C. R. Palevol 13 (2014) 747–754

Contents lists available at ScienceDirect

Comptes Rendus Palevol

www.sciencedirect.com

Human palaeontology and prehistory (Palaeoanthropology)

The Regourdou 1 Neandertal body size

Nouvelles données sur la taille du Néandertalien Regourdou 1 (Dordogne, France)

Joseph Michael Plavcan[a], Valentine Meyer[b], Ashley S. Hammond[c], Christine Couture[b], Stéphane Madelaine[b,d], Trenton W. Holliday[e], Bruno Maureille[b], Carol V. Ward[f], Erik Trinkaus[g,*]

[a] *Department of Anthropology, University of Arkansas, Fayetteville AR 72701, USA*
[b] *UMR 5199 PACEA, Université Bordeaux-1, allée Geoffroy-Saint-Hilaire, CS 50023, 33615 Pessac, France*
[c] *Department of Anatomical Sciences, Stony Brook University, Stony Brook NY 11794, USA*
[d] *Musée National de Préhistoire, 1, rue du Musée, 24620 Les Eyzies-de-Tayac, France*
[e] *Department of Anthropology, Tulane University, New Orleans LA 70118, USA*
[f] *Department of Pathology and Anatomical Sciences, University of Missouri School of Medicine, Columbia MO 65212, USA*
[g] *Department of Anthropology, Washington University, Saint Louis MO 63130, USA*

ARTICLE INFO

Article history:
Received 13 June 2014
Accepted after revision 19 July 2014
Available online 16 September 2014

Handled by R. Macchiarelli

Keywords:
Femur
Pelvis
Acetabulum
Body proportions
Europe
Late Pleistocene

Mots clés :
Fémur
Bassin
Acétabulum
Proportions corporelles
Europe
Pléistocène supérieur

ABSTRACT

In order to maximize sample sizes for the assessment of body size and proportions among Late Pleistocene humans, the femoral head diameter of the Regourdou 1 Neandertal was estimated from its ischial acetabular lunate surface, so as to provide a reliable measure for body mass assessment. This estimate was accomplished by fitting a sphere to the 3D surface of the acetabulum and then estimating femoral head diameter using a regression of acetabular sphere diameter to femoral head diameter based on associated recent human femora and ossa coxarum. The resultant mean and range of values for the Regourdou 1 femoral head dimension place it among the smaller of the European and southwest Asian Neandertals, although its humeral length is above average for that sample. Regourdou 1 therefore joins Kebara 2 in having moderately long arms for body core size, and it thereby emphasizes the variation in Neandertal body proportions.

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RÉSUMÉ

Le diamètre de la tête fémorale de Regourdou 1 a été estimé à partir des dimensions de la portion ischiatique de l'acétabulum. Cette mesure permet d'estimer certaines variables corporelles et apporte ainsi de nouvelles données sur la taille et les proportions corporelles des hommes du Pléistocène supérieur. L'estimation de ce diamètre s'est faite en deux étapes. Dans un premier temps, une sphère a été virtuellement conformée sur la surface 3D de l'acétabulum ischiatique. Dans un second temps, le diamètre de la tête fémorale a été estimé à partir du diamètre de la sphère acétabulaire grâce à une formule de régression calculée sur un échantillon de référence moderne. La moyenne des résultats obtenus, comme l'étendue des valeurs, place Regourdou 1 parmi les plus petits Néandertaliens (Europe et Asie du

* Corresponding author.
E-mail address: trinkaus@wustl.edu (E. Trinkaus).

http://dx.doi.org/10.1016/j.crpv.2014.07.003
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Sud-Ouest confondus), bien que cet individu présente une longueur humérale supérieure à la moyenne de ce même échantillon. Ces caractéristiques permettent de rapprocher Regourdou 1 de Kebara 2, ces deux individus présentant des bras relativement longs par rapport à la taille du corps. Ces nouvelles données sont ainsi l'occasion d'enrichir la variation des proportions corporelles chez les Néandertaliens.

