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BULLETINS ET MÉMOIRES
DE LA SOCIÉTÉ D'ANTHROPOLOGIE DE PARIS

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Sommaire

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Lavoisier

Composé et imprimé par Jouve, 1, rue du Docteur Sauvé, 53100 Mayenne
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ARTICLE / *ARTICLE*

Leprosy in a Medieval Cemetery from Sudanese Nubia (Mouweiss, Shendi Area, Sudan)

La lèpre dans un cimetière médiéval de Nubie soudanienne (Mouweiss, région de Shendi, Soudan)

Y. Ardagna · M. Maillot

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Abstract The Mouweiss site (Shendi area, about 250 km North of Khartoum) is a Nilotic city of the Meroitic period (4th century BCE to 4th century CE), which the Louvre Museum (Paris) began to excavate in 2007. This was a large settlement that included a palace, which was later destroyed. The ruined walls of the palace also housed a medieval necropolis. About thirty rather crudely fashioned pits dug directly into the rubble of the palace were excavated. Radiocarbon dating from the tombs suggests funerary occupation from the "early Christian" to the "classic Christian" period. A macroscopic examination of the skeletal remains of the individual in grave 13 revealed palaeopathological signs pointing to Rhinomaxillary syndrome. The cranium of this 40- to 50-year-old woman showed significant bone resorption, particularly in the nasal area. Associated with these lesions are several modifications of the hands and feet, namely phalangeal acro-osteolysis and destructive diaphyseal remodelling. Differential diagnostic testing, in particular for other infectious/inflammatory diseases, concluded that the type and distribution of the lesions displayed by the individual from grave 13 at Mouweiss were indicative of leprosy. These findings contribute new data to understand the distribution of this disease and new evidence for leprosy in Sudanese Nubia, where there are very few palaeopathological cases illustrating its presence.

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Keywords Medieval Nubia · Sudan · Palaeopathology · Leprosy · Hansen's disease

Résumé En 2007, les fouilles de la mission archéologique du musée du Louvre au Soudan du site de Mouweiss (région de Shendi à 250 km de Khartoum) ont révélé un large ensemble méroïtique (du IV[e] siècle avant notre ère au IV[e] siècle de notre ère) comportant notamment les ruines d'un palais. Les murs arasés du palais ont aussi accueilli une nécropole médiévale. Près d'une trentaine de fosses, de facture plutôt fruste, creusées directement dans les déblais du palais furent fouillées. Des datations radiocarbone provenant des tombes évoquent une occupation funéraire située entre le *early Christian* et le *classic Christian* (VIII–XI[e] et XII–XIII[e] siècles ap. J.-C.) du Soudan médiéval. L'examen de l'un des sujets (tombe 13, femme adulte mature) livre, au niveau de la face et de la région nasale, des signes de résorption osseuse. Ces derniers sont associés à des altérations, de type acro-ostéolyse et remodelage diaphysaire, observées sur les mains et les pieds. Après analyse et diagnostic différentiel, notamment avec d'autres atteintes inflammatoires ou infectieuses chroniques, il apparaît que le type et la distribution de ces lésions suggèrent la présence de la lèpre. Ce cas serait une nouvelle preuve ostéoarchéologique de cette infection qui permet d'améliorer nos connaissances sur sa présence et sa répartition, notamment en Nubie médiévale où elle demeure particulièrement rare.

Mots clés Nubie médiévale · Paléopathologie · Lèpre · Bacille de Hansen

Introduction

Leprosy was long thought to be exclusively caused by the unculturable bacillus *Mycobacterium leprae*. However, in 2008, Han et al. suggested that *Mycobacterium lepromatosis*, a different and distinct unculturable species, could cause another form of leprosy (diffuse lepromatous leprosy) [1]. Leprosy is the second most frequent mycobacterial disease in the world after tuberculosis [2]. Because of its high clinical polymorphism and complex pathogenesis, leprosy is considered a "spectral" disease, as illustrated by its classification into five forms [3,4]. This spectrum ranges from low resistance to infection or lepromatous leprosy (multibacillary) to individuals with a "high immune status" who mostly develop the tuberculoid (paucibacillary) form of the disease [4]. Leprosy predominantly affects the skin and peripheral nerves, mainly at limb extremities. The more severe cases are characterised by late-onset lesions of the nasal tissues and osteoarticular regions [3,5].

Genomic analyses indicate that Leprosy (Hansen's disease) spread from Africa as early as the Pleistocene period, following early human migration patterns [6,7]. Historical data point to an origin in India around 2000 BC [8,9], a theory supported by descriptions in texts and palaeopathological cases dating from around 2000 BC [9,10]. A recent phylogenetic study indicates that leprosy could have been present in the eastern part of Europe at about the same period [11]. The known pattern of dissemination in Europe and the Mediterranean area following the Phoenicians expansion after 1500 BC [9] evolved with subsequent palaeopathological and microbiological discoveries.

Cases of Hansen's disease then multiplied in Rome and throughout Europe and the Byzantine world [12–16]. During the Middle Ages, leprosy became so endemic in Europe that several authors describe it as the disease that "metaphorically" represents this particular period [15]. Many recent palaeopathological cases support this description and provide more data for palaeoepidemiological and palaeomicrobiological studies on medieval Europe [17–21].

Leprosy was present in ancient Egypt and could have been introduced during intense commercial trade with inland African regions, such as Nubia (Sudan, South Sudan and Darfur) during the reign of Ramses II (circa 1300 BC) [22]. However, compared to Europe, osteoarchaeological evidence of leprosy is extremely rare in Ancient Egypt, Nubia and the Near East [8,23,24].

This study describes the lesions observed on an individual (grave 13) from the medieval necropolis of Mouweiss in the Shendi area of Northern Sudan. The skeletal modifications and their distribution indicate a systemic disease consistent with a differential diagnosis of Hansen's disease. A palaeomicrobiological analysis was conducted on bone samples, but the results were negative for *Mycobacterium leprae*. This was due to the very small amount of DNA extracted from the samples and the poor state of preservation of the genetic material. Therefore, a thorough macroscopic analysis of the specimen was performed with a stringent differential analysis of the lesions.

The site and the necropolis

Under an agreement with the National Corporation for Antiquities and Museums, Sudan Antiquities Department (NCAM), the Louvre Museum began an archaeological excavation of the Mouweiss site, in the Shendi region of central Sudan (250 km north of Khartoum, Fig. 1). The site presented features indicating the presence of a large city dating from the Meroitic period (4th century BCE to 4th century CE) [25]. In 2007, thick mud-brick was discovered, eventually revealing a Meroitic palace [26]. Based on potsherds collected on the surface and in ditches excavated on the mound, the monument was dated to the Classical or Late Meroitic period (1st to 4th century CE) [27].

The ground previously occupied by the palace was subsequently occupied by a small medieval necropolis. A total of 28 burials were excavated in conditions of extreme urgency according to the excavation program report. The Mouweiss necropolis was isolated, with no visible link to any church or settlement or vestiges of medieval occupation, unlike most Christian Nubian cemeteries, especially during the early Christian period [28]. The necropolis is almost exclusively composed of primary individual burials. The graves are elongated pits of various widths, mostly lying in an east-west direction, and matching the size of the buried individual. No ceramic artefacts were found with the burials. The few grave goods found *in situ* were personal ornaments (iron ankle bracelet, bone or coralline pearls). No funeral offerings were found but traces of shrouds (fabric with applied resin) in the graves [29] provide evidence of the presence of perishable materials surrounding and holding the body, as noted at other medieval necropolises in the region [30]. Radiocarbon dating of the tombs indicates that the necropolis was occupied between the Early Christian (600–850 AD) and Classical Christian (850–1100 AD) periods in medieval Sudan (550–1500 AD) [28]. The osteoarchaeological sample as a whole represents 29 articulated individuals, mainly adults (24 adults, 5 juveniles).

This distinctive re-use of a palace for funerary purposes seems to be concentrated around the northern region of Khartoum (Fig. 1). For example, the Wad ben Naga and Abu Erteila sites have revealed the inside, periphery and walls of a former Meroitic palace similarly disturbed by its transformation into a burial space during the medieval period [30-32].

The skeleton in grave 13

The skeleton in grave 13 is almost complete, despite fragmentation of the cranial vault, right upper limb and right os

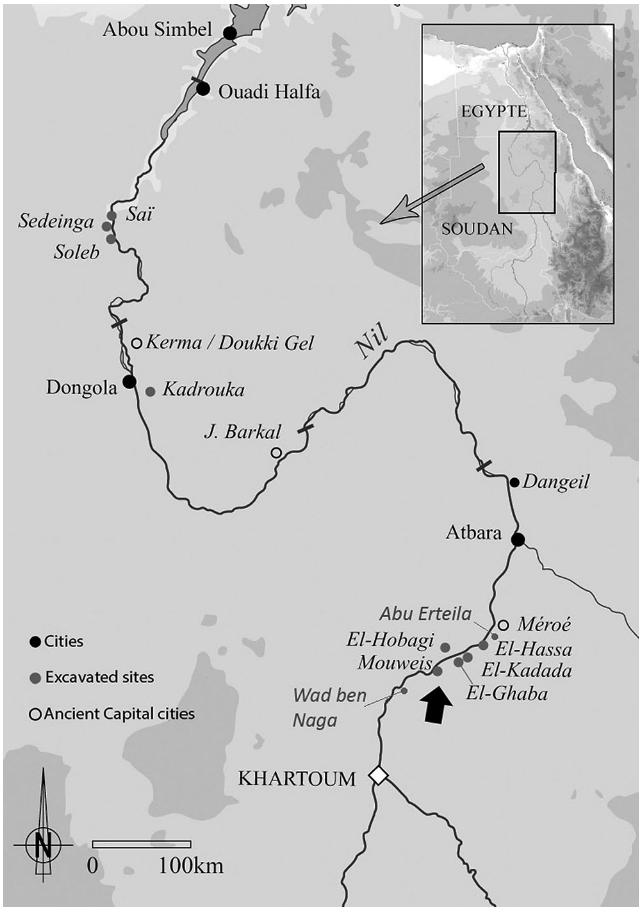

Fig. 1 Map of the Nile Valley showing various archaeological sites, including Mouweiss (arrow), in the region north of Khartoum. Source: Marc Maillot 2016 / *Carte de la vallée du Nil indiquant divers sites archéologiques de la région du nord de Khartoum. Source : Marc Maillot 2015*

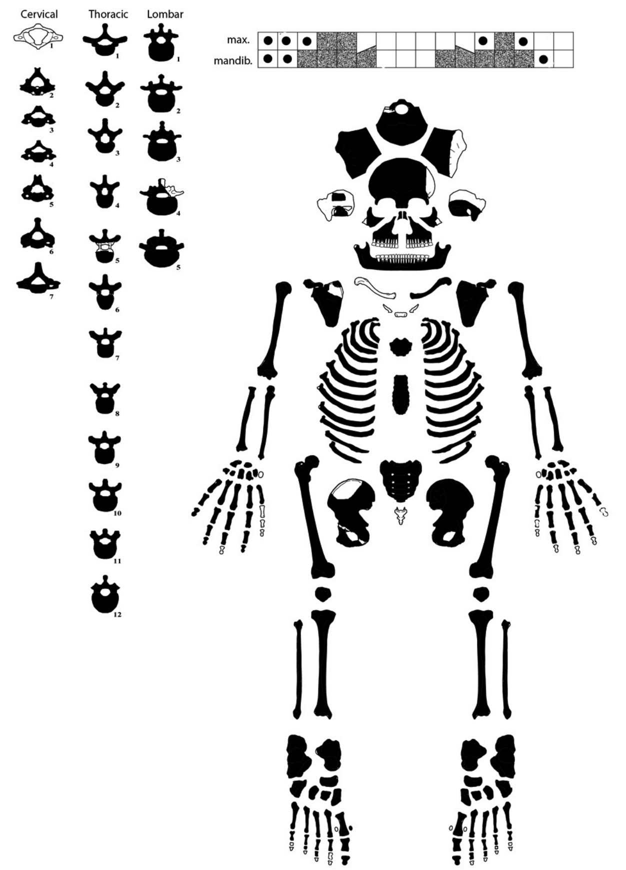

Fig. 2 Anatomical state of preservation of the grave 13 skeleton (preserved bones and teeth in black, fragmentary but identifiable bones or teeth in grey) / *Représentation schématique des éléments préservés du squelette de la tombe 13 (ossements et dents présents en noir ; ossements ou dents fragmentaires mais identifiables en gris)*

coxa (Fig. 2). Bone samples from grave 13 were AMS-radiocarbon dated to 695–1017 AD[1].

As in other individuals from the necropolis, the teeth were very badly preserved. Most of the front teeth were destroyed, leaving a few fragments near the neck region. Osteometric and morphological examination of the hip according to classic methodologies [33–36] showed that the individual was probably a female around 40 to 50 years of age (mature to elderly adult). The palaeopathological study was based exclusively on a macroscopic examination performed in accordance with classic publications [3,37–49].

Rhinomaxillary region

The cranium shows several alterations to the face and the hard palate (Figs 3, 4). The anterior nasal spine is entirely resorbed, which indicates erosive and destructive modifications (Figs 2A, 3). Irregular aspects around the resorbed nasal spine and exposure of cancellous bone can also be observed (Figs 3AB, 4A). There is also bilateral and symmetrical resorption and remodelling of the edges of the nasal aperture (Figs 3AB, 4A). An enlargement of the nasal aperture is also observed (Fig. 3A), with the smooth surface of the lateral margins most likely thickened by cortical bone remodelling. A limited extension of destructive changes to the nasal conchae, the vomer and the perpendicular lamina of the ethmoid bone can also be observed despite the poor state of bone preservation.

Both nasal bones are resorbed and a thin bony bridge has formed at the lower edge of the nasal notch (Fig. 3AC). The notch for the interior nasal nerve has almost completely disappeared and the area exhibits multiple vascular impressions (Fig. 3BC). In conjunction with the changes to the nasal aperture, inflammatory reaction (porosity) of the maxillary

[1] Poznan Radiocarbon Laboratory, OxCal Calibration POZ-67312: 1150 ± 70 BP, 0.15 MgC; 2.4% N_2, 7% C; 695–1017 AD (ca. 95.4%)

Fig. 3 (a) Anterior view of the rhinomaxillary region. (b) Detail of the nasal aperture and nasal bones showing resorption, including of the anterior nasal spine (white arrow). (c) Left lateral view of the face / *(a) Vue antérieure du crâne ; (b) détail de l'échancrure nasale et de la résorption de l'épine nasale antérieure ; (c) vue latérale gauche de la face*

alveolar bone of the incisor and canine sockets can be observed (Figs 3, 4A).

The anterior dentition was lost post-mortem due to poor preservation. Fenestration of the maxillary canine alveoli is probably due to *post-mortem* damage. In the mid-zone of the oral surface of the palate, a dense porosity identified along the palatal suture reveals a probable chronic inflammatory reaction (Fig. 4B). Observation of the cranium in *norma lateralis* suggests overall regression of the lower part of the upper facial region (Fig. 3C).

Mandible

The mandible shows early stages of resorption and inflammatory reaction (porosity), which affected the alveolar sockets of the central and lateral incisors (Fig. 5). Root exposure of the lower right canine and both first premolars can also be observed despite poor bone preservation. There is no evidence of any apical lesion on the mandible.

Hands

Signs of acro-osteolysis and extensive pitting can be seen on the distal facet of the right 2nd intermediate phalanx of the right hand (Figs 6, 7). On the right third intermediate phalanx, lysis of the distal articular surface could have led to fusion with the distal phalanges. Fusion is accompanied by significant concentric narrowing of the distal metaphyseal part of the intermediate phalanx and erosive changes at the distal end of the distal phalanx (Fig. 6).

On the 2nd, 3rd and 4th proximal phalanges of the right hand (Figs 6, 7), an enlargement of the nutrient foramen is

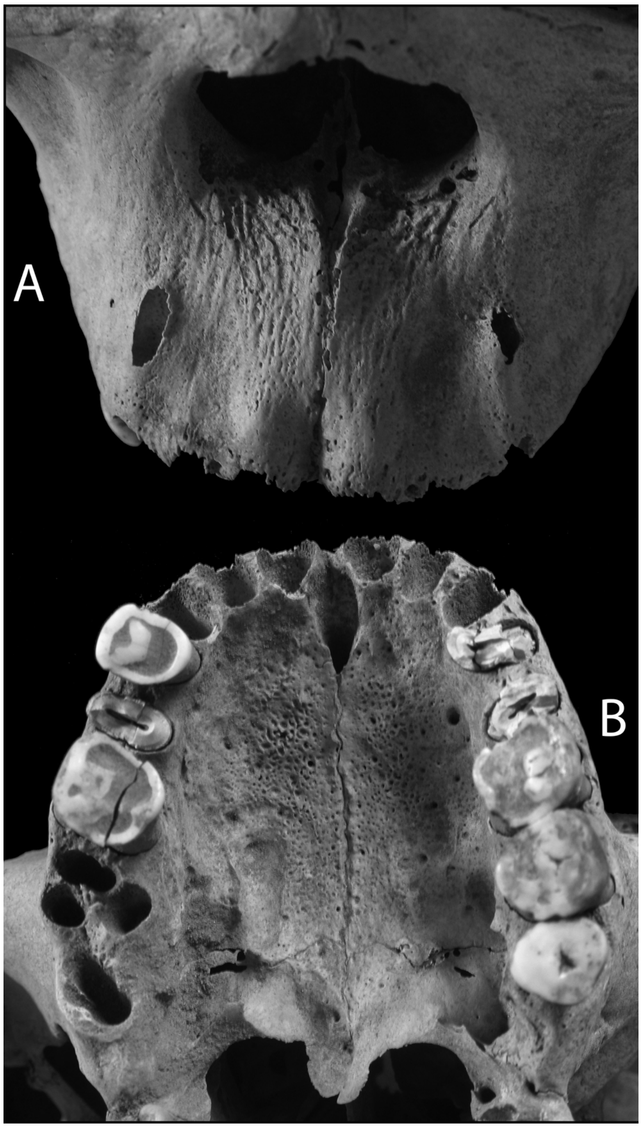

Fig. 4 (a) Detail of the resorbed and remodelled anterior nasal spine. (b) Porous aspect of the oral surface of the palate / (*a) Détail de la résorption de l'épine nasale antérieure et du remodelage périphérique ; (b) vue du réseau de porosité de la surface du palais osseux*

the only observable lesion. Few lesions were observed on the left metacarpal bones, except for a thin periosteal reaction on the first metacarpal (proximal metaphysis, anterior and superior views). Compared to the right side, fewer lesions have been found on the left phalanges. However, the nutrient foramina of several phalanges were enlarged (2nd proximal phalanx and 2nd, 3rd and 4th intermediate phalanges).

Lower limbs

Some tibial and fibular subperiosteal bone reaction can be observed (*more details* presented in the *Supplementary Information)*. These lesions are associated with irregular pitting and fine longitudinally striated woven and compact bone growth located along the interosseous border.

Feet

Pitting and signs of erosion on the right foot were also observed on the distal articular head of the 1st distal phalanx along with porous periosteal reactions. Signs of erosive lesions in the distal joint area can also be observed on the 3rd right proximal phalanx (Fig. 8). The 3rd and 4th intermediate phalanges show extensive signs of resorption and remodelling of their distal portions, which have been completely disappeared and suggest truncated toes. A clear enlargement of the nutrient foramina can be seen on the 2nd, 3rd and 4th proximal phalanges (Fig. 8). The 5th right proximal phalanx shows complete resorption and narrowing of the distal end, giving a “blade-shaped” aspect to the distal part of the diaphysis and the entire distal joint (Fig. 8).

The left foot presents comparable modifications (Fig. 9). The diaphysis of the proximal phalanges has been resorbed and concentrically remodelled, especially at the distal end of the bone. The 1st distal phalanx (Fig. 9) shows resorption of its distal end, which has created a “shark's tooth” deformity. Fusion of the 2nd proximal and intermediate phalanges has formed an angular beak (Fig. 9). The distal portion of the intermediate phalanx is completely resorbed, which could have been associated with complete truncation (Fig. 9). The 5th proximal phalanx shows diaphyseal remodelling and complete destruction of the distal end of the diaphysis, which could have led to truncation of the toe starting from the medial phalanx (Fig. 9). Lastly, the remodelled distal end of the 5th proximal phalanx is consistent with a “blade-shaped” aspect. On the plantar aspect, enlargement of the nutrient foramina can be observed on the 3rd, 4th and 5th proximal phalanges (Fig. 9).

Other than these lesions (and some presented in the *Supplementary Material*), no other significant pathological changes were observed. Furthermore, no other individual at this cemetery has lesions consistent with a diagnosis of specific infection.

