass (kg) and bone length (mm)] and relative fibular/tibial robusticity [100 x (fibular J/tibial J)]. For explanations, see figure 1.

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