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1. Introduction

Assessments of body size among Late Pleistocene humans provide a variety of insights into their paleobiology. Body size estimates provide a baseline for scaling appendicular hypertrophy, especially for weight-supporting elements (Ruff, 2000; Trinkaus and Ruff, 2012). They are an initial step in estimating differential energetic expenditure (Leonard and Robertson, 1997; Ocobock, 2014; Sorensen and Leonard, 2001). They are a core element for assessing body proportions (Carretero et al., 2012; Holliday, 1997a; Trinkaus et al., 2014). Body size estimates also permit assessments of sexual dimorphism, for those specimens with sexually diagnostic pelvic remains (Plavcan, 2001; Ruff, 2010; Trinkaus, 1980). For these reasons, it is desirable to maximize the available sample sizes for the estimation of body mass among the Pleistocene humans. To this end, we have applied the three-dimensional geometric techniques developed by ASH, JMP and CVW (Hammond et al., 2013) to estimate the acetabular size of the Regourdou 1 Neandertal, and then used that value to reconstruct its femoral head diameter. The resultant femoral head diameter can in turn provide a reasonable estimate of body mass for the individual represented by this partial skeleton (cf. Auerbach and Ruff, 2004).

2. Regourdou 1

The Regourdou 1 partial skeleton was discovered during excavations in Level 4 of the collapsed karstic chamber at Regourdou (Montignac, Dordogne) by R. Constant and then E. Bonifay and colleagues in 1957 (Bonifay and Vandermeersch, 1962; Bonifay et al., 2007; Madelaine et al., 2008). Subsequent excavations and sorting through the faunal remains have yielded additional human remains (Madelaine et al., 2008). Assessments of the stratigraphy and faunal remains from Level 4 suggest that it accumulated during a moderately warm phase of the earlier last glacial, probably within Marine Isotope Stage (MIS) 4 (Bonifay et al., 2007).

The partial skeleton consists of major portions of the mandible, the mandibular dentition, a fragmentary vertebral column, the sternum, the bilateral upper limb long bones, major portions of the hands, partial ossa coxarum, partial femora, patellae, talocrural remains, and partial pedal skeletons (Madelaine et al., 2008). Despite the complicated history of the discovery, excavation and identification of the Regourdou 1 human remains (Madelaine et al., 2008), these remains appear to derive from a single individual based on their in situ positions and anatomical concordance; the presence of a second individual is nonetheless suggested by the pedal remains (Vandermeersch and Trinkaus, 1995). Relevant to assessments of body size and proportions are the vertebrae (Gómez-Olivencia et al., 2013), from which a "skeletal trunk height" has been estimated (Holliday, 1995), and the right upper limb long bones, which provide clavicular, humeral and radial lengths (Vandermeersch and Trinkaus, 1995). However, the fragmentary and incomplete pelvis and femora provide limited assessments of body breadth and coxal articular dimensions (Meyer et al., 2011). Moreover, the pelvis exhibits a marked asymmetry (Meyer, 2013), and the femoral diaphyses are abnormal and asymmetrical (Madelaine et al., 2008; BM, VM and ET, pers. observ.); these pelvic and femoral asymmetries are not related to the modest—for a Late Pleistocene human; cf. Cowgill et al. (2012)—, normal, and handedness-related asymmetries evident in the upper limb remains (Volpato et al., 2012).

A small portion of the right femoral neck and head has been identified from among the faunal remains (Madelaine et al., 2008). However, it does not connect to the partial femoral diaphysis and only the neck portion retains cortical bone over much of its surface. The trabecular core of the head has suggested a large femoral head (Madelaine et al., 2008), but insufficient subchondral bone remains for an accurate estimation of the femoral head diameter.

The pelvic remains (Meyer, 2013; Meyer et al., 2011) consist of the first sacral vertebra, a right portion of the second sacral vertebra, the right inferior ilium to the anterior inferior iliac spine with a small portion of the superior acetabulum, the left inferior ilium with a portion of the posterior acetabulum, a small piece of the inferior left ischial acetabulum, a piece of the right superior pubic ramus, and the largely complete right ischium (Fig. 1). The last element (Fig. 2) retains the ischial tuberosity and the intact acetabular surface from the mid-dorsal margin ventrally to the acetabular notch, without erosion and only a thin layer of sediment encrustation on the acetabular subchondral bone (lunate surface). It is to the acetabular surface of this element that a sphere was fitted, in order to estimate the diameter of the Regourdou 1 femoral head. There are portions of the acetabular subchondral bone preserved on the ilia and the left ischium (Fig. 1), but none is sufficiently intact or articulated so as to enhance the acetabular sphere-fitting.