Discussion

Differential diagnosis

Substantial changes in the rhino-maxillary region can occur under other specific conditions [40], some of which are known to have been present in the region in the medieval period, such as tuberculosis which can affect facial bones due to the infection of soft tissues (*lupus vulgaris*). Longstanding tuberculosis affecting facial skin can cause severe alterations of the nasal bone. However, gross destruction of the facial skeleton is extremely rare [16,40,41,50], the

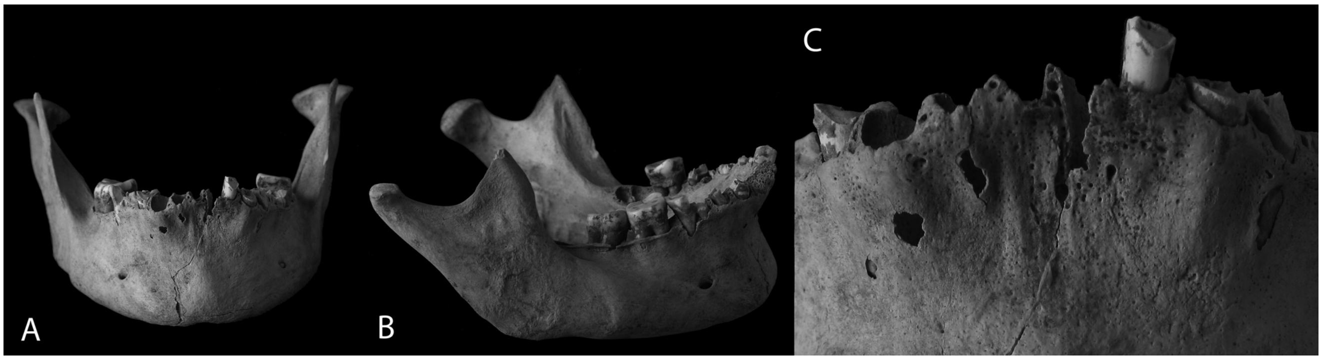

Fig. 5 Anterior view (a), right lateral view (b) and detailed view (c) of the alveolar sockets of the mandible showing signs of inflammatory porosity (arrows) and post-mortem destruction of the teeth / *Vue antérieure (a), vue latérale droite (b) et vue de détails (c) de l'arc alvéolaire antérieur de la mandibule montrant des signes d'inflammation (porosités) et des altérations dentaires post-mortem*

Fig. 6 Palmar view of the right hand. Grey arrows indicate diaphyseal narrowing and distal erosion; white arrows show enlargement of the nutrient foramen / *Vue palmaire de la main droite. Les flèches grises montrent les signes d'atrophie concentrique et d'érosion tandis que les flèches blanches soulignent la présence de l'élargissement du foramen nutritif*

lesions are unlikely to be bilateral and the anterior alveolar process is rarely affected [38]. The skull, especially the frontal and the parietal bones, can be affected by lytic lesions but originating in this case from the inner table [40]. Finally, destructive changes of the hands and feet are not likely to be found in cases of tuberculosis. The most frequent sites for lesions due to tuberculosis are the spine and the weight-bearing joints [40]. The skeleton from grave 13 does not show any sign of vertebral infectious lesions. Dactylitis, associated with the enlargement of nutrient foramina of the hands and feet can occur with tuberculosis. However, when fingers and toes are affected, substantial enlargement of phalangeal diaphysis can be seen instead of the diaphyseal concentric narrowing observed with leprosy [40].

The three syndromes of treponematosis affecting the skeleton may produce rhinomaxillary abnormalities [41] and destruction of the face. However, osteoarchaeological evidence of endemic treponematosis (yaws and bejel) is extremely rare in Ancient Egypt and Nubia [51,52]. In addition, there is no documented evidence of pre-Columbian syphilis (i.e. veneral treponematosis) in Africa. Moreover, unlike leprosy, tertiary syphilis typically involves the nasal bones [41,46]. Necrosis and perforation of the nasal hard palate is also common, but the anterior nasal spine can be spared [40]. Gummatous "crater-like" (*caries sicca*) lesions found primarily on the frontal and parietal bones, with depressed rounded clusters of dense porosity and sclerotic borders, are considered one of the most characteristic skeletal manifestations of treponemal disease, particularly venereal syphilis [40,53]. The skeleton from grave 13 does not display any signs of necrosis of the vault. Treponemal disease also affects long bones, most frequently the tibia, which displays the characteristic "non-gummatous" sabre-shin deformity on its anterior aspect, especially in yaws [40,53]. Extensive periosteal reactions on the tibia with rough external surfaces and cavitation resembling *caries sicca* of the vault can also be considered as a manifestation of

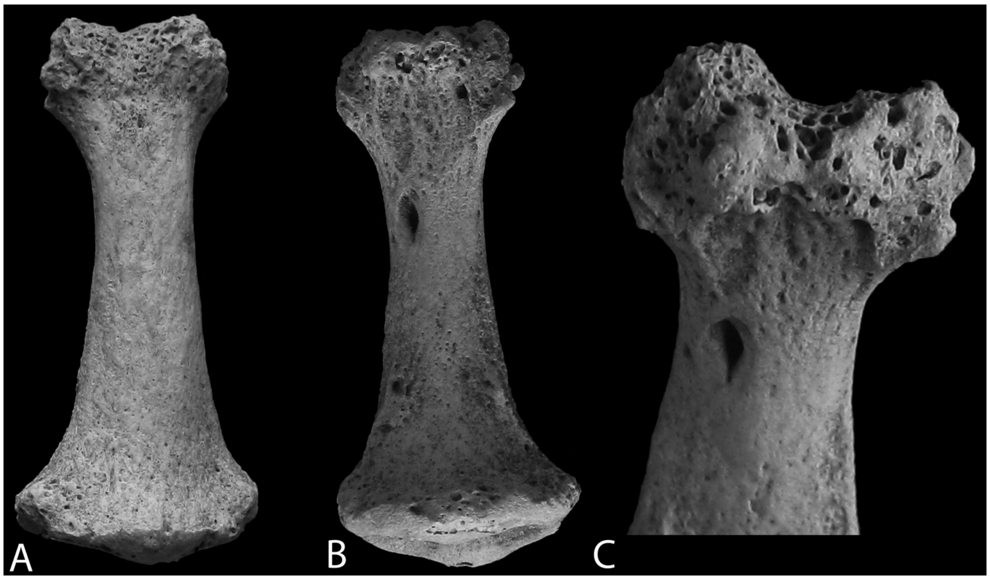

Fig. 7 Dorsal (a), palmar (b) and detailed close-up view (c) of the right 2nd intermediate phalanx showing acro-osteolysis of the distal articular surface / *Vue dorsale (a), vue palmaire (b) et vue de détail (c) des signes d'acro-ostéolyse de la surface articulaire distale de la deuxième phalange médiale droite*

treponemal disease. The skeleton in grave 13 does not display any evidence of hyperostotic changes of this kind, or of gummatous lesions on either tibiae. Dactylitis of the hands and feet is frequent with treponemal infections, especially in yaws [40,53]. When fingers and toes are affected, as a result of subperiosteal bone formation, phalangeal expansion may be seen instead of the concentric atrophy often observed with leprosy [40]. In yaws, destructive dactylitis involving joints and diaphyses can occur, but concentric narrowing producing a pencil or blade shape is not observed [40,53].

Leishmaniasis, caused by the bites of female sandflies, was present in ancient Nubia during the Christian period [54]. This parasitic disease may cause periosteal reactions and destructive lesions of the nasal septum and hard palate [40] but with less than 10% frequency [55]. Unlike leprosy, these destructive lesions affect the frontal and the zygomatic bone, leading to significant bone loss in portions of the face [55].

Fungal infections (such as aspergillosis, mycetoma, cryptococcus or sporotrichosis) can also cause bone destruction with thin or no marginal repair and remodelling [56]. These infections can attack many bone sites, including cranial bones [56]. Actinomycosis can affect the mandible, with lesions mostly a development of reactive periosteal bone formation. Furthermore, these fungal infections generally cause vertebral lesions, such as a vertebral collapse [40]. The grave 13 skeleton does not display lytic changes on the spine. Mycetoma, which are widespread in present-day Sudan, include tarsal lytic lesions and multiple lytic foci on metatarsal bones as well as the distal tibia and fibula [56]. The grave 13 skeleton does not display any lytic changes of this kind.

Sarcoidosis, an uncommon granulomatous disease, can produce lytic lesions similar to those observed in leprosy. In the skull, destructive lesions can be seen on the nasal bone, but rarely on the maxilla and the anterior nasal spine [40] as found in leprosy and as seen in this case. Like leprosy, sarcoidosis tends to affect fingers and toes, which show small and circular lytic lesions but without reactive bone formation or sclerosis with concentric atrophy [40]. The proximal and intermediate phalanges of the hands and feet are more often affected by uni- or bi-lateral lesions, but unlike those found in the case of the individual from grave 13, distal phalanges are rarely affected [40].

Both nasal bones of the grave 13 skeleton show remodelling, which may evoke other pathological conditions such as healed trauma. As nasal bones are fragile and easily dislocated and fractured, nasal trauma, which can rarely be reduced to the correct position, frequently results in badly aligned healing [57]. Trauma on the lateral aspect of the nasal bone can produce additional fracture lines near the margins of the nasal aperture. Bone loss, as found in the individual from grave 13, is also considered as a criterion for fracture identification [57]. However, no additional fracture lines were seen here on the nasal bones or elsewhere in the nasal cavity. The thin bony bridge observed on the lower edge of the nasal notch does not evoke callus formation or altered alignment. However, trauma of both nasal bones cannot be ruled out as a possible cause.

Many other pathological conditions can cause metacarpal/metatarsal abnormalities or lytic phalangeal lesions, including inflammatory rheumatism. Spondyloarthropathies, especially psoriatic arthritis, can produce lytic lesions

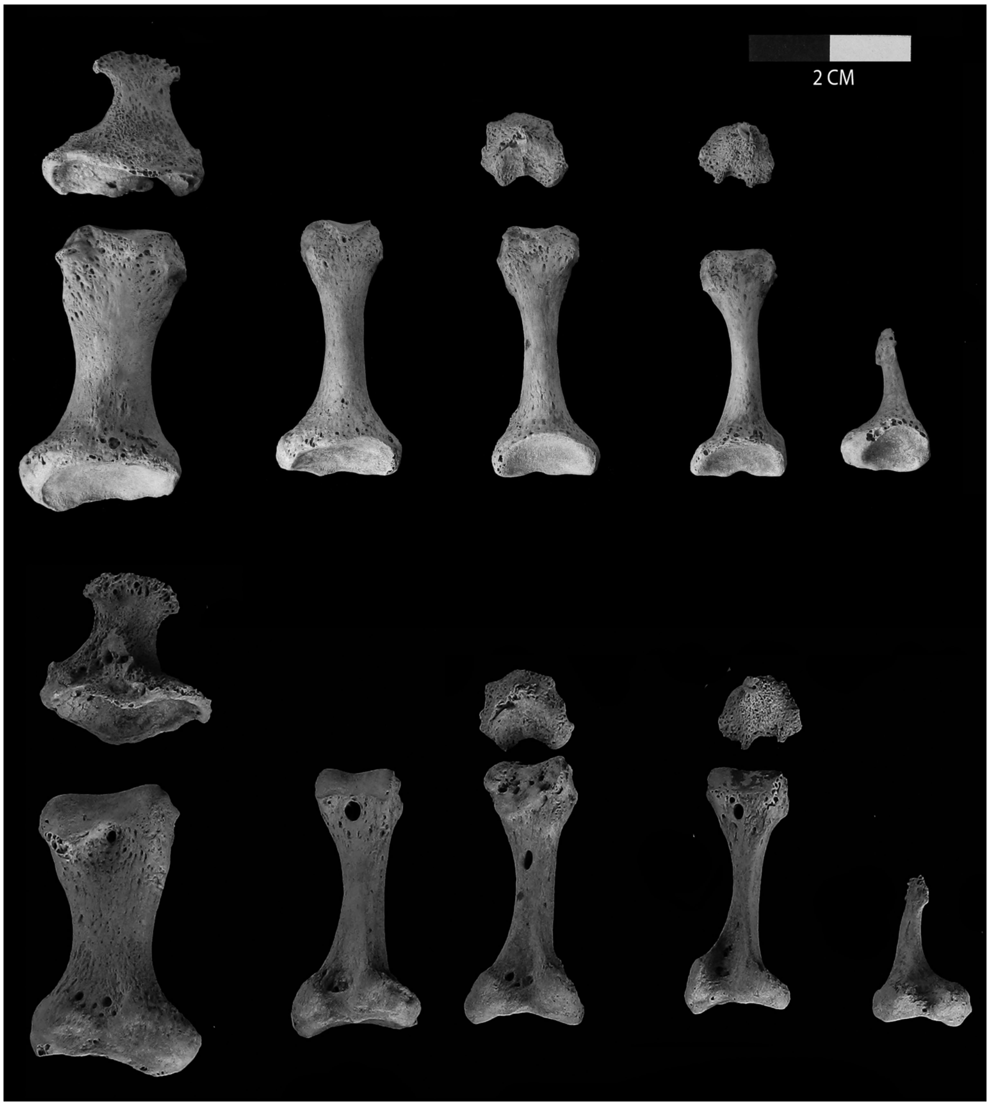

Fig. 8 Dorsal (a) and palmar (b) view of the preserved phalanges of the right foot showing destructive concentric diaphyseal remodelling, distal erosion and truncation of the 3rd, 4th and 5th toes / *Vue dorsale (a) et vue palmaire (b) des phalanges du pied droit livrant des signes d'atrophie concentrique diaphysaire, d'érosions distales et d'amputation pathologique des 3e, 4e et 5e rayons*

(acro-osteolysis) on the distal and proximal interphalangeal and metatarsophalangeal joints [58]. Resorption of the distal portion of the phalanx may result in shortening [59]. However, psoriatic arthritis typically involves the sacro-iliac joint and does not affect the skull [60]. As in psoriatic arthritis, rheumatoid arthritis can lead to resorption of the distal hand phalanges into a "cup and pencil" shape that may resemble leprosy. However, the lesions are usually symmetrical, without any concentric remodelling, and spread to involve other joints such as the wrist or elbow [59].

Neuropathy due to other causes may lead to the destruction of the hand and foot bones [12]. Diabetes can affect the lower limbs and feet by producing resorptive bone changes of the distal parts of the metatarsals and proximal phalanges, which become distally tapered [12]. However, diabetes does not involve facial bones [12] as seen in the grave 13 skeleton.

Some of the bone modifications observed on the face of the individual from grave 13 can be included among the classic features of rhinomaxillary syndrome, which can be defined by the presence of: 1) absorption and ultimate loss of the anterior nasal spine associated with resorption of the ridges of the anterior nasal aperture; 2) absorption and recession of the alveolar process of the maxillae starting centrally; 3) rounding and widening of the anterior nasal aperture with recession of the normal sharp margins; 4) destructive changes of the nasal conchae possibly associated with irregular subperiosteal new bone formation; and 5) an inflammatory reaction of the surfaces of the palatine process of the maxilla, with dense pitting centred on the palatine suture

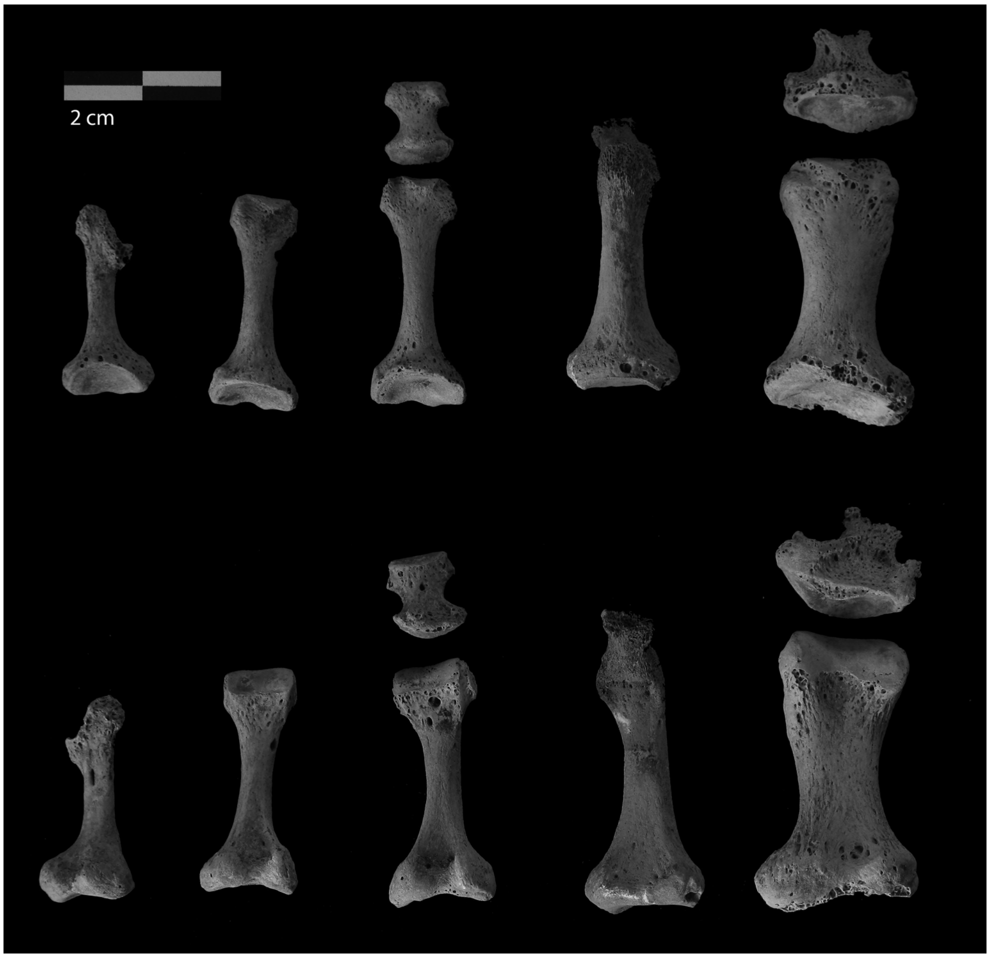

Fig. 9 Dorsal (a) and palmar (b) view of the preserved phalanges of the left foot showing destructive concentric diaphyseal remodelling, fusion, distal resorption and truncation of the 1st, 2nd and 5th toes phalanges) / *Vue dorsale (a) et vue palmaire (b) des phalanges du pied droit livrant des signes d'atrophie concentrique diaphysaire, de fusion, de résorption distale d'amputation pathologique des 1er, 2^{e} et 5^{e} rayons*

and possible perforation [37]. However, the resorption of the alveolar margins of the maxillae of the individual from grave 13 is not very extensive and is only concentrated on the sockets of the anterior teeth.

The mandible shows more severe resorption but this location in leprosy is uncommon [10,24], making it quite difficult to argue that these lesions are related to the infection. They could be related to other dental diseases due to a deteriorated state of health. On the other hand, no other subjects in the sample showed similar lesions and some palaeopathological evidence of mandibular involvement can be found [10,24]. The mandible alterations must therefore be considered with caution.

Bony alterations of the hands and feet in leprosy are consecutive to necrosis and infection of the nerves [5]. This is reflected by resorption of the cortical bone and the formation of new endosteal bone, leading to a decrease in size of the medullar cavity, known as concentric narrowing or concentric bone atrophy of the proximal end of the diaphysis [45,48,49]. Concentric atrophy occurs in both extremities of the individual from grave 13. However, the alterations are more pronounced on the feet, as described in the literature [42]. In addition to concentric resorption, erosive lesions with an acro-osteolysis pattern can appear on the hands and feet [47-49] as observed in this Sudanese case. Besides concentric narrowing and the "knife-edge" and "shark's tooth" appearances of both foot phalanges, truncation of these phalanges, observed bilaterally on the skeleton from grave 13, is also generally found in Hansen's disease [37]. Enlargement of the nutrient foramen, as noted on the hands and feet of the individual from grave 13, is difficult to associate systematically with leprosy, although some authors in the medical literature consider that this widening could be associated with specific destructive bony changes due to direct invasion by *Mycobacterium leprae* [61-63]. These destructive lesions are characterized by a granulomatous reaction and can lead to foci of bone rarefaction. When the disease involves the phalanges of the hands or feet, thinning of the endosteum associated with widening of the medullary canal is occasionally associated with enlarged nutrient foramina [61], which are thought to result from infection of the nutrient vessels [64]. This lesion, described in several paleopathological cases [24], can therefore be considered as a "valuable corroborative addition" to a diagnosis of leprosy [65]. Several additional and less disabling lesions are also involved in confirming this diagnosis (see Figs 10-12 in *Supplementary Information*).

Rhinomaxillary syndrome is considered, *per se*, as pathognomonic of a lepromatous form [46,47]. However, leprous osteomyelitis or concentric diaphyseal remodelling can also be considered as "virtually" pathognomonic of leprosy [41,47]. The pattern and skeletal distribution of concomitant destructive and remodelled alterations of the individual from grave 13 are then consistent with a diagnosis of a lepromatous form of leprosy.

Presence in Nubia

Palaeopathological evidence for leprosy in Egypt and Nubia had been described as very scarce [66]. Concerning Egypt, other than four isolated skulls showing signs of leprosy at the Ptolemaic (2nd century BC) site of Dahkleh [24,67], only two obvious and two "possible" Egyptian cases have been reported. These are from the Roman necropolis of Kellis 2, dated to the Early to Mid 4th century AD. More recently, an isolated skull showing a rhinomaxillary syndrome from the Valley of the Queens (West Thebes, Upper Egypt) dating from the first Roman period (1st–4th century AD) has been suggested as being that of a leprous individual [68]. In Ancient Nubia, the earliest published case of leprosy was a 4th–7th century AD Coptic mummy from the Christian cemetery of Biga, near Aswan (modern-day Egypt), which presented obvious alterations of the hands and feet [37,69,70]. In addition, Møller-Christensen and Hughes described facial changes observed on a skull from the same site of Biga, dating from 500 AD [71].