Although the greater sciatic notch and the auricular area are preserved on both ilia, they are ambiguous as to the sex of Regourdou 1. The greater sciatic notch is largely "male" in

Fig. 1. (Color online.) Ventral view of the articulated Regourdou 1 ilia and sacrum with the ischial portions and the superior pubic ramus in approximate anatomical positions.
Fig. 1. (Couleur en ligne.) Vue antérieure du bassin Regourdou 1: sacrum et iliums en connexion, associés aux fragments ischiatiques et pubiens en position anatomique.

Fig. 2. (Color online.) Ventrolateral view of the Regourdou 1 right ischium, showing the acetabular lunate surface used for the 3D sphere-fitting.
Fig. 2. (Couleur en ligne.) Vue antérolatérale de l'ischium droit de Regourdou 1, montrant la surface semi-lunaire utilisée pour l'estimation 3D de la sphère acétabulaire.

shape, but the composite arch is "female" (cf. Brůžek, 2002). It is therefore considered to be of indeterminate sex.

3. Femoral head diameter estimation

To estimate the Regourdou 1 femoral head diameter, data were gathered for 91 recent human ossa coxarum and articulating femora. The sample consists of Native Americans (13 male; 14 female), EuroAmericans (16 male; 17 female) and AfroAmericans (15 each sex), from the archeological sites of Zuni and Puye Hawikkuh and the Terry, Hamann-Todd and University of Missouri collections. All are fully mature and non-pathological. Given the close developmental and functional correspondence of the femoral head and acetabulum (Bonneau et al., 2014), they are expected to covary closely in dimensions. Variations in acetabular versus femoral head orientation (Bonneau et al., 2014) do not affect the estimation of femoral head diameter applied here.

The acetabular dimensions and 20 of the femoral head diameters were quantified from 3D surface scans, collected with either a Konica-Minolta Vivid 9i or a Next-Engine laser scanner, which yield comparable results (Aguilar et al., 2009; Guidi et al., 2007, 2010; Sholts et al., 2010). Acetabular and femoral head diameters were estimated as the diameter of a best-fit sphere in PolyWorks software (v.12) (InnovMetric, Québec, Canada). Methods and accuracy of the sphere-fitting technique for the acetabulum are described in Hammond et al. (2013). The technique yields intra- and inter-observer error rates of < 1.7% for repeated trials. Repeated trials within and among observers for femoral head diameters yield errors of < 1.2%. For 71 of the specimens, for which only scans of the acetabulae are available, superoinferior femoral head diameters were measured by D. Hunt of the United States National Museum using calipers. Comparison of femoral head diameters from scan data versus those taken on femora with calipers yields error rates of < 1.5% (Plavcan et al., 2014).

A resin cast of the Regourdou 1 right ischium provided by B. Vandermeersch and R. Larche was scanned using a Next-Engine laser scanner to generate a 3D surface scan (Fig. 3). To check for cast shrinkage, four linear measurements on it were compared to the same ones taken by ET on the original specimen (cotylosciatic breadth, tuberosity length and breadth, and preserved acetabular rim chord). The cast to original dimension differences varied from –1.3% to +0.5%, for an average of –0.6%.

The preserved portion of the Regourdou 1 acetabulum corresponds to regions 5 to 7 of the acetabulum, as designated by Hammond et al. (2013). PolyWorks software (v.12) was used to determine the best-fit sphere to the surface. A sphere was fit to the Regourdou 1 scan three times yielding diameters of 51.980, 51.930 and 51.926 mm, for a mean acetabular sphere value of 51.945 mm (note that these values are given to the precision of the scanners and the software; they are used to avoid rounding errors, but then reduced to the nearest 0.1 mm for comparative assessments; see Table 1 and below). The maximum and minimum values for the acetabular diameter were then calculated from the mean value using the prediction error of 3.2% for regions 5 and 6 of the acetabulum, as detailed in

Table 1
Femoral head diameter estimates for Regourdou 1 (Smearing correction = 1.0003).
Tableau 1
Estimations du diamètre de la tête fémorale de Regourdou 1 (correction de Smearing = 1,0003).

Acetabular Sphere Diameter[a]		Femur Head Diameter (mm)	95% Confidence Interval	
Estimates	Ln-Estimate		Minimum	Maximum
50.3	3.918	44.5	42.1	47.0
51.9	3.950	45.9	43.5	48.5
53.6	3.982	47.4	44.8	50.0

[a] The three estimates for acetabular sphere diameter are from the mean determination value (51.9 mm) ± 3.2%, the prediction error for using regions 5 and 6 of the acetabulum (cf. Hammond et al., 2013).

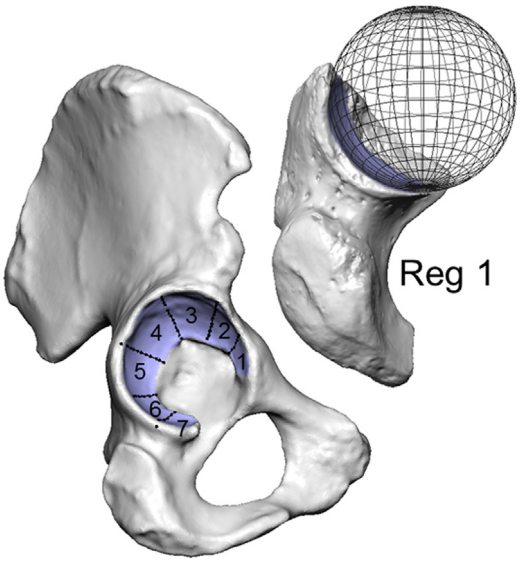

Fig. 3. (Color online.) A modern human male os coxae (NMNH 1360) with the numbered sections of the acetabular portions (following Hammond et al., 2013) indicated, plus the Regourdou 1 ischium with a sphere fit to the acetabular lunate surface. The Regourdou ischial surface corresponds approximately to sections 5–7, although we approach this conservatively and used error rates associated with areas 5–6. Both images derive from scans. Pelves not to the same scale.
Fig. 3. (Couleur en ligne.) Os coxal moderne masculin (NMNH 1360) présentant les différentes portions acétabulaires; ischium droit de Regourdou 1, associé à la sphère corrélée à la surface semi-lunaire. L'ischium de Regourdou correspond approximativement aux sections 5 à 7, mais le taux d'erreur considéré correspond aux sections 5–6. Les deux images proviennent de laser-scans et ne sont pas à la même échelle.

Hammond et al. (2013). Applying this error rate resulted in a 95% confidence interval (CI) of acetabular sphere estimates from 50.3 to 53.6 mm for Regourdou 1. From these estimates of acetabular sphere diameter, the diameter of the contained femoral head was predicted using regression analysis (Table 1) as follows.

All data were ln-transformed, and a least squares (LS) regression line between femoral head and acetabular diameters was fit. LS regression is preferred over reduced major axis (RMA) for prediction purposes (Smith, 2009). The correlation between the acetabular and femoral head sphere diameters is high ($r = 0.967$). The resultant equation is:

$$\ln(\text{FemHd}) = 0.991 \times \ln(\text{Acet}) - 0.090;\ SE_{est}: 0.028$$

in which: ln(FemHd) = natural logarithm of the femoral head diameter, and ln(Acet) = natural logarithm of the acetabular sphere diameter. The slope of the relationship does not significantly differ from 1.00. All femoral head diameter estimates were back-transformed from ln-space and corrected using the "Smearing" estimate (Smith, 1993). Percent prediction error for the back-transformed data is 1.7%.

Note that this acetabular sphere diameter is not the same as acetabular height, measured with calipers from the acetabular rim adjacent to the anterior inferior iliac spine to the opposite caudal rim. Acetabular height has been employed to estimate femoral head dimensions (Ruff, 2010; Trinkaus, 1980; Trinkaus and Ruff, 2012), and it provides values close to those using the acetabular sphere (Table 2). The prediction of femoral head diameter from acetabular height using LS regression of ln-transformed data from a pooled sample of recent human associated femora and ossa coxarum (Table 2) provides a correlation of 0.971 and a slope of 1.130; the slope 95% CI is 1.07–1.19, and hence it exhibits slight allometry.