Overall, this means that the case of skeleton 13 from Mouweiss appears to be one of the rare Sudanese cases of leprosy described since the 1960s. Eleven possible cases (6 isolated skulls and 5 individuals) of leprosy have been reported previously in Ancient Egypt and Nubia (Table 1), a particularly low figure considering the large number of skeletonised or mummified individuals from this area that have been examined and published since the beginning of the 20th century.

For example, among the 2000 mummies dating from 600 BC to 600 AD studied by Møller-Christensen, only two were consistent with a diagnosis of leprosy [22]. In this geographical area where leprosy is nowadays endemic, the scarce palaeopathological presence is difficult to explain.

Sudan currently has the largest number of registered cases of leprosy (1117 cases in 2015) in the entire Eastern Mediterranean region, comparable to that of central Africa [72]. Although the latest data for southern Sudan are not known, 3,273 cases were registered in 2011 [73]. Sudan is currently considered by the WHO as having a "high leprosy burden (including high transmission)" [72]. Chronological changes in the prevalence of the disease, funerary treatments (such as mummification) preventing exhaustive examination of the skeletons, changes in palaeopathological study protocols, varying periods of excavation and anthropological studies are a few unsatisfactory explanatory factors, to which may be added the links between ancient Nubian and Egyptian societies and leprosy (segregation, exclusion) which it is hazardous to assess.

Social responses to leprosy

Because of the lack of evidence of leprosy in Egypt and Nubia in antiquity and the medieval period, most relevant insights on social responses to leprosy come from European or Byzantine sources. In Europe, segregation of people with Hansen's disease is frequently reported in palaeopathological and historical literature, most notably in works on medieval Europe [74]. However, some bioarchaeological observations show that behaviour towards leprosy in medieval European societies could be more complex and varied than systematic exclusion [20,75,76]. Recent data show that segregation of leprosy sufferers did not necessarily imply systematically comparable funerary treatments. Bodies did not typically leave their original community and were even brought back to be buried. Several medieval European occurrences show that people who suffered from leprosy were not given any separate funerary treatment [12,77–80]. Within the variety of behaviour towards people with leprosy, there seems to have been a will to keep these individuals within their community, without resorting to any special funerary treatment. However, this does not necessarily mean that they were not socially excluded in some way during their life [18].

There are no specific data for the medieval period in Sudan apart from a rare mention of the existence of a leprosarium [81]. However, Sudan's neighbouring countries were more tolerant than in Europe, and an attitude of acceptance was prevalent in medieval Islamic societies of the Near East [8,82]. According to Dols, medieval Arabic medicine did not recommend isolating lepers from society, as was common in the Judaeo-Christian world [82]. In medieval Ethiopia, leprosy was known because it is referred to in several religious texts, by a word deriving from a verb meaning to amputate. Ethiopian society seems to have been more tolerant than European society, especially during the early medieval period. Indications of the more tolerant Ethiopian attitude

Table 1 Summary of published palaeopathological cases of leprosy for Egypt and Sudan / *Récapitulatif des cas paléopathologiques de lèpre publiés pour l'Égypte et le Soudan*

Site	Individual/ Skull	Dating	Age	Sex	Diagnostic	Lesions	Ref.
Dakhleh Oasis (Dakhleh, Egypt)	Skull 15/77	Ptolemaic period (2nd century BC)	Adult	Male?	Case (isolated skull)	Inflammatory reaction and perforation of the palate, resorption of the central alveolar margins of the maxilla (ante-mortem tooth loss)	[67]
Dakhleh Oasis (Dakhleh, Egypt)	Skull 35/77	Ptolemaic period (2nd century BC)	Adult	Male	Case (isolated skull)	Destructive changes of the nasal conchae, with resorption of the central alveolar margins of the maxilla	[67]
Dakhleh Oasis (Dakhleh, Egypt)	Skull 36/77	Ptolemaic period (2nd century BC)	Adult	Male?	Case (isolated skull)	Resorption of the anterior nasal spine, asymmetry of the anterior nasal aperture, inflammatory reaction and large perforation of the palate	[67]
Dakhleh Oasis (Dakhleh, Egypt)	Skull 37/77	Ptolemaic period (2nd century BC)	Adult	Male?	Case (isolated skull)	Resorption of the anterior nasal spine, inflammatory reaction and perforation of the palate	[67]
Kellis 2 (Dakhleh, Egypt)	K2-B6	Roman period (early-mid 4th century AD)	Young adult	Male	Case	Complete features of rhinomaxillary syndrome, erosive changes on hands and feet and periosteal reaction on lower limb	[24]
Kellis 2 (Dakhleh, Egypt)	K2-B116	Roman period (early-mid 4th century AD)	Young adult	Male	Case	Complete features of rhinomaxillary syndrome and erosive changes on hands and feet	[24]
Kellis 2 (Dakhleh, Egypt)	K2-B9	Roman period (early-mid 4th century AD)	Young adult	Male	Possible case	Osteopenic palate with perforation, inflammatory changes (porosity) of the nasal conchae and periosteal reaction on the right fibula	[24]
Kellis 2 (Dakhleh, Egypt)	K2-222	Roman period (early-mid 4th century AD)	Young adult	Male	Possible case	Resorption of the anterior nasal spine and of the ridges of the anterior nasal aperture, pitting on the inferior nasal conchae and periosteal reaction on the tibias	[24]
Queen Valley (West Thebes, Upper Egypt)	Skull C16-18	First Roman period (1st-4th century AD)	Adult?	Unknown	Case (isolated skull)	Resorption of the anterior nasal spine, destructive changes of the nasal conchae, resorption of the central alveolar margins of the maxillae and inflammatory reaction (porosity) of the surfaces of the palatine process of the maxillae	[68]
Cemetery 5, Temple of Biga (Aswan, Egypt)	Coptic mummy	4th to 7th century AD	Adult mature	Male	Case	"Typical hand and feet mutilations"	[69–71]
Cemetery 6, Temple of Biga (Aswan, Egypt)	Skull 5: 135: D	About 500 AD	Adult mature	Woman?	Case (isolated skull)	Complete features of rhinomaxillary syndrome	[69–71]

towards the disease can be found in the accounts of 16th century travellers who claimed that people suffering from the disease were living among the general population [83]. This tolerance or absence of exclusion can also be inferred from archaeological evidence on funerary treatments in Egypt and Nubia.

From the case of leprosy found in the Coptic mummy in Biga (Table 1), some authors hypothesize that leprosy could have been "not less frequent in the social classes where embalming was more likely to take place, and that there was no negative selection regarding these funeral practices because of the disease" [22]. In reports of other medieval cases of leprosy in Sudan (Table 1) there is no mention of the exclusion of affected individuals, at least as regards their funerary treatment [69-71]. Concerning the Egyptian cases from the Ptolemaic period in Dakhleh, Dzierzykray-Rogalski suggests that "the Oasis was used as a place of deportation of lepers belonging to the ruling class" [67]. However, the hypothesis of lifetime exclusion cannot be completely excluded in the case of the Mouweiss necropolis even if attitudes towards leprosy mimicked those observed in neighbouring regions of Sudan.

Conclusion

The lesions described in this skeleton of a mature woman point to a case of Hansen's disease affecting the rhinomaxillary region. Other incapacitating damage discovered on the bones of the hands and feet support this diagnosis. This skeleton from Mouweiss grave 13 brings new evidence of the presence of Hansen's disease in Ancient Nubia during the early Christian period. The discovery of other cases will enable us to advance our knowledge on leprosy and on social attitudes towards this disease and those who suffered from it during the medieval period.

Supplementary Information
Lesions and differential diagnosis

Hands

Fusion of the hand phalanges, as seen in the 3rd right intermediate and distal phalanges (Fig. S1) is not typical in leprosy and a traumatic origin can be suggested. In the case of

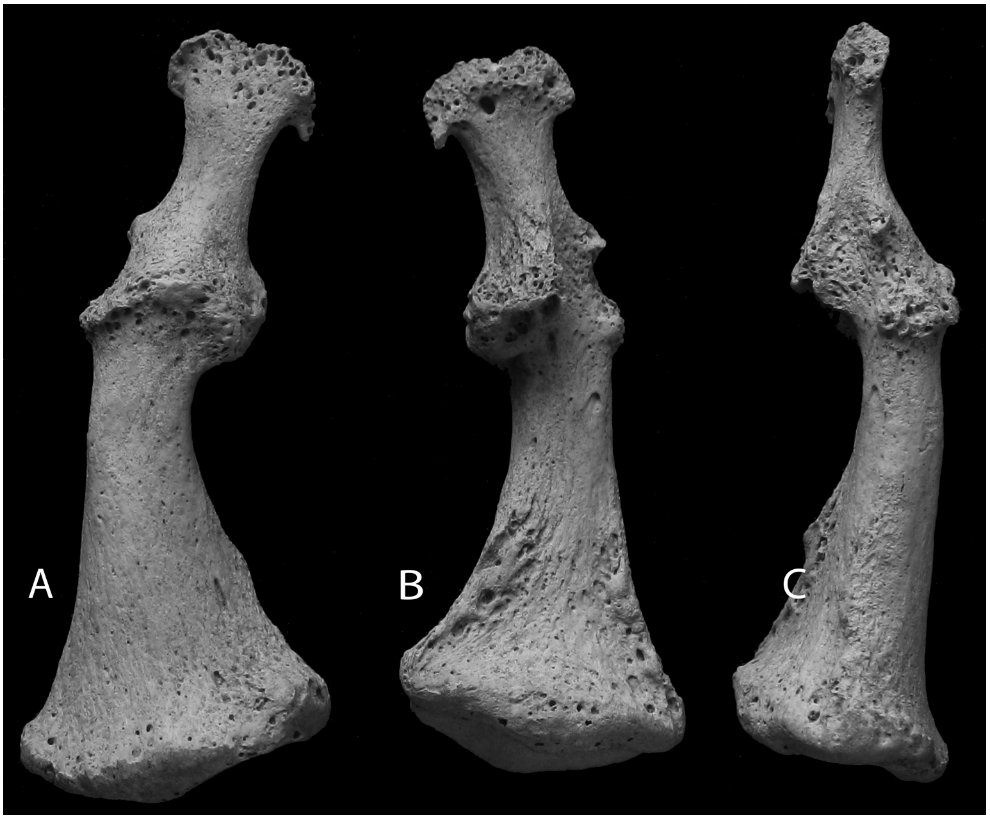

Fig. S1 (a) Dorsal, (b) palmar and (c) left lateral view of fusion of the right 3rd intermediate and distal phalanges, narrowing of the metaphyseal part of the middle phalanx and distal erosion of the distal phalanx / *(a) Vue dorsale, (b) vue palmaire et (c) vue latérale gauche de la fusion entre les phalanges médiale et distale du 3^{e} rayon de la main droite accompagnée d'un amincissement concentrique et d'une érosion distale de la dernière phalange*.

the grave 13 skeleton, the fused phalanges are associated with more typical signs of leprosy such as diaphyseal narrowing and distal erosion. Furthermore, fusion could be consecutive to septic arthritis due to soft tissue trauma and secondary infection [75]. Fusion could then be considered as a non-specific bone change observed in a context of leprosy [17,63,75,84] and may also indicate that the skeleton could present claw-hand deformity [75] (Fig. S1).

Lower limbs

On the lower extremities, the tibiae show subperiosteal bone reactions with irregular pitting and fine longitudinally striated woven and compact bone growth. The anterior surfaces of both tibiae are involved. However, the lesion can be more easily detected on the lateral distal surfaces of both tibiae and fibulae, especially along the interosseous border Fig. S2). (These periosteal reactions extend to the inferior part of the tibial shaft and to the mid-shaft of the fibulae (Fig. S2).

The periosteal bone formation at the distal ends of the tibiae and fibulae is commonly observed in osteoarchaeology [85] and considered as a non-specific reaction because many factors of "stress" can lead to this condition (traumatic, inflammatory, infection, neoplasm) [80,86]. As the tibia is particularly vulnerable to lesions of this type, extreme caution is required to differentiate their origins [20,85,86]. Periosteal bone formation of the tibiae and fibulae alone is not considered as a diagnostic criterion of leprosy [80]. In leprosy, loss of sensation leads to injuries of the foot, which may be complicated by secondary chronic infections [40]. The onset of periostitis in cases of leprosy could be due to its extension towards the tibae and fibulae from a primary site of infection in the foot. Thus, bone reaction in leprosy is primarily located, and most severe, near the ankle with its severity decreasing upwards towards the knee [40,41]. Periostitis can extend proximally, but it has been suggested that if the major focus of reactive bone is on the mid-shaft or the proximal extremities rather than the distal extremities of the bone, diagnostic options other than leprosy are more probable [41]. Periosteal bone formation on the grave 13 skeleton is restricted to the distal tibiae and fibulae, particularly at the interosseous border. This is also often observed in cases of leprosy [37,84].

Feet

On the 1st, 2nd, 3rd and 4th metatarsals of the right foot, periosteal reactions are present around the distal epiphyses. The 2nd, 3rd and 5th metatarsals also display thin subperiosteal striated woven bone along the dorsal aspect of the diaphysis. Thin and comparable subperiosteal bone along the dorsal and plantar aspects of the diaphysis can be observed on the left metatarsals (Fig. S3).

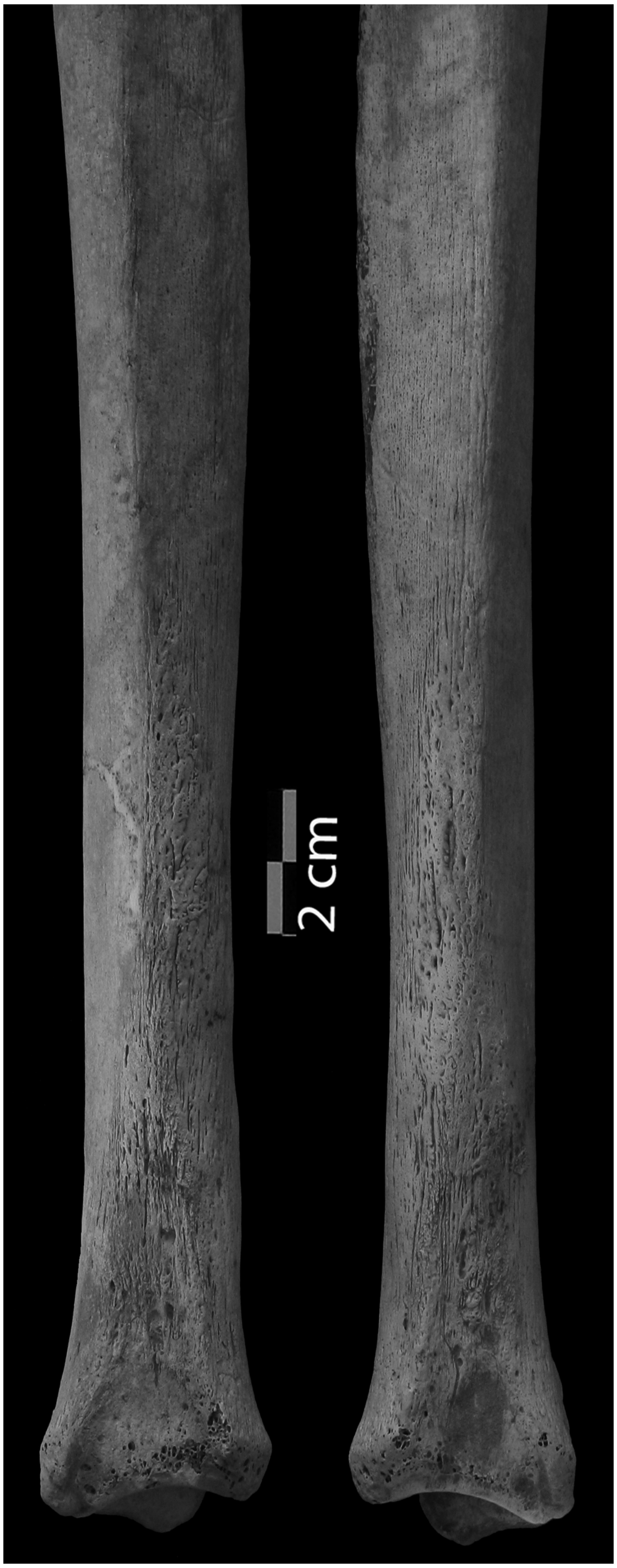

Fig. S2 Medial view of both tibiae showing periosteal reactions / *Vue médiale du remodelage périosté des deux tibias*

Fig. S3 (a) Dorsal view of right and (b) left 2nd metatarsal showing thin periosteal reactions / *(a) Vue dorsale de la MT2 droite et (b) gauche, montrant de fines appositions périostées*

Even though the thin subperiosteal porous and striated woven bone, observed mostly on the dorsal aspect of the metatarsals, and the fusion of the 2nd proximal and intermediate phalanges of the left foot could relate to septic bone changes of the feet that occur during leprosy [44], they could not be included as diagnosis criteria. Infectious lesions of the joints during leprosy are due to pyogenic bacteria, not to direct infection of the joints by the mycobacterium [44]. Bacterial spread from an adjacent ulcer through the invasion of both joint surfaces will be initially involved. If the bacteria spreads from a nearby infected bone site to the joint, the initial pathological site may be one of the joint surfaces. It can produce irregular destruction of the joint surface and evolve into ankylosis of the joint [44].

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References

1. Han XY, Seo YH, Sizer KC, et al (2008) A new *Mycobacterium* species causing diffuse lepromatous leprosy. Am J Clin Pathol 130:856–64
2. Flageul B (2010) Lèpre. Maladie de Hansen. Encyclopédie médico-chirgicale Dermatologie (98-370-A-10):1–16
3. Consigny P, Matheron S (2003) Rheumatic manifestations of leprosy. Rev Rhum 70:111–14
4. Massone C, Brunasso AMG (2012) Classification. In: Nunzi E, Massone C (eds) Leprosy: a practical guide. Springer, Milan, pp 43–51
5. Di Schino M, de Belenet H, Drouin C, et al (2004) Lésions du pied dans la lèpre. Encyclopédie Médico-chirurgicale Podologie Kinésithérapie (27-070-B-10):59–81
6. Monot M, Honore N, Garnier T, et al (2005) On the origin of Leprosy. Science 308:1040–42. PubMed PMID: 15894530
7. Monot M, Honore N, Garnier T, et al (2009) Comparative genomic and phylogeographic analysis of *Mycobacterium leprae*. Nat Genet 41:1282–89. PubMed PMID: 19881526
8. Zias J (2002) New evidence for the history of leprosy in the Ancient Near East: an overview. In: Roberts C, Lewis M, Manchester K (eds) The past and present of leprosy archaeological, historical, palaeopathological and clinical approaches. BAR International Archaeopress, Oxford, pp 259–68
9. Cole ST, Singh P (2012) History and phylogeography of leprosy. In: Nunzi E, Massone C, (eds) Leprosy: a practical guide. Springer, Milan, pp 3–14
10. Robbins G, Tripathy VM, Misra VN, et al (2009) Ancient skeletal evidence for leprosy in India (2000 B.C.). PLoS ONE 4:e5669
11. Schuenemann VJ, Avanzi C, Krause-Kyora B, et al (2018) Ancient genomes reveal a high diversity of *Mycobacterium leprae* in medieval Europe. PLOS Pathogens 14:e1006997
12. Belcastro MG, Mariotti V, Facchini F, et al (2005) Leprosy in a skeleton from the 7th century necropolis of Vicenne- Campochiaro (Molise, Italy). Int J Osteoarchaeol 15:431–48
13. Mariotti V, Dutour O, Belcastro MG, et al (2005) Probable early presence of leprosy in Europe in a celtic skeleton of the 4th-3rd century BC (Casalecchio di Reno, Bologna, Italy). Int J Osteoarchaeol 15:311–25
14. Rubini M, Yilmaz SE, Spigelman M, et al (2014) Paleopathological and Molecular Study on Two Cases of Ancient Childhood Leprosy from the Roman and Byzantine Empires. Int J Osteoarchaeol 24:570–84
15. Karamou M, Kyriakis KP, Poulakou-Rebelakou E, et al (2012) La lèpre à Byzance. Presse Med 41:1290–93