The acetabular sphere values for Regourdou 1 were ln-transformed, femoral head diameter estimates calculated, and the values back-transformed. 95% confidence intervals were calculated in ln-space for each estimate using the standard error of the relationship between the acetabular sphere and femoral head diameters, and back-transformed to raw data space. The best estimate of femoral head size for Regourdou 1 using the mid-point value for the acetabular estimate is 45.9 mm, with a 95% confidence interval ranging from 43.5 to 48.5 mm. Substituting the minimum and maximum estimates of acetabular sphere diameter yields estimates of 44.5 and 47.4 mm, respectively. From the 95% CIs of these two limits of the acetabular sphere 95% CI, the absolute minimum estimated femoral head diameter would be 42.1 mm and the maximum 50.0 mm. However, this total range probably overestimates the true 95% CI, since the maximum value approaches the measured sphere diameter; a more likely range is provided by the 95% CIs of the mean femoral head diameter estimate, 43.5 to 48.5 mm (Table 1). These three values (a mean of 45.9 mm, and a range of 43.5 and 48.5 mm) are therefore used in the comparisons below, bearing in mind that the maximum possible range may have been slightly larger.

4. Regourdou 1 comparative body size and proportions

4.1. Body size

Given the relationship between femoral head diameter and body mass in recent humans (Grine et al., 1995;

Table 2
Comparative Neandertal femoral head diameters and humeral lengths. Estimates are in parentheses; such values for femoral head diameters provide the mean estimate from acetabular or condylar dimensions. Personal measurement from original remains unless otherwise indicated.
Tableau 2
Diamètres des têtes fémorales et longueurs humérales des Néandertaliens. Les données entre parenthèses sont des estimations moyennes, celles pour les têtes fémorales sont calculées à partir des dimensions de l'acétabulum et du condyle fémoral. Sauf mention contraire, les données sont personnelles.

	Pelvic Sex[a]	Femur Head Diameter (mm)	Humerus Maximum Length (mm)	Body Mass Estimation (kg)[b]
European				
La Chapelle-aux-Saints 1	M	52.4	312	81.1
Feldhofer 1	M	52.2	312	80.6
La Ferrassie 1	M	54.0	337	84.9
La Ferrassie 2	F	45.9	286	66.4
Fond-de-Forêt 1		(48.5)[c]		72.9
Krapina 208		(46.3)[d]		66.5
Krapina 209	F	(44.2)[d]		62.6
Krapina 213		52.7		80.9
Krapina 214		44.2		61.2
Lezetxiki 1			321	
Palomas 77		45.6		64.9
Palomas 92		(44.2)[e]		61.7
Palomas 96	F	43.0	272	59.9
Prince 1	F	(49.2)[d,e]		75.5
La Quina 5			(312)	
Regourdou 1		(45.9)	310	65.6
El Sidrón 1609		52.5[f]		82.1
Spy 2		54.0		85.5
Southwest Asian				
Amud 1	M	(51.5)[g]		79.0
Kebara 2	M	(45.9)[g]	320	64.8
Shanidar 3	M		(319)	
Shanidar 4	M	49.2	305	73.5
Shanidar 5		47.5		70.6
Shanidar 6			(293)	
Tabun 1	F	44.5	286	63.2

[a] Sex is attributed to Neandertal specimens only when the appendicular remains are associated with sexually diagnostic pelvic remains, principally from the region of the greater sciatic notch. Approaches using body size alone, although applicable within samples (e.g., Carretero et al., 2012), are considered inappropriate across the temporal and geographic range of the Neandertal sample.

[b] The body mass estimates derive from the formulae of Ruff et al. (1991), McHenry (1994) and Grine et al. (1995) and follow the protocol of Ruff (2010). For femoral head diameters < 47 mm, an average of the results of the three formulae is provided; for femoral head diameters > 47 mm, the average of the Ruff et al. (1991) and Grine et al. (1995) formulae is employed. McHenry (1994) and Grine et al. (1995) have pooled sex samples; Ruff et al. (1991) provided sex-specific samples, such that their sex-specific formulae were used for pelvically-sexed fossils and the average of the two sex-specific formulae was used for those of uncertain sex, including Regourdou 1.

[c] Femoral head diameter estimated from lateral condyle depth [M-22 (Bräuer, 1988)] using a least squares regression based on diverse recent humans and the available Late Pleistocene specimens: FemHdDia = 0.641 × LatCondAP + 5.8, r^2 = 0.881, n = 45; SE_{est} = 1.6 mm (FemHdDia: femoral head diameter; LatCondAP: lateral condyle depth).

[d] Femoral head diameter estimated from its associated acetabular height (from the rim adjacent to the anterior inferior iliac spine, using a least squares regression based on a pooled sample of recent humans: lnFemHdDia = 1.130 × lnAcetHt – 0.710, r^2 = 0.943, n = 89; SE_{est} = 1.3 mm (AcetHt: acetabular height).

[e] Acetabular height (59.0 mm) from de Lumley (1973).

[f] Femoral head diameter from A. Rosas (pers. comm.).

[g] Estimated using the mean diameter of the sphere fit to the acetabulum (Hammond et al., 2013; Plavcan et al., 2014), and the same regression formula as for Regourdou 1, including the Smearing correction of 0.0003. Estimation of the Kebara 2 femoral head diameter from its acetabular height (57.2 mm) provides a mean value of 47.6 mm, and estimation of the Amud 1 femoral head diameter from its acetabular height (60.0 mm) furnishes a mean value of 50.2 mm.

McHenry, 1994; Ruff et al., 1991; cf. Auerbach and Ruff, 2004), the body size of Regourdou 1 relative to the other Neandertals can be estimated by comparing femoral head diameters (Table 2; Fig. 4), as well as body mass estimates (Table 2), bearing in mind the confidence intervals of the Regourdou 1 femoral head diameter estimation and those for the other estimated Neandertal values. The average femoral head value for Regourdou 1 (45.9 mm) is relatively modest for a Neandertal, falling well below the high values for the Amud 1, La Chapelle-aux-Saints 1, Feldhofer 1 and La Ferrassie 1 males, as well as those of three specimens that lack sexually diagnostic pelvic remains and are therefore indeterminate as to sex (Krapina 213, El Sidrón 1609 and Spy 2) (see Table 2). However, it falls close to the estimate for the southwest Asian Kebara 2 male, as well as the probably male Shanidar 5. It is similar to the Neandertal female femoral head diameters, as well as those of the remainder of the specimens. The higher and lower estimates remain largely within the same position relative to the other Neandertal values, among the females and the smaller ones of indeterminate sex. The unlikely maximum value of 50.0 mm would place it among most of the males, but still below seven of the male (or possibly male) diameters (or below 35% of the Neandertal sample).

In contrast, the Regourdou 1 maximum humeral length (310 mm), from the complete right humerus, is moderately large for a Neandertal (Fig. 4). It falls well above the three Neandertal female ones and among the shorter of the male

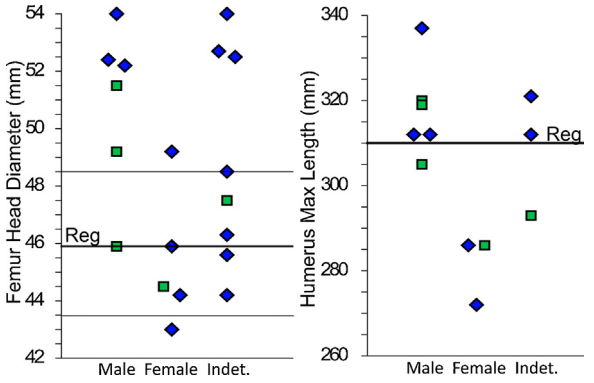

Fig. 4. (Color online.) Femoral head diameter (left) and humeral maximum length (right) for male, female and sex indeterminate Neandertals. European Neandertals: blue diamonds; Southwest Asian Neandertals: green squares. Center line (Reg): mean estimate for Regourdou 1. Superior and inferior lines for femoral head diameter: the probable range of values for its femoral head diameter.