16. Rubini M, Zaio P (2009) Lepromatous leprosy in an early medieval cemetery in Central Italy (Morrione, Campochiaron 6th-8th AD). J Archaeol Sci 36:2771–79
17. Antunes-Ferreira N, Matos VMJ, Santos AL (2013) Leprosy in individuals unearthed near the Ermida de Santo André and Leprosarium of Beja, Portugal. Anthropol Sci 121:149–59
18. Baker BJ, Bolhofner KL (2014) Biological and social implications of a medieval burial from Cyprus for understanding leprosy in the past. Int J Paleopathol 4:14–27
19. Blondiaux G, Naji S, Bocquet-Appel JP, et al (2016) The leprosarium of Saint-Thomas d'Azier: the cementochronological proof of the medeival decline of Hansen disease in Europe? Int J Paleopathol 15:140–51
20. Roffey S, Tucker K (2012) A contextual study of the medieval hospital and cemetery of Saint Mary Magdalen, Winchester, England. Int J Paleopathol 2:170–80
21. Lunt DA (2011) The first evidence for leprosy in early Mediaeval Scotland: two individuals from cemeteries in St. Andrews, Fife, Scotland, with evidence for normal burial treatment. Int J Osteoarchaeol 23:310–18
22. Lechat M (1999) The Palaeoepidemiology of leprosy: an overview. Int J Lepr 67:460–70
23. Cockitt J (2013) Does the Surviving palaeopathological evidence support the case for a medical tradition in ancient Nubia? Bull John Rylands Libr 89:45–65
24. Molto JE (2002) Leprosy in Roman period skeletons from Kellis 2, Dakhleh, Egypt. In: Roberts C, Lewis M, Manchester K (eds) The past and present of leprosy archaeological, historical, palaeopathological and clinical approaches. BAR International Archaeopress, Oxford, pp 179–92
25. Lenoble P, Sokari A (2005) A Forgotten Meroitic Agglomeration in the Region of Meroe (NE-36-O/8-H-2). Sudan Nubia 9:59–61
26. Baud M (2011) Premières données sur le palais royal de Mouweis. In: Rondot V, Alpi F, Villeneuve F (eds) La pioche et la plume, Hommages Lenoble. PUF, SFDAS & IFPO Paris, pp 339–57
27. Maillot M (2015) The Meroitic Palace and Royal City. Sudan Nubia, pp 80–7
28. Adams WY, Adams NK, Van Gerven DP, et al (eds) (1999) Kulubnarti III the Cemeteries. SARS, London, 87 p
29. Baud M (2008) The Meroitic Royal City of Muweis: first steps into an urban settlement of riverine Upper Nubia. Sudan Nubia 12:52–63
30. Fantusati E, Baldi M, Bellaciaria F, et al (2015) Seventh excavation season at Abu Erteila. Preliminary report. JIIA:133–46
31. Maillot M (2017) The Palace of Muweis and its Medieval Necropolis. In: Archeology SoA (ed) 82nd annual meeting of the Society of American Archaeology. Symposium abstract volume. Vancouver, Canada, p 354
32. Fantusati E, Kormysheva E, Malykh S (2012) Abu Erteila. Preliminary results of the Italian-Russian archaeological mission excavations, seasons 2009-2011. Beiträge zur Sudanforschung 11:21–59
33. Murail P, Bruzek J, Houët F, et al (2005) DSP: a tool for probabilistic sex diagnosis using worldwide variability in hip-bone measurements. BMSAP 17:167–76
34. Lovejoy CO, Meindl RS, Pryzebeck TR, et al (1985) Chronological metamorphosis of the auricular surface of the ilium: a new method for the determination of adult skeletal age at death. Am J Phys Anthropol 68:15–28
35. Schmitt A (2005) Une nouvelle méthode pour estimer l'âge au décès des adultes à partir de la surface sacropelvienne iliaque. BMSAP 17:89–103
36. Schmitt A (2008) Une nouvelle méthode pour discriminer les individus décédés avant ou après 40 ans à partir de la symphyse pubienne. J Med Leg Droit Med 51:15–24
37. Møller-Christensen V (1961) Bone Changes in Leprosy. Munksgaard, Copenhagen, 51 p
38. Møller-Christensen V (1967) Evidence of leprosy in earlier people. In: Brothwell D, Sandison AT (eds) Disease in antiquity: a survey of diseases, injuries and surgery. CC Thomas, Springfield, pp 295–306
39. Møller-Christensen V (1978) Leprosy changes of the skull. Odense University Press, Odense, 148 p
40. Ortner DJ (2003) Identification of pathological conditions in human skeletal remains. Academic Press, San Diego-London, 645 p
41. Ortner DJ (2008) Differential diagnosis of skeletal lesions in infectious disease. In: Pinhasi R, Mays S (eds) Advances in human palaeopathology. John Wiley and Sons, Chichester, pp 191–214
42. Ortner DJ (2008) Skeletal evidence of Leprosy. In: Magilton J, Lee F, Boylston A (eds) Lepers outside the gate Excavations at the cemetery of the Hospital of Saint James and Saint Mary Magdalene, Chichester, 1986-7 and 1993. 158. CBA report, York, pp 198–207
43. Andersen JG (1992) The rhinomaxillary syndrome in leprosy: a clinical, radiological and paleopathological study. Int J Osteoarchaeol 2:121–29
44. Andersen JG, Manchester K, Roberts C (1994) Septic bone changes in Leprosy: a clinical, radiological and palaeopathological review. Int J Osteoarchaeol 4:21–30
45. Anderson JG, Manchester K (1992) The rhinomaxillary syndrome in leprosy: a clinical, radiological and paleopathology study. Int J Osteoarchaeol 2:121–29
46. Manchester K (1994) Rhinomaxillary lesions in syphilis: differential diagnosis. In: Dutour O, Palfi G, Berato J, Brun JP (eds) L'origine de la Syphilis en Europe : avant ou après 1493? Errance - CAV, Paris-Toulon, pp 79–80
47. Manchester K (2012) Bone changes in leprosy: pathogenesis, palaeopathological diagnostic criteria, and clinical interpretation, University of Bradford, Bradford
48. Resnick D, Niwayama G (2002) Leprosy. In: Resnick D, Niwayama G (eds) Diagnosis of bone and joint disorders 3. Chap 61. Saunders, Philadelphia
49. Barneston J (1950) Osseous changes in neural leprosy. Acta Radiologica 34:47–56
50. Rogers J, Waldron T (1989) Infections in palaeopathology: the basis of classification according to most probable cause. J Archaeol Sci 16:611–25
51. Rothschild BM, Rothschild C (1996) Analysis of treponemal disease in North Africa: The case for Bejel in the Sudan, but absence in West North Africa. Hum Evol 11:11–15
52. Melo de FL, Mello de JM, Fraga AM, et al (2010) Syphilis at the crossroad of phylogenetics and paleopathology. PLoS Negl Trop Dis 4:e575
53. Aufderheide AC, Rodridez-Martin C (1998) The Cambridge encyclopedia of human paleopathology. Cambridge University Press, Cambridge, 478 p
54. Zink AR, Spigelman M, Schraut B, et al (2006) Leishmaniasis in Ancient Egypt and Upper Nubia. Emerg Infect Dis 12:1616–17
55. Marsteller S, Torres-Rouff C, Knudson K (2011) Pre-Columbian Andean sickness ideology and the social experience of leishmaniasis: a contextualized analysis of bioarchaeological and paleopathological data from San Pedro de Atacama, Chile. Int J Paleopathol 1:24–34
56. Grauer AL, Roberts CA (2019) Fungal viral multicelled parasitic and protozoan infections. In: Buikstra J (eds) Ortner's identification of pathological conditions in human skeletal remains. Academic Presse, San Diego, pp 441–78

57. Lessa A, Mendonça de Souza S (2006) Broken noses for the gods: ritual battles in the Atacama Desert during the Tiwanaku period. Memorias do Instituto Oswaldo Cruz 101:133–38
58. Rogers J, Waldron T, Dieppe P, et al (1987) Arthropathies in paleopathology: the basis of classification to most probable cause. J Archaeol Sci 14:179–93
59. Waldron T (2009) Palaeopathology. Cambridge University Press, Cambridge, 279 p
60. Zias J, Mitchell P (1996) Psoriatic arthritis in a fifth-century Judean Desert monastery. Am J Phys Anthropol 101:491–502
61. Moonot P, Ashwood N, Lockwood D (2005) Orthopaedic complications of leprosy. J Bone Joint Surg Br 87-B:1328–32
62. Ankad BS, Halawar RS (2015) Bone involvement in leprosy: early changes. Radiol Infect Dis 1:88–89
63. Ankad BS, Hombal A, Rao S, et al (2011) Radiological changes in the hands and feet of leprosy patients with deformities. J Clin Diagn Res 5:703–7
64. Faget GH, Mayoral FA (1944) Bones Changes in Leprosy: a clinical and roentgenologic study of 505 cases. Radiology 42:1–12
65. Andersen JG, Manchester K (1987) Grooving of the proximal phalanx in leprosy: a paleopathological and radiological study. J Archaeol Sci 14:77–82
66. Mitchell P (1993) Leprosy and the case of King Baldwin IV of Jerusalem: mycobacterial disease in the crusader states of the 12th and 13th centuries. Int J Lepr Other Mycobact Dis 61:283–91
67. Dzierzykray-Rogalski T (1980) Paleopathology of the Ptolemaic inhabitants of Dakhleh Oasis. J Hum Evol 9:71–74
68. Macke A, Macke-Ribet C (1994) Paléodémographie et paléopathologie d'une population égyptienne inhumée dans la nécropole de la Vallée de Reines (Thèbes Ouest, Haute Égypte). Anthropologie et Préhistoire 105:5–28
69. Smith EG (1910) Report on the human remains. The archaeological survey of Nubia: report for 1907–1908, vol 2. National Printing Department, Cairo, 374 p
70. Stone AC, Wilbur AK, Buikstra J, et al (2009) Tuberculosis and leprosy in perspective. Yearb Phys Anthropol 52:66–94
71. Moller-Christensen V, Hugues DR (1966) An early case of leprosy from Nubia. Royal Anthropological Institute of Great Britain and Ireland 1:242–45, PubMed PMID: 4606880
72. WHO (2016) Global Leprosy situation. World Health Organisation, Geneva, Switzerland
73. WHO (2012) Global Leprosy situation. World Health Organisation, Geneva, Switzerland
74. Lynnerup N, Boldsen J (2012) Leprosy (Hansen's Disease). In: Grauer AL (ed) A companion to paleopathology. Wiley-Blackwell, Oxford pp 459–71
75. Lee F, Manchester K (2008) Leprosy: a review of the evidence in the Chichester sample. In: Magilton J, Lee F, Boylston A (eds) Lepers outside the gate. Excavations at the cemetery of the Hospital of Saint James and Saint Mary Magdalene, Chichester, 1986-7 and 1993. CBA report, York, pp 208–18
76. Rawcliffe C (2006) Leprosy in medieval England. Boydell Press, Woodbridge, 421 p
77. Baker BJ, Bolhofner KL (2014) Biological and social implications of a medieval burial from Cyprus for understanding leprosy in the past. Int J Paleopathol 4:14–27
78. Taylor GM, Widdison S, Brown PJ, et al (2000) A Mediaeval Case of Lepromatous Leprosy from 13–14th Century Orkney, Scotland. J Archaeol Sci 27:1133–38
79. Likovsky J, Urbanova M, Hajek M, et al (2006) Two cases of leprosy from Zatec (Bohemia), dated to the turn of the 12th and confirmed by DNA analysis for *Mycobacterium leprae*. J Archaeol Sci 33:1276–83
80. Roberts C (2002) The antiquity of leprosy in Britain: the skeletal evidence. In: Roberts C, Lewis M, Manchester K (eds) The past and present of leprosy archaeological, historical, palaeopathological and clinical approaches. BAR International Archaeopress, Oxford, pp 213–21
81. El Hassan LA, Khalil EAG, El-Hassan AM (2002) Socio-cultural aspects of leprosy among the Masalit and Hawsa tribes in the Sudan. Leprosy Rev 73:20–8
82. Dols MW (1979) Leprosy in medieval Arabic medicine. J Hist Med Allied Sci XXXIV:314–33
83. Pankhurst R (1984) The history of leprosy in Ethiopia up to 1935. Med Hist 28:57–72
84. Gilmore JK (2008) Leprosy at the Lazaretto on Saint Eustatius, Netherlands Antilles. Int J Osteoarchaeol 18:72–84
85. Weston D (2009) Brief communication: paleohistopathological analysis of pathology museum specimens: can periosteal reaction microstructure explain lesion etiology? Am J Phys Anthropol 140:186–93
86. Weston D (2008) Investigating the specificity of periosteal reactions in pathology museum specimens. Am J Phys Anthropol 137:48–59

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ARTICLE / *ARTICLE*

La question de l'utilisation sépulcrale des cavités naturelles par les populations amérindiennes des Petites Antilles : apports de l'étude archéoanthropologique du site de la grotte des Bambous (Guadeloupe)

Investigating the Sepulchral Use of Natural Caves by Amerindian Populations of the Lesser Antilles: Contributions from the Archaeo-Anthropological Study of the "Grotte des Bambous" Site (Guadeloupe)

C. Partiot · P. Courtaud · A. Lenoble · D. Cochard

Résumé La fréquentation des cavités naturelles de l'archipel des Petites Antilles par les populations amérindiennes, mentionnée par les chroniqueurs européens, est aujourd'hui un phénomène archéologiquement attesté. Les modalités de l'utilisation de ces abris rocheux en tant qu'espaces sépulcraux demeurent cependant peu documentées, avec pour conséquence un manque de données concernant les pratiques funéraires des populations précolombiennes. Dans ce contexte, le site de la grotte des Bambous (Grande Terre, Guadeloupe) offre un nouveau témoignage de l'usage potentiellement funéraire des cavités par les populations amérindiennes des Petites Antilles. Un sondage, puis une fouille archéologique ont livré des vestiges osseux humains datés de la période précolombienne et attribués à un unique sujet décédé au cours de la période périnatale. Bien que le site ait fait l'objet de remaniements de grande ampleur, les résultats de notre étude archéoanthropologique appuient l'hypothèse d'un dépôt primaire, et possiblement d'une sépulture. Ces observations permettent ainsi d'apporter de nouveaux éléments de réflexion concernant l'utilisation sépulcrale des abris rocheux naturels de l'archipel des Petites Antilles au Céramique final, et posent la question des spécificités du comportement funéraire des populations locales par rapport au décès périnatal.

Mots clés Décès périnatal · Troumassoïde · Petites Antilles · Guadeloupe · Pratiques funéraires amérindiennes · Céramique final

Abstract The use by Amerindian populations of natural caves within the Lesser Antilles archipelago, mentioned by European chroniclers, is now archaeologically attested. However, the use of these rock-shelters as sepulchral spaces is not well documented, resulting in a lack of data on the mortuary practices of Pre-Columbian populations. The "Grotte des Bambous" site (Grande Terre, Guadeloupe) has yielded new evidence on the potential funerary use of rock cavities by Amerindian populations of the Lesser Antilles. The survey and the subsequent archaeological excavation, which was carried out in 2017, resulted in the discovery of human remains dating from the pre-Columbian period, with an attribution to a single individual who died during the perinatal period. Although the site had been extensively disturbed, the results of the archaeo-anthropological study support the hypothesis of a primary deposition, possibly to be identified as a burial. Moreover, these observations provide new insights into the sepulchral use of natural rock-shelters in the Lesser Antilles archipelago during the Final Ceramic period, and raise questions about specific characteristics of the funerary behaviour of native populations in connection with perinatal death.

Keywords Perinatal death · Troumassoid · Lesser Antilles · Guadeloupe · Amerindian funerary practices · Final Ceramic period

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Introduction

Les pratiques funéraires des populations amérindiennes, dépeintes dans leurs grandes lignes dans les récits des chroniqueurs et écrivains européens (e.g. [1–6]), se positionnent depuis plusieurs décennies comme un axe majeur de la recherche archéologique dans les Petites Antilles. Les découvertes récentes de sites sépulcraux en plein air [7] ont ouvert la voie à une analyse fine des comportements mortuaires des groupes du Céramique ancien (ca 500 BCE–400 CE), moyen (400–750 CE), récent (750–1100 CE) et final (1100–1500 CE) [8]. Avec des habitats amérindiens parfois conséquents à l'image de Morel, l'Anse à la Gourde ou La Pointe de Grande Anse [7,9], l'archipel de la Guadeloupe présente, au sein du paysage archéologique régional, un potentiel informatif important.

Les études archéothanatologiques menées sur les sites de plein air des Petites Antilles ont mis en évidence des pratiques funéraires complexes et variées impliquant majoritairement des dépôts primaires individuels, parfois multiples, avec ou sans manipulations prédépositionnelles [7,9–10]. Ces dernières peuvent inclure une phase de préparation du corps, parfois déposé dans un panier et laissé à sécher près d'une source de chaleur. Les inhumations intègrent parfois des prélèvements temporaires ou définitifs de portions de corps ou de vestiges osseux, voire l'exposition du corps dans sa fosse sépulcrale comblée plusieurs mois après l'enterrement. L'existence de pratiques impliquant un dépôt secondaire est également relevée, avec des réarrangements (déplacement des os en fagots), voire des crémations de vestiges osseux durant les phases les plus récentes de la période Céramique. Ces sépultures de plein air sont étroitement liées aux sites d'habitats, les défunts étant inhumés à proximité, voire dans les maisons elles-mêmes, ou la nécropole se trouvant implantée sur une ancienne zone de village [7,9]. L'étude du recrutement funéraire a, par ailleurs, montré une sous-représentation, voire une quasi-absence des individus non adultes sur des sites comme La Pointe de Grande Anse en Guadeloupe ou Lavoute à Sainte-Lucie, constat amenant à poser la question d'un traitement spécifique des sujets immatures dans certains groupes [9–11].

Si les modalités de la fonction sépulcrale des habitats de plein air sont ainsi de mieux en mieux connues, celles relatives au milieu souterrain restent encore peu investies. Ce décalage a pu s'appuyer sur l'hypothèse, longtemps prédominante, selon laquelle l'occupation des cavités naturelles constituerait une caractéristique fondamentale des groupes implantés dans les Grandes Antilles, mais ne serait qu'un phénomène marginal dans les sociétés des Petites Antilles [12,13]. Les résultats des campagnes de prospection des abris sous-roches [14], ainsi que des projets de recherche axés sur la fréquentation des cavités de l'archipel [15–17], ont récemment amené à contester cette hypothèse, cette disparité étant plutôt à mettre sur le compte de l'état de la recherche. Ces projets ont ainsi participé à mettre en lumière la multiplicité des fonctions de ces abris, utilisés comme habitats ponctuels, lieux « cérémoniels », et espaces sépulcraux [18–20]. Dans ce contexte, l'étude de nouveaux sites, comme celui de la grotte des Bambous, apparaît comme cruciale, en particulier dans la perspective de documenter la variabilité des pratiques funéraires observées dans les abris et grottes par rapport à celles observées sur les sites de plein air.

Le site de la grotte des Bambous est localisé sur le littoral oriental de l'île de Grande-Terre (Le Moule, Guadeloupe, figure 1). La grotte, constituée d'une salle unique de 5 m par 3 avec une hauteur maximale de 2 m, s'ouvre à environ 500 m du rivage de la côte atlantique, à mi-pente du versant exposé au nord d'une ravine affluente de celle de l'Anse Patate (Fig. 1). Le site a fait l'objet d'une déclaration de découverte fortuite par son inventeur, C. Mas, au printemps 2014, ce qui a donné lieu à la mise en œuvre d'un sondage exploratoire en décembre 2014, avec pour objectif d'estimer le potentiel archéologique et paléontologique du site [21]. Ce sondage a livré des ossements humains appartenant à un individu décédé au cours de la période périnatale. Une fouille (Resp. D. Cochard) a été entreprise au printemps 2017 dans le cadre du projet ECSIT (*ECoSystèmes Insulaires Tropicaux, réponse de la faune indigène terrestre de Guadeloupe à 6 000 ans d'anthropisation du milieu*, resp. A. Lenoble).

Cette nouvelle opération, qui avait entre autres objectifs de questionner la fonction funéraire du site, a livré des vestiges osseux humains dispersés appartenant, là encore, à un sujet décédé en période périnatale [22]. L'ensemble des vestiges a été identifié comme appartenant à un seul et même individu, lequel a fait l'objet d'une datation radiocarbone réalisée sur un fragment de voûte pariétale. Le résultat donne un âge calibré de 1223–1289 CE et 1297–1405 CE (Lyon-12960 [SacA-45279] : 745 ± 30 BP), ce qui situe le sujet dans la période du Céramique final, confirmant l'intérêt du site pour la documentation de l'occupation amérindienne des cavités naturelles. L'étude anthropologique s'est donnée pour objectif de discuter la nature funéraire du dépôt en s'appuyant sur les données archéologiques, ainsi que sur la caractérisation biologique de l'individu.

Méthodes

Fouille et enregistrement des données

Le sondage de 2014 a été réalisé à 1 m de l'entrée de la grotte, à proximité de la paroi nord et sur une surface de 0,5 m^2 (Fig. 2). L'opération de mai 2017 s'est développée dans la partie sud de la cavité sur une emprise d'un peu plus de 5 m^2. Deux des trois unités stratigraphiques reconnues au sondage, l'US 1 et l'US 3, y sont représentées. Le remplissage, d'une puissance variant entre 5 et 30 cm, a été fouillé manuellement par décapages successifs de 2–5 cm d'épaisseur (épaisseur variant selon la part de fraction grossière) tout en respectant le maillage du carroyage (1/9 de m^2) et la géométrie des contacts entre les unités stratigraphiques. Tous les vestiges identifiables ou supérieurs à 2 cm ont été coordonnés spatialement (*x*, *y*, *z*). Le sédiment des 150 décapages effectués a été systématiquement tamisé à l'eau sur

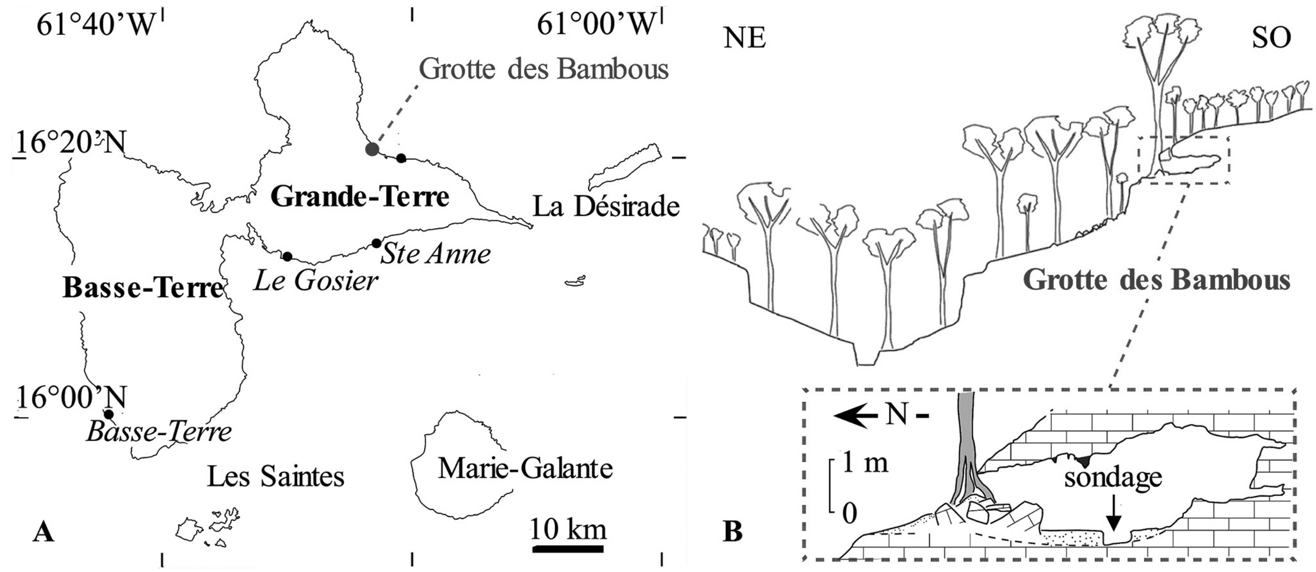

Fig. 1 Localisation géographique de la Grotte des Bambous et topographie du site. Modifié d'après Lenoble et al. [21] et Cochard et al. [22] / *Geographical location of the Grotte des Bambous and topography of the site. Modified from Lenoble et al.* [21] *and Cochard et al* [22]

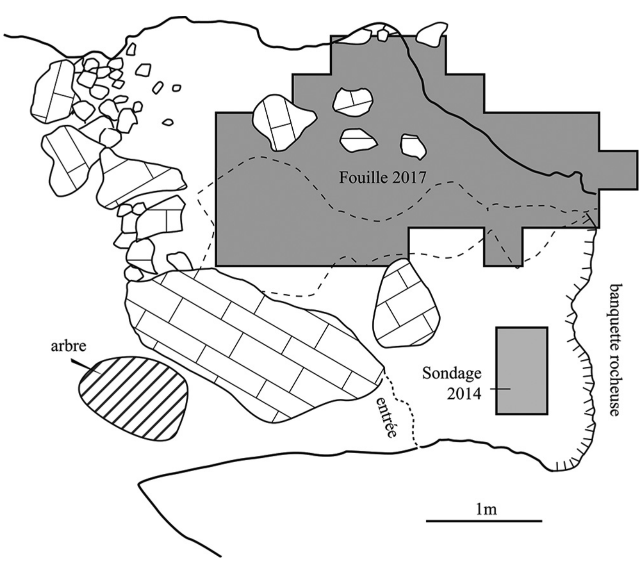

Fig. 2 Localisation de l'emprise du sondage de 2014 et de la fouille de 2017 dans la Grotte des Bambous. Modifié d'après Lenoble et al. [21] et Cochard et al. [22] / *Location of the 2014 survey and of the 2017 excavation in the Grotte des Bambous. Modified from Lenoble et al.* [21] *and Cochard et al.* [22]

une maille de 2 mm. Une attention particulière a été portée à l'identification d'éléments de très faibles dimensions (germes dentaires, points d'ossification secondaires, côtes surnuméraires cervicales [23]), ainsi qu'à la reconnaissance d'éventuelles connexions ou logiques anatomiques, et indices de bioturbations. La répartition spatiale relative des différents vestiges osseux a été analysée par un test Rho de Spearman calculé sur le logiciel libre Past.

Étude biologique et datation

Les vestiges humains ont fait l'objet d'un protocole d'étude comprenant l'identification et l'inventaire des ossements, le remplissage d'une fiche de conservation, puis une analyse métrique et non métrique. Celle-ci a suivi les protocoles classiques pour la classe d'âge périnatale [24–26], dont une synthèse est présentée dans Partiot [27]. L'estimation de l'âge au décès du sujet décédé en période périnatale a été réalisée grâce aux formules de Fazekas et Kósa [24] révisées par Sellier et publiées dans Schmitt et Georges [28].

Les âges radiométriques sont présentés dans l'ère commune (CE/BCE) lorsqu'ils sont calibrés et en âge radiocarbone conventionnel (BP) lorsqu'ils ne le sont pas. La calibration des datations est réalisée en ayant recours au logiciel Calib online 7.1 [29]. Dans le cas du vestige humain, une courbe IntCal 13/Marine 13 50 % : 50 % a été utilisée, cela pour tenir compte du régime alimentaire des populations amérindiennes des îles de petite taille, ou des îles carbonatées peu élevées des Petites Antilles, fortement dépendant des ressources marines [30,31]. L'écart régional à l'effet réservoir (dR) est considéré nul, comme habituellement fait dans la Caraïbe [32].

Résultats

Analyses de terrain

Le sondage de 2014 a livré 11 ossements humains appartenant à un individu décédé au cours de la période périnatale. La fouille de 2017 a, quant à elle, livré 41 vestiges osseux appartenant à un sujet périnatal de même stade de maturation, ainsi qu'une unique dent définitive. Le tri des refus de tamis a permis la collecte de près de 10 000 ossements appartenant à au moins 45 taxons auxquels s'ajoutent plusieurs milliers de fragments d'invertébrés (mollusques marins et terrestres, crustacés). Les ossements humains sont donc présents aux côtés d'un assemblage osseux varié riche de plusieurs milliers d'ossements accumulés au cours des trois derniers millénaires [33], où sont représentés rongeurs, indigènes et introduits, chauve-souris et squamates, oiseaux, l'ensemble documentant la modification de la biocénose vertébrée terrestre de l'île depuis l'époque amérindienne [22].

Les résultats de l'opération de sondage de 2014 concluent à un remplissage de la cavité ayant subi d'importantes perturbations [21], constat confirmé par la fouille de 2017. Ces perturbations se traduisent, du point de vue sédimentaire, par une homogénéité de l'unité stratigraphique de surface (US1), un contact érosif avec la couche sous-jacente (US3) et des amas de cailloux situés en pied de paroi sud du fait de l'épierrage du sédiment excavé (cf. infra). Le non-respect du principe de superposition stratigraphique des datations 14C confirme ce brassage sédimentaire. En outre, les données biostratigraphiques témoignent tout autant de l'absence d'ordonnancement stratigraphique du remplissage de la cavité, les espèces indigènes disparues étant associées à des espèces introduites à la période historique dans l'ensemble de la séquence.

Ces importants mouvements verticaux et horizontaux ont au moins deux origines. Une partie résulte de l'activité biologique dans la cavité comme l'atteste la présence de bioturbateurs dans le remplissage (cf. bernard-l'hermite, chouettes des terriers, rongeurs, ratons laveurs) et de traces de racines visibles sur les ossements. Une autre partie est liée aux activités humaines. Les actes de fouilles non autorisés dans la cavité, préalables à la déclaration de découverte du site et visibles au moment du sondage, se superposent en effet à des remaniements anthropogènes plus anciens (cf. pot à mélasse). Ils accentuent les redistributions stratigraphiques et spatiales par le jeu combiné des creusements, de l'épierrage du sédiment, du comblement des excavations et de l'étalement des déblais. En outre, du fait de ces fouilles, l'intégrité archéologique de l'assemblage n'est pas garantie, des éléments archéologiques ayant pu être soustraits à notre connaissance.

Les vestiges osseux humains ont été affectés par ces perturbations. Ils se révèlent en effet fortement dispersés horizontalement, les éléments étant répartis sur 32 décapages avec une concentration maximale de sept vestiges dans un sous-carré (B5C) et de trois restes par décapage (Fig. 3A). La redistribution verticale est également élevée avec des restes humains présents dans toutes les passes, même les plus profondes. Il est intéressant de souligner que la répartition spatiale des restes humains ne diffère pas significativement des autres vestiges biologiques ($Rs = 0{,}43$, valeur de $p < 0{,}001$), le nombre de restes étant le plus élevé dans la partie sud et centrale de la fouille. Cette distribution est liée à la taille de l'échantillon. Il existe en effet une corrélation hautement significative entre le volume de sédiment tamisé par sous-carré et le nombre de restes osseux déterminés ($Rs = 0{,}92$, valeur de $p < 0{,}001$). La concentration des restes humains dans le carré B5 peut donc s'expliquer par le volume de sédiment plus important dans cette partie de l'emprise. Aucune logique ou connexion anatomique, ni même de concentration d'ossements, n'ont ainsi été identifiées, et aucun indice traduisant possiblement l'existence d'un appareillage funéraire (creusement ou aménagement) n'a, par ailleurs, été relevé.

Les traces d'activités humaines dans la cavité se sont révélées peu nombreuses, l'importance des processus taphonomiques et du brassage des sédiments limitant fortement les interprétations. L'existence, en fond de cavité, d'une vasque naturelle recueillant des eaux d'égouttement serait susceptible d'avoir été un facteur d'attractivité, du fait du manque de sources dans la région et de la localisation de la cavité dans une voie de communication naturelle. Les tessons de céramique présents dans le remplissage ($n = 80$) sont de très petites dimensions (longueur moyenne de 12,7 mm) et proviennent en grande partie de la fracturation accidentelle in situ d'un pot à mélasse datant de la période historique, et donc sans rapport avec l'individu immature. Seuls deux ou trois tessons peuvent se rattacher à la période amérindienne. En dehors de ces vestiges, seule une perle intacte, d'un diamètre de 3,5 mm, vraisemblablement produite à partir d'une coquille de mollusque marin, a été collectée (Fig. 3B). Au regard de la faible abondance et diversité du matériel archéologique collecté, les occupations humaines apparaissent de toute évidence comme ayant été très brèves. Dès lors, la reconnaissance des ressources animales (vertébrées et invertébrées) susceptibles d'être associées avec le dépôt de l'individu immature est délicate à mettre en évidence, ces vestiges se mêlant à l'important bruit de fond déposé naturellement. Les perturbations sédimentaires susmentionnées renforcent ces difficultés interprétatives. La présence de 68 restes de poissons marins, dont certains de grande taille (poisson-perroquet de 30 à 40 cm de long), peut cependant difficilement s'expliquer par un phénomène naturel. La datation de l'une de ces vertèbres (Lyon-15374

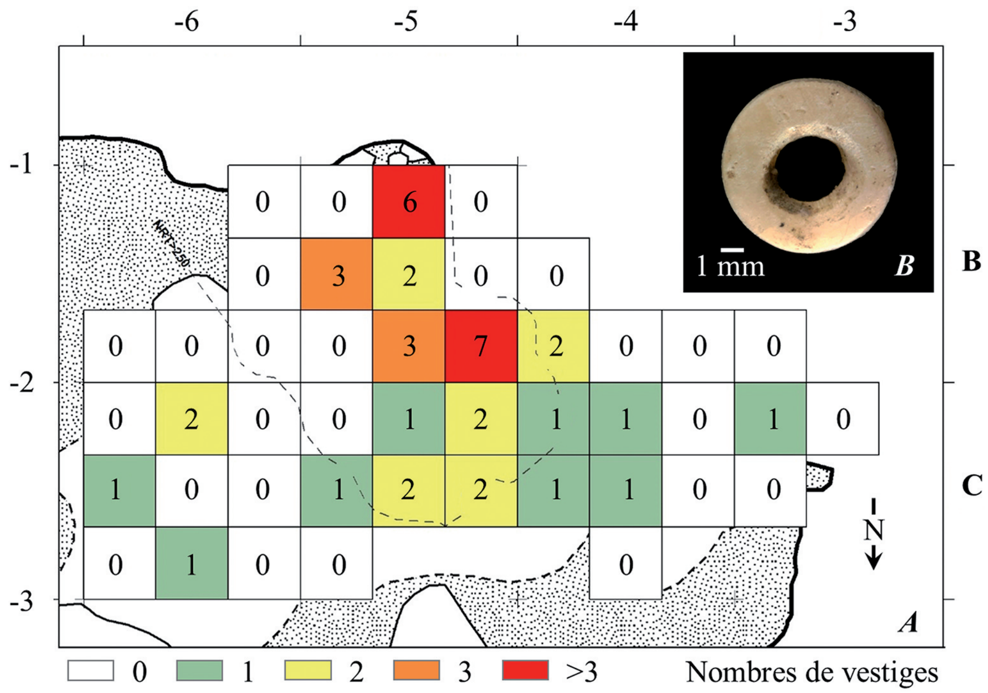

Fig. 3 A : distribution spatiale et abondance des restes humains collectés durant la campagne de fouille de 2017 à la grotte des Bambous (décapages cumulés US1 et 3). B : photographie de la perle en coquillage, découverte dans le décapage de surface du carré C4. Avec NRD : nombre de restes osseux déterminés / *A: Spatial distribution and abundance of the human remains collected during the 2017 excavation at the Grotte des Bambous (cumulative scraping of US1 and 3). B: photograph of the shell bead discovered in the surface scraping of the C4 square. With NRD: number of bone remains determined*

[SacA-53697] : 1278–1399 CE) renforce ce lien potentiel, même si l'absence de traces anthropiques sur les ossements ne permet pas de valider cette hypothèse (Ephrem *in* Cochard et al. [22]). La présence de nombreux microcharbons, ainsi que de quelques restes de rongeurs brûlés ($n = 16$), soulève également la question d'un lien entre ces éléments et les restes de l'enfant. La datation de l'un de ces charbons (Lyon-15373 [SacA-53697] 945–1005 CE) ne corrobore pas cette hypothèse, tout en ne l'infirmant pas non plus, l'effet vieux bois étant susceptible de produire un décalage de quelques siècles entre le matériau et la date de combustion [34].

Étude biologique et taphonomique

La représentation anatomique ainsi que l'état de maturation des 11 vestiges osseux retrouvés lors du sondage s'accordaient avec l'hypothèse d'un seul et même sujet décédé en période périnatale. Les 41 ossements immatures retrouvés lors de la fouille corroborent cette hypothèse (Fig. 4), en dépit de la découverte d'une unique dent définitive mature (une première ou seconde prémolaire inférieure gauche altérée et fortement concrétionnée) qui a porté le nombre minimum d'individus théoriquement présents sur le site à deux. Dans la mesure où cette dent est le seul vestige attribuable à un sujet n'appartenant pas à la classe d'âge périnatale, et qu'il est susceptible d'avoir fait l'objet d'une perte ante-mortem, sa présence sur le site est toutefois considérée comme non indicative de la présence d'un individu supplémentaire.

Concernant le squelette de l'individu immature, toutes les régions anatomiques sont représentées, avec 16 éléments osseux issus du squelette céphalique, 14 du rachis, quatre du gril costal, quatre des membres supérieurs et de leurs ceintures, trois des membres inférieurs et de leurs ceintures, et 12 issus des mains et des pieds (Fig. 4). De nombreux éléments osseux de très faibles dimensions (germes dentaires, points d'ossification secondaires, phalanges de main et de pied) sont par ailleurs préservés. Ces indices suggèrent un dépôt primaire. Les os ont subi une fragmentation mécanique, ancienne et sur os sec. L'humérus droit présente, en outre, deux perforations de la surface corticale, localisées entre 0,5 et 1 cm sous la région métaphysaire proximale (Fig. 5). Il est vraisemblable que ces altérations aient été produites par un crustacé (bernard-l'hermite), bien que l'on ne puisse pas exclure l'action d'un petit mammifère charognard (e.g. raton-laveur ou mangouste).

L'âge au décès de l'individu immature a été estimé à 38 semaines d'aménorrhée (intervalles de confiance [36,3–39,6]), soit neuf mois lunaires et demi (intervalles de confiance [9,1–9,9]) sur la base de la longueur maximale

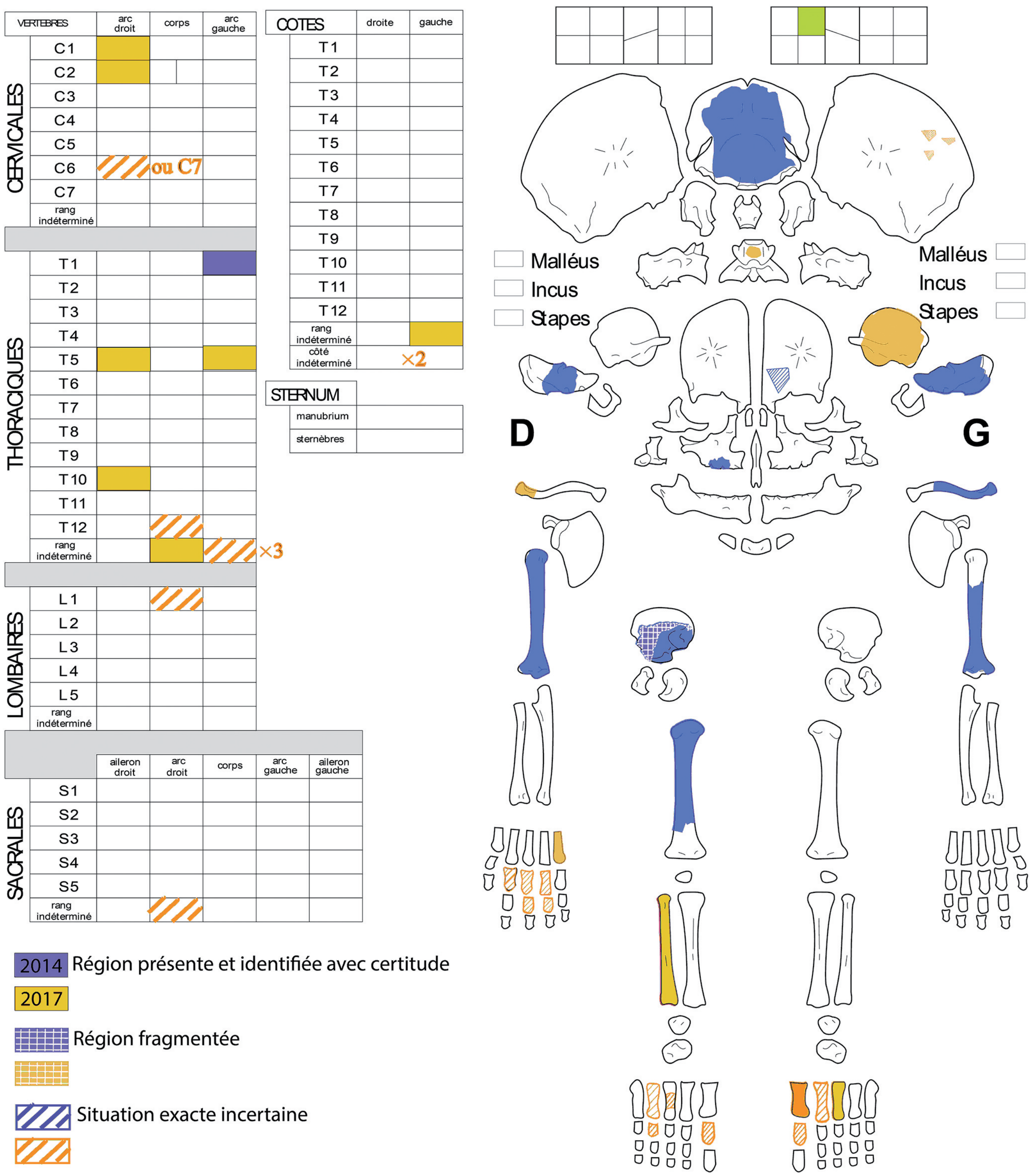

Fig. 4 Ossements immatures retrouvés sur le site de la grotte des Bambous, représentation anatomique concordant avec la présence d'un seul individu décédé au cours de la période périnatale. / *Immature remains found on the Grotte des Bambous site. The anatomical representation is consistent with the presence of a single individual who died during the perinatal period*

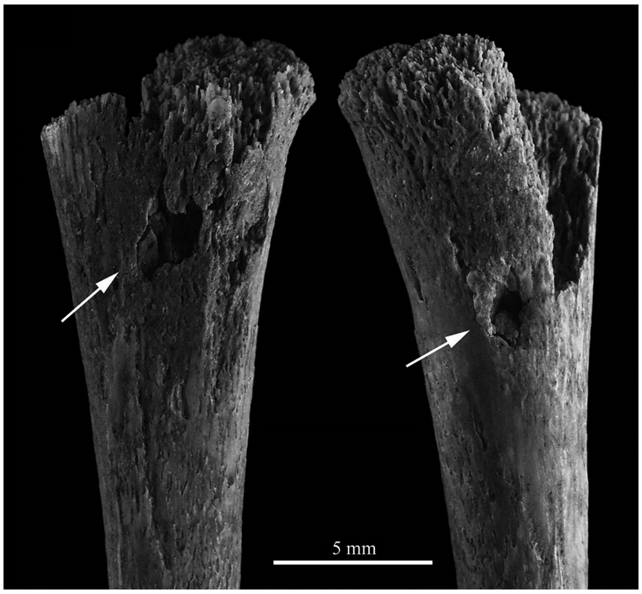

Fig. 5 Vue de détail des altérations taphonomiques de la région proximale de l'humérus droit, à gauche : vue antérolatérale ; à droite : vue postéromédiale / *Detail of the taphonomic alterations on the proximal region of the right humerus, left: antero-lateral view; right: postero-medial view*

de la diaphyse de la fibula droite, seul os long ayant conservé toute sa diaphyse. Dans la mesure où l'os présente tout de même de légères altérations corticales distales et proximales, il s'agit d'une estimation basse. D'après ces résultats, le sujet est décédé dans la période proche du terme théorique de la grossesse (dont la durée est classiquement fixée à 40 ou 41 semaines d'aménorrhée, soit dix mois lunaires). En raison de l'état de conservation des ossements, l'acquisition de données métriques n'a pu être réalisée que sur sept vestiges et n'a pas permis la réalisation d'analyses anthropométriques (Tableau 1). Les ossements ne présentaient par ailleurs aucune variation anatomique non métrique ou particularité morphologique remarquable.