Fig. 4. (Couleur en ligne.) Diamètre de la tête fémorale (à gauche) et longueur humérale maximale (à droite) pour des Néandertaliens (hommes, femmes et sexe indéterminé). Losanges bleus: Néandertaliens européens; Carrés verts: Néandertaliens du sud-ouest asiatique. Ligne centrale (Reg): estimation moyenne pour Regourdou 1. Pour le diamètre de la tête fémorale, les lignes inférieure et supérieure correspondent au domaine de variation de cette estimation.

humeri, close to the La Chapelle-aux-Saints 1 and Feldhofer 1 males (plus La Quina 5) and modestly above the Shanidar 4 male.

4.2. Body proportions

The contrast between the relative dimensions of the Regourdou 1 femoral head diameter and humeral length raises questions regarding its body proportions; since femoral head diameter is a reflection of body mass and humeral length is related to appendicular length and by extension stature. Given this contrast, and the ecogeographical variation in body proportions both between recent humans and across Late Pleistocene human samples (Holliday, 1995, 1997b; Ruff, 1994; Trinkaus, 1981), these dimensions for Regourdou 1 are compared to samples of Middle and Upper Paleolithic modern humans and latitudinally delimited samples of recent humans.

These two skeletal dimensions are compared using the ratio of humeral length to femoral head diameter (Fig. 5). The ratio is ln-transformed, since femoral head diameter scales allometrically to linear body dimensions (Ruff, 2002; Ruff et al., 1993). Recent human variation is represented by four global latitudinal samples, at 20° intervals from the equator, designated equatorial (0°–20°; $n = 115$), warm temperate (20°–40°; $n = 623$), cold temperate (40°–60°; $n = 469$), and arctic (> 60°; $n = 359$). In addition, a pan-Old World sample of earlier Upper Paleolithic modern humans (all > 15 ka BP; $n = 31$), the three Middle Paleolithic modern humans providing both measurements (Qafzeh 9 and Skhul 4 and 5), and the eight other Neandertals with both measurements or estimates thereof (Table 2) are included. The earlier Upper Paleolithic sample includes specimens from Barma Grande, Caviglione, Cro-Magnon, Dolní Věstonice, Fanciulli (Grotte-des-Enfants), Kubbaniya, Minatogawa,

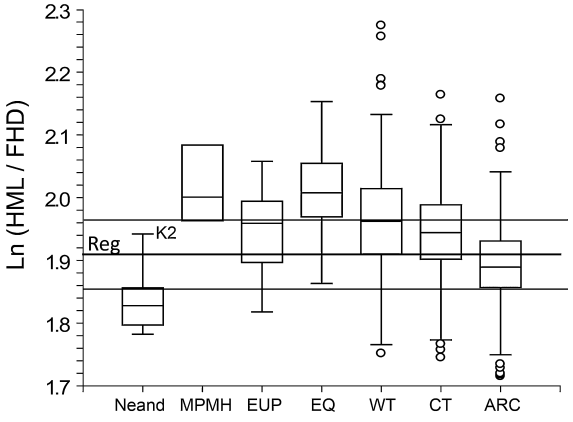

Fig. 5. Box plots of the ln-transformed ratio of humeral maximum length (HML) versus femoral head diameter (FHD) for Neandertals (Neand), Middle Paleolithic modern humans (MPMH), earlier Upper Paleolithic modern humans (EUP), and recent human samples (equatorial: EQ; cold temperate: CT; warm temperate: WT; arctic: ARC). The value for Kebara 2 (K2), the Neandertal high value, is indicated. The ratio from the mean femoral head diameter estimate for Regourdou 1 is provided (center line; Reg) with the ratios from the probable range of values for its femoral head diameter (superior and inferior lines) (see text for justification).

Fig. 5. Diagrammes en boîte de la proportion entre la longueur humérale maximale (HML) et le diamètre de la tête fémorale (FHD) (valeurs ln-transformées) pour les Néandertaliens (Neand), les hommes modernes du Paléolithique moyen (MPMH) et supérieur (EUP), ainsi que des échantillons de populations actuelles issues de différentes zones climatiques (EQ: zone équatoriale; CT: zone tempérée froide; WT: zone tempérée chaude; ARC: zone arctique). La valeur pour Kébara 2 (K2) est indiquée. Dans le cas de Regourdou 1, ce rapport est calculé pour la valeur moyenne de l'estimation du diamètre fémoral (ligne centrale, Reg) ainsi que pour son domaine de variation (lignes inférieure et supérieure). Voir texte.