Discussion

Le relatif bon état de conservation du squelette, la représentation de toutes les régions anatomiques, ainsi que la conservation d'ossements de très faibles dimensions appuient l'hypothèse selon laquelle l'individu de la grotte des Bambous aurait fait l'objet d'un dépôt primaire. La localisation d'origine de ce dernier demeure cependant inconnue, et sa nature reste également à préciser. L'hypothèse d'un dépôt de surface, avec des ossements dont la préservation et la conservation auraient été favorisées par l'absence de carnivores charognards indigènes, par l'effet protecteur du milieu souterrain vis-à-vis du *weathering*, ainsi que par un recouvrement rapide des vestiges, ne peut toutefois pas être écartée. Cette possibilité pourrait être soutenue par la relative similitude entre l'état de conservation du squelette de nouveau-né et celui observé sur plusieurs espèces de vertébrés terrestres (rongeurs et squamates) collectés dans la cavité et dont l'accumulation résulte d'une mortalité attritionnelle. Ces taxons n'étant pas fouisseurs, leurs corps ont donc vraisemblablement été exposés en surface, et ce, sans impacter leur conservation.

Dans la mesure où il s'agit d'un sujet décédé autour de la naissance, et dont le squelette a été retrouvé dispersé et sans aménagement identifié, l'hypothèse selon laquelle le corps de l'enfant aurait été abandonné sans geste particulier, voire dissimulé, doit aussi être considérée. Il s'agit de pratiques connues pour cette classe d'âge, laquelle fait, dans de nombreux contextes chronogéographiques, l'objet de traitements funéraires différentiels et remarquablement variés [35]. Entre grossesse avortée et décès d'un membre à part entière de la communauté, la mort périnatale, dont la gestion repose sur les modalités ambiguës d'un statut social incertain, correspond ainsi à ce que l'on peut décrire comme une « zone grise de l'individualité ». Dans un contexte de mortalité infantile très élevée, et si l'enfant n'est pas reconnu comme disposant pleinement du statut de personne, son corps peut être traité à l'image d'un « produit de conception », dans la lignée du concept encore pleinement usité aujourd'hui [36], et faire par conséquent l'objet d'une « non-sépulture » [35].

Même dans le cas où l'hypothèse d'un dépôt de surface se trouverait vérifiée, ces observations ne permettent cependant pas à elles seules de privilégier l'hypothèse de l'abandon de corps à celle de l'existence d'un geste funéraire. Au contraire, si le dépôt du corps dans une grotte pouvait être interprété comme un geste de dissimulation, le fait que ce type d'espace soit particulièrement fréquenté au Céramique final, et ce même de manière ponctuelle [18], pourrait laisser penser que l'enfant a fait l'objet d'une attention particulière de protection, plutôt indicatrice d'une volonté de lui dédier une sépulture [37]. Dans ce contexte, la présence de possibles marqueurs d'attention matérielle [37], dont en premier lieu la perle en coquillage (Fig. 3B), pourrait également être envisagée comme l'indice d'un soin particulier apporté à l'enfant. D'après les études de séries existantes dans les Antilles, ce matériau apparaît comme fréquemment utilisé, tout en étant rarement identifié en contexte funéraire [38]. Sur certains sites, du matériel et des dépôts votifs ont été identifiés comme associés au défunt, faisant écho aux pratiques témoignées par les chroniqueurs [39]. Dans les Bahamas, l'individu 1E du site Céramique final de Preacher's Cave a par exemple été déposé dans un hamac accompagné de nombreux coquillages travaillés, d'un morceau d'ocre, d'un outil en arêtes de poisson et des vestiges d'une pièce de tortue de mer [40]. Les dépôts votifs alimentaires sont, de même, fréquents dans la Caraïbe [41]. Dans ce contexte, les

Tableau 1 Données métriques acquises sur les éléments osseux de l'individu de la Grotte des Bambous. Variables métriques extraites de Fazekas et Kósa [24], Duday et al. [25] et Partiot [27]. Intitulés des variables d'après Partiot [27]

Élément osseux	Variable	Définition	L (mm)
Pétreux G	Pe 2 bis	Hauteur mesurée dans un plan vertical entre le point supérieur de l'*eminentia arcuata* et le bord inférieur du pétreux	12,9
	Pe 3	Diamètre vertical maximal du méat acoustique interne	3,2
	Pe4	Diamètre horizontal maximal du méat acoustique interne	5,2
Pétreux D	Pe 2 bis	Hauteur mesurée dans un plan vertical entre le point supérieur de l'*eminentia arcuata* et le bord inférieur du pétreux	13,2
Humérus D	Hu 1	Longueur maximale de la diaphyse	[59]
	Hu 2	Périmètre au milieu de la diaphyse	[14,5]
	Hu 3	Diamètre maximal au milieu de la diaphyse	[4,9]
	Hu 4	Diamètre minimal au milieu de la diaphyse	[4,1]
	Hu 10	Largeur de la fosse olécranienne, les repères latéral et médial étant situés sur le bord postérieur de la surface distale	8,2
Fémur D	Fe 2	Périmètre au milieu de la diaphyse	[21]
	Fe 3	Diamètre antéropostérieur au milieu de la diaphyse	[6]
	Fe 4	Diamètre transversal au milieu de la diaphyse	[6,8]
	Fe 5	Diamètre maximal de l'extrémité proximale	[16,4]
	Fe 1 bis	Longueur entre l'extrémité proximale de la diaphyse et le foramen nourricier	25,5
Fibula D	Fi 1	Longueur de la diaphyse	57,7
	Fi 2	Diamètre maximal au milieu de la diaphyse	3,4
	Fi 3	Diamètre minimal au milieu de la diaphyse	2,3
	Fi 4	Périmètre au milieu de la diaphyse	10
	Fi1 bis	Longueur entre l'extrémité proximale de la diaphyse et le foramen nourricier	19,4
Hémi-arc G de l'atlas	An 1	Longueur maximale au point le plus antérieur à l'extrémité postérieur de la lame, le repère antérieur de la mesure se situant sur le processus transverse	15,7
	An 2	Largeur maximale de l'hémi-arc	10
	An 3	Hauteur de la lame	4,4
MT Grayon 1	MC 1	Longueur maximale	11,9

[X] : donnée « approximative » acquise sur un vestige présentant une altération taphonomique de surface ; G : côté gauche ; D : côté droit ; L : longueur ; Mt : métatarsien / *Metric data acquired fromthe bone remains of the individual from the Grotte des Bambous. Metric variables from Fazekas et Kósa* [24], *Duday et al.* [25] *and Partiot* [27]. *Variable references from Partiot* [27]. *[X]: "approximate" data acquired from a slightly eroded bone; L: left side; R: right side; L: length; Mt: metatarsal bone*

ossements de poissons, dont l'introduction est possiblement anthropique et synchrone du dépôt de l'individu, ainsi que les tessons possiblement amérindiens, pourraient appuyer l'hypothèse d'un acte funéraire. De même, la présence dans l'assemblage de la grotte des Bambous d'une dent définitive pourrait éventuellement être discutée au regard des pratiques de dépôts funéraires de « marmousets » faits de coton et de vestiges humains dans les grottes sépulcrales des Grandes Antilles, mentionnées dans les récits d'explorateurs du XVII^e siècle [3] et retrouvées par les explorateurs du XIX^e siècle. L'interprétation du matériel de la grotte des Bambous demeure toutefois limitée, d'autant plus que les fouilles clandestines menées dans la cavité ont pu, par ailleurs, amener à en soustraire une partie. Dès lors, seule la prise en compte du contexte archéologique général dans lequel s'insère le site pourrait appuyer une interprétation funéraire du dépôt.

Cette découverte s'inscrit en effet dans le cadre global du phénomène d'utilisation des cavités naturelles en tant qu'espace sépulcral par les populations céramiques de l'archipel des Antilles. La description que donnent les chroniqueurs des pratiques funéraires ne renvoie toutefois qu'aux cas d'inhumations en habitat de plein air. La scène qui y est décrite est celle d'un mort toiletté et apprêté, enveloppé dans un linceul et placé assis en position fœtale dans une fosse creusée dans sa case ou une case bâtie à dessein. La cérémonie de chants et de pleurs qui s'achève par le comblement de la fosse et la combustion des effets du mort [4–6], après un possible temps où la fosse est laissée ouverte pour laisser aux parents la réalisation d'une visite funèbre [1]. Ces pratiques d'inhumations primaires individuelles de sujets adultes à même l'espace domestique du village sont aujourd'hui attestées par les sources archéologiques [7,9–11]. Dans les Grandes Antilles et les Bahamas, il s'agit principalement de sépultures primaires en pleine terre, même si des pratiques de préparation du corps (e.g. un dessèchement du corps avant inhumation dans un contenant en matière périssable), de réductions, de dispersion et de dépôts crématoires sont parfois observées [7,40].

Les pratiques funéraires en grotte sont en revanche très peu évoquées dans les récits de voyageurs européens [1,2], et les découvertes de cavités amérindiennes à vocation funéraire restent elles-mêmes particulièrement rares dans les Petites Antilles. Cette situation apparaît en partie induite par l'essor encore récent des prospections archéologiques en contexte souterrain et le peu de territoires calcaires, plutôt que par l'existence d'une réelle disparité des pratiques sépulcrales entre les différents groupes insulaires [18]. Avant la grotte des Bambous, cinq cavités ont livré des vestiges humains datés du Céramique récent jusqu'au début de la période historique : la Voûte à Pin à la Désirade [18], Cadet 2 [16], la grotte Blanchard [42] à Marie-Galante, Airport Cave et Tanglewood Cave à Anguilla [43]. Parmi elles, trois sont situées sur l'archipel de Guadeloupe, et deux ont révélé des sujets immatures datés du Céramique final. La première est la grotte de la Voûte à Pin, dans laquelle la présence de dépôts funéraires incluant des individus immatures aurait déjà été relevée au XVIII^{e} siècle par le Père Labat [1], puis par le poète et romancier Nicolas-Germain Léonard : « *[…] on y trouva, il y a 40 ans, des têtes et des ossements humains, rangés sur des bancs de pierre, et noués avec des fils de coton. On ajoute que plusieurs étaient d'une grandeur démesurée. Je ne vis que des os d'enfants dans ce souterrain…* » (2, rééd. de 2015, p. 234). Une opération de sondage et le tamisage des sédiments remaniés ont par ailleurs confirmé la présence d'ossements immatures associés à des tessons de céramique [44], avec une datation obtenue sur ossement humain donnant un âge calibré de 1408–1455 CE (Lyon 8457, 720 ± 30 BP) [45].

En 2005, la fouille de la grotte de Cadet 2 a également livré, outre les vestiges de deux adultes partiellement représentés et porteurs de traces de décharnement intentionnel, ainsi que d'un enfant mort entre cinq et dix ans, la sépulture en place d'un sujet périnatal [16]. Le squelette était bien conservé, les vestiges étant majoritairement en connexion anatomique, à l'exception du membre supérieur gauche qui avait subi des perturbations. L'analyse taphonomique a permis d'identifier qu'il s'agissait d'un dépôt primaire dans une fosse colmatée immédiatement, le corps ayant été déposé sur le dos, les membres inférieurs en flexion sur l'abdomen, le membre supérieur droit fléchi. La datation réalisée sur les ossements du sujet immature a donné un âge calibré de 1333–1490 CE (Erl-8478 : 692 ± 39 BP) [16]. Si la nature du statut des nouveau-nés dans les sociétés amérindiennes demeure ainsi mal connue, la découverte de la sépulture de la grotte de Cadet 2 est un argument en faveur de l'existence d'une certaine reconnaissance de la communauté des vivants vis-à-vis de ces petits défunts. Ajoutée à la découverte de la Voûte à Pin ainsi qu'à nos observations archéoanthropologiques, son existence pourrait ainsi appuyer l'hypothèse de la nature funéraire du dépôt de la grotte des Bambous. Par ailleurs, comme à Cadet 2, une inhumation en pleine terre pourrait être envisagée dans cette cavité en considérant l'état de conservation des ossements et leur représentation anatomique, même si l'hypothèse d'un dépôt de surface rapidement recouvert par les sédiments et la végétation ne peut pas, en l'état, être écartée.

Les datations réalisées sur les trois sites de l'archipel, remontant toutes au Céramique final ou Suazan Troumassoïde (1300–1500 CE), témoignent par ailleurs du synchronisme de ce phénomène sépulcral, lequel correspond aussi à la période où les grottes des Petites Antilles sont particulièrement fréquentées et investies en tant qu'habitats ponctuels ou « lieux cérémoniels » par les populations amérindiennes [18]. Le synchronisme du phénomène n'est, en outre, pas limité aux îles de Guadeloupe, puisque c'est également au Céramique final que sont rattachées les sépultures en cavités de l'âge Céramique dans les Grandes Antilles. À Porto Rico et Hispaniola, ce phénomène est associé à une multiplicité des lieux d'inhumations, elle-même superposée à une structuration et hiérarchisation des sociétés ayant mené au caciquat [39,46]. Ce type de chefferie n'est toutefois pas connu pour avoir existé aux Petites Antilles, il s'agit même d'un des principaux éléments de différenciation de la sphère caraïbe des Petites Antilles de la sphère Taïno des Grandes Antilles [12,13]. Dans les Grandes Antilles et les Bahamas, les inhumations en cavités de la période Céramique auraient été réservées aux personnes de haut rang, telles que les caciques [39,41]. Ces interprétations reposent toutefois sur de rares témoignages historiques, ainsi que sur des découvertes parfois remarquables, mais anciennes, faites au XIX^{e} ou au début du XX^{e} siècle [40,47].

La question de la place spécifiquement réservée aux individus immatures dans ces pratiques d'inhumation en grotte demeure toutefois difficile à appréhender. Pour la période Céramique en Guadeloupe, l'identification du phénomène pose la question du lien avec les pratiques identifiées sur les sites de plein air, au premier rang desquelles les cas de recrutement funéraire sélectif [9–11]. L'hypothèse selon laquelle, dans ce contexte chronogéographique précis, l'inhumation en grottes des plus jeunes défunts répondrait à la sous-représentation des individus immatures dans les lieux d'inhumation proches des villages amérindiens (avec par conséquent des pratiques sélectives fondées sur le critère de l'âge au décès), peut ainsi être formulée. En revanche, en ce qui concerne le contexte, plus général, des inhumations en grotte dans les Petites et Grandes Antilles, très peu d'informations contextuelles et encore moins d'études biologiques accompagnent les publications, rendant difficile l'appréciation de la place des sujets immatures dans les dépôts funéraires en cavités. L'inhumation d'enfants en grottes est possiblement mentionnée à Porto Rico dans les grottes de Hollow Hill [48], mais le problème du rattachement du site à la période céramique ou à la période archaïque n'est pas résolu. Le phénomène est plus fermement attesté à Cuba à la période archaïque comme sur les sites de la Cueva del Ninos ou de Marien 2 [49]. Si ces études documentent effectivement la présence d'enfants avec des sujets plus âgés parmi les dépôts funéraires en grotte, elles n'ont cependant pas amené, à notre connaissance, à identifier l'existence de pratiques spécifiquement sélectives en fonction de l'âge au décès pour les Grandes Antilles. Les sujets immatures pourraient donc, dans ce contexte, y être inhumés au même titre que les individus appartenant aux classes d'âge supérieures.

Les travaux menés en Guadeloupe, desquels participe l'étude du sujet de la grotte des Bambous, confirment néanmoins que l'inhumation en cavités des sujets immatures, bien que n'étant pas un phénomène nouveau à l'échelle de l'aire Caraïbe, pourrait être un trait commun à la période finale de l'âge Céramique. Ils pourraient également amener à préciser les modes de recrutement liés à ce type de lieu funéraire dans les Petites Antilles, en montrant la place qu'y tiennent les sujets immatures, dont les nouveau-nés.

Conclusion et perspectives

Si la nature sépulcrale du site de la grotte des Bambous était amenée à être confirmée, l'élaboration de sépultures primaires dédiées aux enfants en bas âge dans les cavités naturelles de l'archipel de Guadeloupe n'apparaîtrait plus comme un fait isolé. L'étude du site, tout en offrant de nouveaux éléments de discussion quant aux pratiques funéraires dédiées aux nouveau-nés dans les populations du Céramique final, s'insérerait dans le phénomène global de structuration sociale identifié à cette période dans l'ensemble de l'archipel. À l'échelle individuelle, cette étude aura vocation à être poursuivie avec la détermination du sexe [50,51], et la discussion de sa vitalité à la naissance par histologie dentaire ou osseuse [52–55]. Ces résultats pourraient ouvrir des perspectives quant à une analyse plus fine de la variabilité des traitements funéraires des enfants en bas âge dans les populations amérindiennes. À l'échelle populationnelle, des analyses ADN permettront d'apporter des éléments de réponse au débat concernant les différents schémas de peuplement des Petites Antilles par les lignées amérindiennes, dont le pool génétique demeure relativement méconnu du fait de l'importance des phénomènes de métissage avec les lignées africaines [45,56]. Des études récentes mettent ainsi en évidence que les populations céramiques présenteraient des affinités génétiques plus importantes avec les populations du Nord-Est du continent sud-américain qu'avec les groupes caraïbes archaïques [57]. Ces données appuyant actuellement davantage l'hypothèse d'un modèle de migration graduelle depuis l'Amérique du Sud, qu'un modèle d'expansion méridionale depuis Porto Rico, les données issues de la grotte des Bambous pourraient contribuer à une meilleure connaissance du contexte macrorégional des flux populationnels.

Tout en confirmant le fort potentiel informatif des cavités naturelles de l'archipel, la découverte de la grotte des Bambous témoigne ainsi de la nécessité, voire de l'urgence, à poursuivre l'exploration scientifique des cavités naturelles antillaises, et ce dans une perspective en premier lieu conservatoire [10]. Malgré leur caractère discret et la quasi-absence en surface d'indices de fréquentation humaine, ce type de sites est en effet soumis à de fortes perturbations environnementales et humaines. Leur impact risque d'apparaître comme d'autant plus dommageable si les caractéristiques de l'occupation sépulcrale des sites souterrains étudiés jusqu'à présent (pauvreté du matériel et absence d'aménagements funéraires plus ou moins pérennes) se révèlent, à l'avenir, être généralisées.

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Références

1. Labat JB (1722) Nouveau voyage aux isles de l'Amérique. Édition Guillaume Cavelier, Paris
2. Léonard NG (1797) Lettre sur un voyage aux Antilles. In: Campenon V (éd) Œuvres de Léonard. Didot Jeune, Paris, pp 173–240
3. de Rochefort C (1658) Histoire naturelle et morale des îles Antilles de l'Amérique. Arnold Lucas, Rotterdam, 539 p
4. Breton R (1978) Relations de l'île de la Guadeloupe. Nouved, Société d'Histoire de la Guadeloupe, Basse-Terre, Guadeloupe, 210 p
5. Du Tertre JB (1667) Histoire générale des Antilles habitées par les Français, vol. 2. Thomas Iolly, Paris, 539 p
6. Anonyme de Carpentras A, Grunberg J (2013) Relation d'un voyage infortuné fait aux Indes occidentales. In: Grunberg B, Roux B, Grunberg J (eds) Voyageurs anonymes aux Antilles. Collection Corpus Antillais. L'Harmattan, Paris, pp 17–111
7. Hoogland MLP, Hofman CL (2013) From corpse taphonomy to mortuary behavior in the Caribbean - a case study from the Lesser Antilles. In: Keegan WF, Hofman CL, Ramos RR (eds) The Oxford Handbook of Caribbean Archaeology. OUP, USA, pp 452–69
8. Bérard B (2019) About boxes and labels: a periodization of the Amerindian occupation of the West Indies. J Caribbean Archaeol 19:51–67
9. van den Bel M, Romon TA (2010) Troumassoid Site at Trois-Rivières, Guadeloupe FWI; Funerary practices and house patterns at La Pointe de Grande Anse. J Caribbean Archaeol 9:1–17
10. Hofman CL, Hoogland MLP, Mickleburgh HL, et al (2012) Life and death at Precolumbian Lavoute, Saint Lucia, Lesser Antilles. J Field Archaeol 37:209–25
11. Hofman CL (2013) The post-Saladoid in the Lesser Antilles (A.D. 600/800-1492). In: Keegan WF, Hofman CL, Ramos RR (eds) The Oxford Handbook of Caribbean Archaeology. OUP, USA, pp 205–20
12. Rouse I (1992) The Tainos: rise & decline of the people who greeted Columbus. Yale University Press, New Haven, CT, 224 p
13. Keegan WF (2000) West Indian archaeology. 3. Ceramic Age. J Archaeol Res 8:135–167
14. Stouvenot C (2005) Cavités naturelles dans l'archipel guadeloupéen prospections et sondages archéologiques Campagne 2004. Rapport de prospections–sondages, Direction des Affaires culturelles de la Guadeloupe, service régional de l'Archéologie, Basse-Terre, 46 p
15. Lenoble A, Grouard S, Fouéré P, et al (2010) Cavités naturelles de Guadeloupe. Aspects géologiques, fauniques et archéologiques. Service régional de l'archéologie de Guadeloupe, direction de l'Archéologie, pp 76–9
16. Courtaud P (2011) La cavité sépulcrale de Cadet 2 (Capesterre-de-Marie-Galante, Guadeloupe) et la question du cannibalisme. Cah Hist Am Lat 5, pp 49–58
17. Courtaud P, Henry-Gambier D, Lenoble A, et al (2005) Grotte Cadet 2, commune de Capesterre de Marie-Galante. Rapport de fouille programmée, Service régional de l'archéologie, direction régionale des Affaires culturelles de la Guadeloupe, Basse-Terre, 90 p
18. Grouard S, Bonnissent D, Courtaud P, et al (2013) Fréquentation amérindienne des cavités des Petites Antilles. In: Bérard B (ed) 50 ans d'archéologie caribéenne 1961–2011, 24e Congrès de l'Association internationale de l'archéologie de la Caraïbe (AIAC), juillet 2011, Fort-de-France, Martinique, pp 277–95
19. Lenoble A, Queffelec A, Bonnissent D, et al (2015) Rock art taphonomy in Lesser Antilles: study of wall weathering and engravings preservation in two PreColumbian caves on Marie-Galante Island. In: Del Olmo L (ed) Proceeding of the 25th international Congress for Caribbean Archaeology, juillet 2013, San Juan, Puerto Rico, pp 634–57
20. Fouéré P, Monney J, Mora P (2014) Capesterre-de-Marie-Galante, Grotte du Morne Rita - Bilan scientifique de la région Guadeloupe 2011–2012–2013, 2014, pp 25–6
21. Lenoble A, Cochard D, Bochaton C, et al (2016) Grotte Des Bambous - Commune Du Moule - rapport de sondage archéologique. Service régional de l'archéologie de Guadeloupe, Basse-Terre, 53 p
22. Cochard D, Bochaton C, Courtaud P, et al (2019) Grotte des Bambous - Commune du Moule, Guadeloupe. Rapport d'opération archéologique. Direction des Affaires culturelles, Service régional de l'archéologie de la Guadeloupe, Basse-Terre, 176 p
23. Partiot C, Guillon M, Peressinotto D, et al (2020) Cervical ribs in human early life: morphological variability and first identification as a morbidity criterion in a past population. J Anat 00:1–14
24. Fazekas IG, Kósa F (1978) Forensic foetal osteology. Akadémiai-Kiadó, Budapest, 344 p
25. Duday H, Laubenheimer F, Tillier AM (1995) Sallèles d'Aude - Nouveau-nés et nourrissons gallo-romains. Centre de recherches d'histoire ancienne, vol. 144, Presses Universitaires de Franche-Comté, Les Belles Lettres, Paris, 146 p
26. Schutkowski H (1990) Zur Geschlechts Diagnose von Kinder Skeletten: Morphognostische, Metrischeund Diskriminanz Analytische Untersuchungen. Georg-August-Universität
27. Partiot C (2018) Diversité biologique des enfants décédés en période périnatale et traitements funéraires au Kerma classique - Les exemples de la nécropole 8B-51 (Kerma classique, Soudan) et des cimetières de Blandy-les-Tours (xe–xiie siècles, France) et de Provins (xiiie–xviiie siècles, France). Thèse de doctorat, Université de Bordeaux, Pessac, 738 p
28. Schmitt A, Georges P (2008) Quelle démarche suivre pour estimer l'âge au décès à partir du squelette ? In: Charlier P (ed) Manuel pratique de paléopathologie humaine. De Boccard, Paris, pp 269–80
29. Stuiver M, Reimer PJ, Reimer R (2020) CALIB Radiocarbon Calibration 7.1 [WWW program] at http://calib.org, accessed 9 june 2020
30. Krigbaum J, Fitzpatrick SM, Bankaitis J (2013) Human paleodiet at Grand Bay, Carriacou, Lesser Antilles. J Island Coastal Archaeol 8:210–27
31. Stokes AV (2000) A biogeographic survey of prehistoric human diet in the West Indies using stable isotopes. Thèse de doctorat, University of Florida, Gainesville, 296 p
32. Napolitano MF, DiNapoli RJ, Stone JH, et al (2019) Reevaluating human colonization of the Caribbean using chronometric hygiene and Bayesian modeling. Sci Adv 5:eaar7806
33. Goedert J, Cochard D, Lorvelec O, et al (sous presse) Isotopic ecology and regional extirpation chronology of the extinct Lesser Antillean rat Antillomys rayi. Quat Sci Rev
34. Stouvenot C, Beauchêne J, Bonnissent D, et al (2015) Datations radiocarbone et le « problème vieux bois » dans l'arc antillais : état de la question. In: del Omo L (ed) 25e Congrès international de l'archéologie de la Caraïbe, Instituto de Cultura Puertorriqueña, el Centro de Estudios Avanzados de Puerto Rico y el Caribe y la Universidad de Puerto Rico, Recinto de Río Piedras, Jul 2013, San-Juan, Porto Rico, pp 459–94
35. Charrier P, Clavandier G, Gourdon V, et al (2018) Morts avant de naître, la mort périnatale. Collection « Perspectives historiques », Presses Universitaires François-Rabelais, Tours, 444 p

36. Schalk C (2017) Le travail des soignants dédiés à la vie face à la mort périnatale : Sages-femmes et gynécologues-obstétricien(ne)s. Thèse de doctorat, Paris, CNAM, 393 p
37. Courtaud P, Duday H (2008) Qu'est-ce qu'une sépulture ? Comment la reconnaître. Première humanité : gestes funéraires néandertaliens. Réunion des musées nationaux, Paris, pp 16–24
38. Murphy AR, Hozjan DJ, de Mille CN, et al (2000) Pre-Columbian gems and ornamental materials from Antigua, West Indies. Gems&Gemology 36:234–45
39. Curet LA, Oliver JR (1998) Mortuary practices, social development, and ideology in Pre-Columbian Puerto Rico. Latin Am Antiq 9:217–39
40. Carr RS, Schaeffer WC, Ransom JB, et al (2012) Ritual cave use in the Bahamas. In: Moyes H (ed) Sacred darkness: a global perspective on the ritual use of caves. University Press of Colorado, Boulder, Colorado, pp 285–93
41. Winter JH, Wing E, Newson L (1999) A Lucayan funeral offering. In: Winter JH (ed) Proceedings of the 17th Congress for Caribbean Archaeology. Molloy College, New York, pp 197–210
42. Stouvenot C, Grouard S, Bailon S, et al (2005) Grotte Blanchard. Capesterre de Marie-Galante. Notice scientifique. Bilan scientifique 2005. Service régional d'archéologie de Guadeloupe, Direction des Affaires culturelles de la Guadeloupe, Basse-Terre, 115 p
43. Crock JG (2005) Archaeological evidence of Eastern Taínos: Late Ceramic Age interaction between the Greater Antilles and the northern Lesser Antilles. In: Tavarez G, Garcia Arevalo MA (eds) Proceedings of the International Congress for Caribbean Archaeology, Saint Domingue, Departamento de Difusion y Relaciones Públicas del Museo del Hombre 20(2), pp 835–42
44. Lenoble A, Grouard S (2008) Histoire des peuplements animaux de la Guadeloupe au Pléistocène et à l'Holocène (15 000 BC–1500 AD) Rapport final, Diren, CNRS, MNHN, 80 p
45. Mendisco F, Pemonge MH, Leblay E, et al (2015) Where are the Caribs? Ancient DNA from ceramic period human remains in the Lesser Antilles. Phil Trans R Soc B 370:20130388
46. Siegel PE (1999) Contested places and places of contest: The evolution of social power and ceremonial space in prehistoric Puerto Rico. Latin Am Antiq 10:209–38
47. Morton SG (2015) The Taino use of caves: a review. Caribb Connect 4:1–16
48. Aitken RT (1917) Porto Rico Burial Caves. In: Hodge FW (ed) Proceedings of the Nineteenth International Congress of Americanists, Washington, December 27–31, 1915, Washington, p. 224–8
49. La Rosa Corzo G (2003) La orientacion este de los entierros aborigenes en vuevas de Cuba : remate de una fabula. Lat Am Antiq 14:143–57
50. Stewart NA, Gerlach RF, Gowland RL, et al (2017) Sex determination of human remains from peptides in tooth enamel. Proc Natl Acad Sci 26 114:13649-54
51. Braga J, Samir C, Risser L, et al (2019) Cochlear shape reveals that the human organ of hearing is sex-typed from birth. Sci Rep 9:10889
52. Rushton MA (1933) On the fine contour lines of the enamel of milk teeth. Dent Rec 53:170–1
53. Schour I (1936) The Neonatal line in the enamel and dentin of the human deciduous teeth and first permanent molar. J Am Dent Assoc 1922, 23:1946–55
54. Skinner M, Goodman AH (1992) Anthropological uses of developmental defects of enamel. Skeletal biology of past peoples: research methods. Wiley-Liss, New York, pp 153–174
55. Booth TJ (2020) Using bone histology to identify stillborn infants in the archaeological record. In: Gowland R, Halcrow S (eds) The mother–infant nexus in anthropology: small beginnings, significant outcomes. Springer International Publishing, Cham, Switzerland, pp 193–209
56. Deguilloux MF, Pemonge MH, Courtaud P, et al (2015) Le peuplement amérindien céramique des Petites Antilles : apports de l'analyse génétique de vestiges humains et de groupes actuels. In: Grunberg B (ed) À la recherche du Caraïbe perdu — les populations amérindiennes des Petites Antilles de l'époque précolombienne à la période coloniale. Cahiers d'histoire de l'Amérique latine 5, L'Harmattan, Paris, pp 79–98
57. Nägele K, Posth C, Iraeta Orbegozo M, et al (2020) Genomic insights into the early peopling of the Caribbean. Sci 369:456–60

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ARTICLE / *ARTICLE*

Which Factors Are Associated with Body Mass Index Among Elderly People Living at Home in France?

Quels sont les facteurs associés à l'indice de masse corporelle chez les personnes âgées vivant à domicile en France ?

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Abstract Obesity is a complex and multifactorial chronic disease. Body weight can be affected by environmental and socio-economic conditions, genetic factors, lifestyle, etc. The aim of this study was to investigate the links between body mass index (BMI) categories and socio-demographic, health and life style variables among people aged 60 years or over who live at home. Data were collected from the 2008 cross-sectional national survey on health and disability (*Handicap Santé Ménages*) and are representative of the elderly population in France living at home (N = 9,867). We have performed multinomial logistic regressions with weight status as the outcome variable. Compared to individuals aged 75 to 79, people aged 80 and over were more likely to be overweight than obese, and of normal weight rather than overweight. Having at least one chronic disease increased the probability of being obese as opposed to overweight. Women with severe physical limitations were also more likely to be obese than overweight. Doing physical exercise decreased the probability of being obese as opposed to overweight and overweight vs. normal weight. Time spent watching TV increased the probability of being overweight vs. normal weight. There is an urgent need for public health measures to prevent obesity among the elderly, such as those that promote good nutrition, exercise and social relationships, in order to help old people to maintain their capacities and autonomy.

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Keywords BMI · Overweight · Obesity · Older adults · Health · Lifestyle

Résumé L'obésité est une maladie chronique complexe et multifactorielle. Le poids peut être affecté par des facteurs environnementaux, socio-économiques, génétiques et de mode de vie. Notre objectif est d'étudier, chez les personnes de 60 ans et plus, les liens entre les catégories d'indice de masse corporelle (IMC) et des variables sociodémographiques, de santé et de mode de vie. Les données sont issues de l'enquête *Handicap Santé Ménages 2008*, représentative de la population résidant en France et vivant à domicile (n = 9 867). Les données ont été analysées au moyen de régressions logistiques multinomiales, la variable dépendante étant l'IMC en trois catégories. Comparées aux personnes de 75 à 79 ans, les personnes de 80 ans et plus ont une probabilité majorée d'être en surpoids plutôt qu'obèses, et en poids normal qu'en surpoids. Avoir une maladie chronique accroît le risque d'être obèse plutôt qu'en surpoids. Les femmes âgées souffrant de limitations physiques importantes ont une plus grande probabilité d'être obèses qu'en surpoids. Faire de l'exercice diminue la probabilité d'être obèse plutôt qu'en surpoids, et en surpoids plutôt qu'en poids normal. Le temps passé à regarder la télévision augmente la probabilité d'être en surpoids plutôt qu'en poids normal. Il est nécessaire de poursuivre la mise en œuvre des mesures de santé publique visant à prévenir l'obésité chez les personnes âgées, comme celles favorisant l'alimentation saine, l'exercice, les relations sociales, pour maintenir l'autonomie et les capacités des aînés.

Mots clés IMC · Surpoids · Obésité · Vieillissement · Santé · Mode de vie

Introduction

In different times and cultures, fat or even obese bodies may represent an ideal of beauty and even health. Nowadays, the body aesthetics of the Willendorf Venus or the Lespugue Venus in the Paleolithic period, or more recently the female models of Renoir, would be called obese. Obesity has only been identified as a public health concern in the last few decades [1]. It contributes to the onset, or increases the severity, of chronic diseases such as diabetes or cardiovascular diseases. Prevention messages encourage people to check their weight, and programs such as the PNNS (*Programme National Nutrition Santé*) in France invite everyone to be careful of their diet and to practice physical activity [2].

The World Health Organization (WHO) classifies ranges of body mass index (BMI) into categories that are meant to represent distinct levels of risk to health [3]. For adults, four categories are usually defined: underweight (BMI < 18.5 kg/m^2), normal weight (18.5 kg/m^2 $\leq$ BMI < 25 kg/m^2), overweight (25 kg/m^2 $\leq$ BMI < 30 kg/m^2), and obese (BMI $\geq$ 30 kg/m^2). A BMI in the underweight [4], overweight, and obese [5] categories is considered to be a risk factor for health problems and premature mortality. A high BMI is known to be associated with increased mortality from all causes.

Body weight increases throughout early and middle adulthood, as shown by cross-sectional [6] and longitudinal [7] studies. This has been confirmed in several European countries [8] and in France [9]. The body weight trajectory shows an increase until the age of 60, and then a slight decrease [10–12]. Similarly, the prevalence of obesity decreases from the age of 60 [13,14]. Mortality and morbidity associated with being overweight and obese only increase in the elderly at a BMI above 30 kg/m^2 [15]. Meta-analyses of follow-up studies on subjects over 65 years of age have shown that only severely obese people have an increased risk of mortality [16]. Some suggest that a BMI in the obese range is only associated with a modest increase (about 10%) of the mortality risk in the elderly, and that a BMI in the overweight range is not associated with an increased mortality risk in elderly men and women [17,18]. Several studies on elderly people show high BMI values to be associated with greater functional limitations [19], especially in women [20], and disability [21,22].

There are numerous studies on social relationships and how they are associated with BMI in adults (see Powell et al. [23] for a review); a longitudinal approach successfully demonstrated the protective effect of high-quality social support against weight gain [24]. Some studies on adults show an association between marital status and BMI [25,26] even in people aged 50 years and above [27]. It may also be important to focus on sedentary behavior among older people, because as people age, they spend more and more time in sedentary occupations [28,29] and less time being physically active [29].

The aim of this study was to investigate the links between weight status and socio-demographic, health and lifestyle variables among people aged 60 years or above living at home in France.

Our hypothesis is that there are factors associated with being overweight and/or obese that could be modified by a change in individual lifestyles. Our model aims to highlight those factors using a *ceteris paribus* approach (all other things being equal). Those factors can then be taken into account in public health policies aiming to improve the health and well-being of elderly people.

Materials and methods

Data sources

We used 2008 cross-sectional survey data on 29,931 respondents of all ages (children, adults, and elderly people) living at home, which were collected by the French national survey on health and disability (*Handicap Santé Ménages* — HSM survey) [30–32]. The database documents physical and psychological health status (impairments, functional limitations, and restrictions to daily activities), socio-economic characteristics and social support, housing and living conditions (access to the labor market, educational opportunities and leisure, formal and informal care, and experiences of discrimination). The questionnaire was administered in face-to-face computer-assisted interviews, with the responses of the surveyed person directly recorded on a computer by the investigator. When necessary and if agreed to by the intended subjects, they were helped or even replaced by a proxy respondent (spouse, child, or other relative). Sample weightings ensured that the data were representative of the reference population [33,34].

Ethics

This survey was performed by the French National Institute of Statistics (INSEE) and the Ministry of Health (Direction de la recherche, de l'évaluation, des études et des statistiques — DREES). It was declared to be in the public interest by the National Council for Statistical Information (Conseil national d'information statistique - CNIS) and obtained approval from the French Data Protection Authority (Commission nationale de l'informatique et des libertés – CNIL, the French data protection Act no. 78–17: decision CE2008-721).

Study sample

We have restricted the sample to 9957 individuals those aged 60 years and above. 90 individuals with missing values for some variables necessary to the analyses were withdrawn from the sample. The individuals excluded were found to be not basically different from those remaining in the sample (N = 9867).

Variables

Body mass index (BMI) was the outcome measure of the study and was calculated from self-reported weight and height. Individuals were classified as obese (BMI ≥ 30 kg/m^2), overweight (25 kg/m^2 ≤ BMI < 30 kg/m^2), or normal weight (BMI < 25 kg/m^2). Individuals with a BMI < 18.5 kg/m^2 made up 2.3% of the study sample (N = 9867). This group was merged with the "normal weight" group (also justified by analysis indicating that the groups did not differ in their reporting of chronic diseases), as previously done in the literature [35]. Weight status was then used as a three-class outcome variable.

As socio-demographic and economic variables, we used *sex*, *age* (in 5-year age groups), *living as a couple at home* (yes/no), level of education ((no diploma/less than high school graduate/high school graduate), *income per consumption unit* (ICU ≤ median/ICU > median). The latter two variables were used as proxies for socio-economic status.

Health variables were taken from the minimum European health module [36]. They included *having at least one chronic disease*: "Have you ever had a chronic or long-term illness or health problem"? (yes/no), and *functional limitations*: "Have you been limited in the performance of ordinary activities for at least 6 months because of a health problem"? (very limited/limited but not very/not limited at all).

Lifestyle variables included:

- *exercise*: "In the past 12 months have you practised any sport (with a club or not)"? (yes/no);
- *watching TV*: "In the past 12 months, have you watched television at your home or elsewhere?" (4 hours a day or less/more than 4 hours a day);
- *dietary variety*: "Do you eat the following everyday: a) fruits, b) vegetables, c) dairy products, d) meat, poultry, ham, eggs, fish, or other fish products)? (If "yes" for each of the 4 questions, then "Dietary variety = yes" / otherwise "Dietary variety = no");
- *family contacts*: "Over the past 12 months, how often have you seen one or more members of your family?" (less than once a week/once a week or more).

Respondent variable: if the person was answering for himself/herself, then we have considered him/her as having answered alone. Otherwise, if he/she had been helped or replaced to respond, then "answering alone = no". A proxy respondent was used by 9.8% of the sample; thus, weight and height were reported by carers or other proxies for at most 9.8% of the sample.