Mittlere Klause (Neuessing), Ohalo, Paglicci, Pataud, Paviland, Předmostí, Sunghir, Tam Hang and Tianyuan. The recent human samples derive from Sarasin and Roux (1916), Miyamoto (1925), Hirai and Tabata (1928), Ishisawa (1931), Ohba (1935), Holliday (1995), Auerbach (2007), Holliday and Hilton (2010), and personal observations.

The four recent human samples follow the ecogeographical pattern of average relative limb abbreviation with increasing latitude (cf. Holliday, 1995; Ruff, 1994), despite considerable within sample variation. The equatorial sample has the highest ratios and the arctic one the lowest, although the adjacent samples overlap in individual values. The earlier Upper Paleolithic sample is principally among the middle latitude recent human samples, and the majority of the Neandertals are among the portions of the cold temperate and arctic samples with the more abbreviated limbs. Indeed, the Neandertal interquartile range is below those of all of the recent human samples, and its median only overlaps the lower values of the three higher latitude samples. The small Middle Paleolithic modern human sample is among the recent humans with the relatively longer humeri.

Regourdou 1 and one Southwest Asian Neandertal (Kebara 2) have mean values well above the other Neandertals, near the middles of the arctic and cold temperate samples respectively (Fig. 5). They are also well within the earlier Upper Paleolithic variation. Consideration of the range of estimated femoral head diameters of Regourdou 1

(and a smaller range for Kebara 2; cf. Hammond et al., 2013) changes its proportions only modestly relative to the other samples, primarily the larger femoral head diameter value would place it closer to the other Neandertals. Regourdou 1, along with Kebara 2, therefore extends the amount of variation among the Neandertals with respect to limb to body core dimensions in the direction of more moderate upper limb abbreviation.

5. Discussion

The use of sphere-fitting to the partial acetabulum of Regourdou 1, as well as other partial Pleistocene human remains (Hammond et al., 2013; Plavcan et al., 2014), permits the estimation of femoral head diameters, which in turn serve as proxies for body mass as the principal weight-bearing lower limb articulation and permit assessments of lean body mass from recent human regression formulae. Even when the uncertainties in such estimation are taken into account, it provides a relatively modest value for Regourdou 1, among the smaller of the male and unsexable Neandertals and in the middle of the Neandertal female sample. When combined with the length of its complete right humerus, Regourdou 1 is similar to the Southwest Asian Kebara 2 Neandertal in having modest coxal articular dimensions relative to arm length compared to most other Neandertals. As such, and as with the modest biiliac breadth of La Chapelle-aux-Saints 1 (Trinkaus, 2011), it serves to extend the amount of variation of individual aspects of body proportions among the Neandertals.

It is tempting to ascribe this contrast in this body proportion between Regourdou 1 (plus Kebara 2) and the other Neandertals to the Southwest Asian provenience of Kebara 2 and the association of Regourdou 1 with a warmer climate oscillation within the Last Glacial (Bonifay et al., 2007). However, the other southern Neandertals (Palomas 96, Shanidar 4 and Tabun 1) do not exhibit relatively longer humeri. Yet, given the within-sample variation in these proportions across recent humans, some degree of variation in body proportions should nonetheless be expected among the Neandertals.

6. Conclusion

Estimation of the femoral head diameter for the Regourdou 1 Neandertal from its ischial acetabular lunate surface, using 3D sphere-fitting and regressions based on associated ossa coxarum and femora, provides a relatively modest range of values, among Neandertal females and at the lower limits of Neandertal male variation. Yet, when the Regourdou 1 humeral length is compared to its femoral head estimate, it is separate from most Neandertals, although close to the Southwest Asian Kebara 2. These assessments serve to expand the perceived variation among these late archaic humans in their body proportions.

Acknowledgments

B.M. Auerbach, D. Hunt, A. Rosas and C.B. Ruff provided comparative data, B. Vandermeersch provided the Regourdou ischial cast, and multiple individuals have permitted data collection from human remains in their care. To all, we are grateful.

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