Statistical Analyses

Descriptive statistics were given for the selected variables and presented as percentages. The Rao-Scott Chi-square test was used to test the relationship between weight status and other qualitative variables. Multinomial Logistic Regression (MLR) models were used to study factors associated with BMI categories as the dependent variable. We chose the second class of BMI (overweight) as the reference group. The other variables described above were introduced into the models as independent variables. MLR models make the assumption, referred to as Independence from Irrelevant Alternatives (IIA), that the coefficients in a MLR model will not depend on whether an outcome level within the multinomial response variable is included in the estimation or excluded (and its data removed). The Hausman and Small Hsiao tests were conducted to ensure that the IIA assumption was met in the data [37]. For the 5-class age variable, a nested coding system was used, that is, each class was compared with the class just preceding it. Analyses were performed first for the whole sample, followed by separate analyses by sex. All procedures and tests applied here were selected as they were specific to weighted data. All analyses were conducted with SAS 9.4 Software (SAS Institute Inc., Cary, NC, USA) using the SURVEYFREQ and SURVEYLOGISTIC SAS procedures, and Stata MP Software (StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP). The significance level used for all tests was 0.05.

Results

The overall prevalence figures for obese and overweight elderly people living at home in France were 16.8% and 38.4%, respectively, with 16.4% obese men and 17.2% obese women, and 47% overweight men and 31.8% overweight women. The percentages for "normal weight" (BMI < 25 kg/m^2) were 36.6% for men and 51.0% for women (cf. Table 1).

The association between weight status and sex was significant (P < 0.001). Figure 1 shows overweight and obesity prevalence among French people aged 60 years and above by sex and age. The observed maximum and minimum prevalence figures for overweight men were 50% and 42.5%, respectively, and 35.3% and 27.1% for overweight women. Whatever the age class, being overweight was more prevalent in men than in women. A decrease in the prevalence of obesity between the two oldest classes (75–80 *vs*. 80+) was observed in both men and women.

Multinomial Logistic Regression (MLR) models were used to study factors associated with weight status. The choice of the second BMI class ("overweight") as the

Table 1 Characteristics of the total sample and weight status distribution by category of each variable (N = 9867) / *Caractéristiques de l'échantillon total et répartition des statuts de poids par catégories de chaque variable (N = 9 867)*

Variables	**Total sample %**	**Normal weight**	**Overweight**	**Obese**	P^a
Gender					
Male	43.5	36.6	47.0	16.4	< 0.001
Female	56.5	51.0	31.8	17.2	
Age					
[60;65[	25.6	42.2	41.2	16.6	< 0.001
[65;70[	18.8	42.6	37.9	19.5	
[70;75[	19.5	41.8	40.1	18.1	
[75;80[	15.8	41.1	40.0	18.9	
80 or over	20.4	55.5	32.6	11.9	
Living in couple					
Yes	63.0	43.4	40.1	16.5	< 0.013
No	37.0	46.9	35.6	17.5	
Level of education					
No diploma	26.1	40.1	37.4	22.4	< 0.001
Less than high school graduate	56.4	43.4	40.3	16.3	
High school graduate	17.5	55.8	33.8	10.4	
ICU[b] < median ICU					
Yes	50.0	47.6	37.6	14.7	< 0.001
No	50.0	41.8	39.3	18.9	
Answering alone					
Yes	90.2	44.2	39.0	16.8	0.022
No	9.8	49.3	33.5	17.2	
At least one chronic or long-term illness					
Yes	69.9	42.1	38.3	19.6	< 0.001
No	30.1	50.7	38.8	10.5	
Physical limitations					
Not limited at all	52.3	47.5	39.5	13.0	< 0.001
Limited but not very	27.2	40.8	39.1	20.1	
Very limited	20.4	42.9	34.9	22.2	
Exercise					
Yes	31.5	50.2	38.9	10.9	< 0.001
No	68.5	42.2	38.2	19.6	
Watching TV					
More than 4 hours a day	19.4	35.6	42.7	21.7	< 0.001
Less than 4 hours a day	80.6	46.9	37.4	15.7	
Dietary variety					
Yes	62.7	46.0	38.2	15.8	0.028
No	37.3	42.5	38.9	18.6	
Family contacts at least one a week					
Yes	60.0	42.8	38.9	18.3	0.001
No	40.0	47.6	37.8	14.6	

[a] *P*-value associated with the Rao–Scott Chi-square test; [b] Income per consumption unit

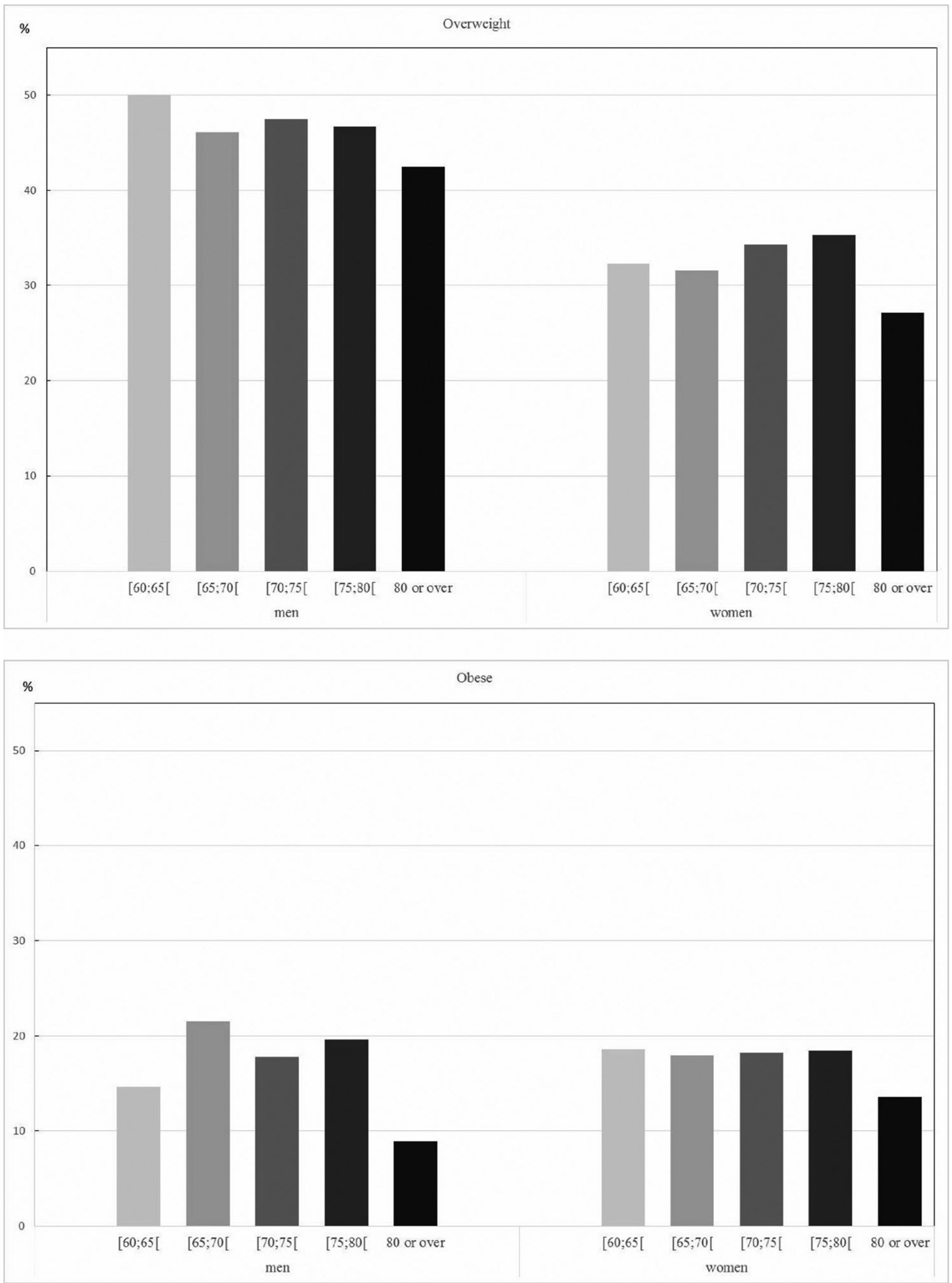

Fig. 1 Prevalence of overweight and obesity among French people aged 60 and over, by sex and age / *Prévalence du surpoids et de l'obésité chez les Français de 60 ans et plus, par sexe et par âge*

reference group allowed comparisons, overweight to be compared with normal weight on the one hand, and with obesity on the other hand, which is not usually done in the literature. Factors associated with BMI categories, their adjusted Relative Risk Ratios (RRR) and their *p*-values are given in table 2 for the whole sample. No significant correlations were found between BMI categories and living alone, income, dietary variety, and family contacts. Sex, age, level of education, health status, and exercise were significantly associated with BMI categories.

Age effects were observed for the oldest age class: comparisons between people aged 80 years and over with people aged 75 to 80 years showed that the oldest people were more likely to be of normal weight than overweight (RRR = 1.63, $P < 0.001$), and less likely to be obese than overweight (RRR = 0.69, $P = 0.008$).

Elderly people with a higher level of education were more likely to be of normal weight than people with no educational qualifications (RRR = 1.48, $P = 0.002$). They were also less frequently obese than people with no educational

Table 2 Factors associated with BMI among French people aged 60 and over (N = 9867) / *Facteurs associés à l'IMC chez les Français de 60 ans et plus (*n *= 9867)*

		Normal weight vs. overweight		**Obese vs. overweight**	
Variable (reference)	**Category**	**RRR [95% CI]**	***P***	**RRR [95% CI]**	***P***
Gender (female)	Male	0.453 [0.388;0.528]	**< 0.001**	0.683 [0.565;0.826]	**< 0.001**
Age (ref. the previous class)					
	[65;70[vs. [60;65[	1.084 [0.854;1.376]	0.505	1.180 [0.892;1.561]	0.247
	[70;75[vs. [65;70[	1.031 [0.804;1.322]	0.809	0.774 [0.580;1.034]	0.083
	[75;80[vs. [70;75[	0.998 [0.785;1.270]	0.989	0.911 [0.689;1.206]	0.516
	80 or over vs. [75;80[	1.633 [1.312;2.033]	**< 0.001**	0.694 [0.529;0.910]	**0.008**
Living in couple (yes)	No	0.954 [0.811;1.123]	0.574	1.069 [0.874;1.308]	0.515
Level of education (no diploma)					
	Non high-school graduate	0.982 [0.826;1.168]	0.839	0.718 [0.587;0.878]	**0.001**
	High-school graduate	1.484 [1.150;1.916]	**0.002**	0.614 [0.428;0.882]	**0.008**
ICU[a] ≥ median ICU	Lower than median ICU	0.878 [0.748;1.031]	0.114	0.907 [0.743;1.106]	0.335
Answering alone (no)	Yes	0.696 [0.560;0.865]	**0.001**	0.996 [0.765;1.295]	0.973
At least one chronic or long-term illness (no)	Yes	0.826 [0.688;0.991]	**0.040**	1.579 [1.219;2.046]	**< 0.001**
Physical limitations (not limited at all)					
	Limited but not very	0.875 [0.727;1.054]	0.159	1.292 [1.023;1.632]	**0.031**
	Very limited	1.025 [0.837;1.255]	0.812	1.523 [1.201;1.931]	**< 0.001**
Exercise (yes)	No	0.816 [0.681;0.977]	**0.027**	1.581 [1.234;2.025]	**< 0.001**
Watching TV (4 hours a day or less)	More than 4 hours a day	0.679 [0.565;0.814]	**< 0.001**	1.031 [0.846;1.256]	0.764
Dietary variety (yes)	No	0.975 [0.838;1.135]	0.746	1.072 [0.894;1.286]	0.454
Family contacts at least once a week (no)	Yes	0.871 [0.749;1.012]	0.072	1.159 [0.960;1.399]	0.124

Source: HSM survey (multinomial logistic regression model, adjusted relative risk ratios (RRR) and their 95% CIs). Values in bold indicate significant associations

[a] Income per consumption unit

qualifications (RRR = 0.72, P = 0.001; and RRR = 0.61, P = 0.008 respectively with and without upper secondary school qualifications).

The three variables used to characterize health status were associated with weight status. People with at least one chronic illness were less likely to be of normal weight than overweight (RRR = 0.83, P = 0.04), and they also were more likely to be obese than overweight (RRR = 1.58, P < 0.001). People who did not use a proxy respondent and answered alone were less likely to be of normal weight than overweight (RRR = 0.70, P = 0.001). Elderly people with physical limitations were more likely to be obese than overweight (RRR = 1.29, P = 0.031 for slight limitations; RRR = 1.52, P < 0.001 for severe limitations).

Our results show a significant link between BMI categories and individual lifestyle habits. People who did not exercise were less likely to be of normal weight than overweight (RRR = 0.82, P = 0.027). They also were more likely to be obese than overweight (RRR = 1.58, P < 0.001). Watching TV more than 4 hours a day decreased the probability of being of normal weight compared to overweight (RRR = 0.68, P < 0.001).

We have also observed a significant association between BMI and sex: men were less likely to be of normal weight (RRR = 0.45, P < 0.001) and less likely to be obese than overweight (RRR = 0.68, P < 0.001). We therefore ran separate models for men and women (Table 3).

As for the whole sample, both men and women aged 80 years or above were more likely to be of normal weight than overweight, compared with those aged 75 to 80 years (RRR = 1.52, P = 0.02 for men, and RRR = 1.78, P < 0.001 for women). The separate model only differed in the "obese

Table 3 Factors associated with BMI among French men and women aged 60 years and over / *Facteurs associés à l'IMC chez les hommes et les femmes français âgés de 60 ans et plus*

		Men (N = 3986)				Women (N = 5881)			
		Normal weight vs. overweight		Obese vs. overweight		Normal weight vs. overweight		Obese vs. overweight	
Variables	**Category**	**RRR [95% CI]**	***P***	**RRR [95% CI]**	***P***	**RRR [95% CI]**	***P***	**RRR [95% CI]**	***P***
Age (the previous class)									
	[65;70[vs. [60;65[	1.00 [0.70;1.42]	0.99	1.47 [0.98;2.21]	0.06	1.10 [0.78;1.53]	0.59	0.97 [0.66;1.43]	0.89
	[70;75[vs. [65;70[	1.09 [0.75;1.59]	0.65	0.70 [0.46;1.07]	0.10	1.03 [0.73;1.44]	0.88	0.85 [0.58;1.25]	0.41
	[75;80[vs. [70;75[	0.93 [0.64;1.34]	0.68	1.01 [0.65;1.55]	0.97	1.06 [0.78;1.46]	0.70	0.87 [0.61;1.25]	0.45
	80 or over vs. [75;80[	1.52 [1.08;2.16]	**0.02**	0.45 [0.29;0.71]	**< 0.001**	1.78 [1.35;2.36]	**< 0.001**	0.90 [0.63;1.27]	0.53
Living in couple (yes)	No	0.96 [0.73;1.25]	0.74	1.25 [0.89;1.75]	0.20	0.96 [0.78;1.19]	0.73	0.96 [0.75;1.23]	0.76
Level of education (no diploma)									
	Non high-school graduate	0.88 [0.67;1.15]	0.34	0.80 [0.58;1.11]	0.19	1.05 [0.84;1.31]	0.68	0.67 [0.52;0.86]	**0.002**
	High-school graduate	1.39 [0.96;2.04]	0.08	0.70 [0.40;1.21]	0.20	1.63 [1.14;2.35]	**0.01**	0.55 [0.33;0.90]	**0.02**
ICU[a] ≥ median ICU	Lower than median ICU	1.01 [0.79;1.30]	0.94	0.89 [0.65;1.23]	0.48	0.78 [0.63;0.96]	**0.02**	0.85 [0.66;1.10]	0.21
Answering alone	Yes	0.67 [0.49;0.92]	**0.01**	1.05 [0.69;1.62]	0.80	0.74 [0.55;0.99]	**0.04**	0.95 [0.69;1.31]	0.74
At least one chronic or long-term illness (no)	Yes	0.85 [0.64;1.12]	0.25	1.74 [1.17;2.58]	**0.01**	0.79 [0.61;1.01]	0.06	1.43 [1.02;2.02]	**0.04**
Physical limitations (not limited at all)									
	Limited but not very	1.01 [0.76;1.35]	0.94	1.31 [0.92;1.87]	0.14	0.80 [0.63;1.03]	0.08	1.29 [0.95;1.75]	0.11
	Very limited	1.15 [0.84;1.57]	0.37	1.21 [0.84;1.74]	0.31	0.96 [0.74;1.26]	0.79	1.79 [1.31;2.46]	**< 0.001**
Exercise (yes)	No	1.12 [0.86;1.46]	0.40	1.96 [1.37;2.81]	< 0.001	0.60[0.46;0.77]	**< 0.001**	1.23 [0.87;1.74]	0.24
Watching TV (4 hours a day or less)	More than 4 hours a day	0.70 [0.53;0.94]	0.02	1.03 [0.75;1.41]	0.85	0.67 [0.53;0.85]	**< 0.001**	1.05 [0.81;1.35]	0.71
Dietary variety (yes)	No	0.98 [0.78;1.23]	0.85	1.14 [0.86;1.52]	0.34	0.96 [0.78;1.18]	0.71	1.01 [0.79;1.28]	0.95
Family contacts at least once a week (no)	Yes	0.85 [0.67;1.06]	0.15	1.06 [0.80;1.41]	0.66	0.91 [0.74;1.12]	0.38	1.28 [0.99;1.65]	0.06

Source: HSM survey (multinomial logistic regression model, adjusted RRR and their 95% CIs). Values in bold indicate significant associations

[a] Income per consumption unit

vs. overweight” comparison. A significant association was observed for only men: those aged 80 years or above were less likely to be obese than overweight, compared to men aged 75 to 80 years (RRR = 0.45, $P < 0.001$).

The results show that the education variable is significant in only women: compared to women with no qualifications, those with lower secondary school education were less likely to be obese than overweight (RRR = 0.67, $P = 0.002$). Women with upper secondary school education were more likely to be of normal weight than overweight (RRR = 1.63, $P = 0.01$), and less likely to be obese than overweight (RRR = 0.55, $P = 0.02$), when compared to women with no qualifications.

Contrary to the model estimated for the whole sample, we have observed a significant association between income and weight status: elderly women on a low income (individual income below the median income) were less likely to be of normal weight than overweight (RRR = 0.78, $P = 0.02$).

Regarding health variables, the association found for the whole sample among those who answered alone was confirmed: men and women who answered alone were less likely to be of normal weight than overweight (RRR = 0.67, $P = 0.01$; and RRR = 0.74, $P = 0.04$ respectively). This was also the case for the “chronic illness” variable: men and women with at least one chronic illness were more likely to be obese than overweight (RRR = 1.74, $P = 0.01$; and RRR = 1.43, $P = 0.04$, respectively). As for the whole sample, the “physical limitations” variable was not significant for the normal weight vs. overweight comparison. For the comparison between obese and overweight, a significant association was observed only for women and for those in the “very limited” category: compared with “not limited” women, those in the “very limited” category were more likely to be obese than overweight (RRR = 1.79, $P < 0.001$).

We have observed differences between men and women when considering lifestyle variables. For instance, exercise was significant in the obesity vs. overweight model for men (those who did not exercise were more likely to be obese; RRR = 1.96, $P < 0.001$). For women, exercise was significant in the normal weight vs. overweight model (women who did not exercise were less likely to be of normal weight; RRR = 0.60, $P < 0.001$). Time spent watching TV was significant for both men and women: those who watched TV for 4 hours a day or more were less likely to be of normal weight than overweight (RRR = 0.70, $P = 0.02$ for men, and RRR = 0.67, $P < 0.001$ for women).

Discussion

The aim of the study was to investigate the correlations between weight status and socio-demographic, health, and lifestyle variables among people aged 60 years or above living at home in France. Our results show that advanced age, education, health, and some lifestyle habits (like exercising, watching TV) are significantly associated with BMI categories. Differences according to sex also appeared.

In France, according to a study conducted in 2015, nearly half of all adults were overweight or obese. The prevalence of obesity exceeded 17%. Men were more often overweight than women [38]. Peralta and collaborators (2018) have reported a 56.1% prevalence of overweight-obesity (BMI ≥ 25 kg/m^2) among the elderly [39]. Our study concurs with these data: more than half (55.2%) of the participants — two men out of three, and one woman out of two — had a BMI equal to or higher than 25 kg/m^2. This difference between sexes is simply due to the prevalence of “overweight”, which is equal to 47% for men and 31.8% for women. For the “obese” category, only slight differences between men and women were observed. These results differ from those of a Mexican study on adults with 60 years of age and older [40], where the prevalence of overweight and obesity combined was greater in women than in men (73% and 64.3% respectively), the difference being mainly due to obesity, which was more prevalent in women than men (37% vs. 21.9% of the sample respectively). However, these differences between sexes for obesity prevalence after 65 years of age were not found in several European countries, including France [8].

It is well known that overweight and obesity prevalence decreases with age in populations aged 60 years and above. This has been shown worldwide [41], in the USA [42] and in Asia [13]. In several European countries, mean BMI values have been observed to decrease after the age of 70 years in both sexes [43]. Using regression between age and BMI in Italian people aged 65 to 84 years, a significant decrease of about 1 unit over two decades was observed [44]. These authors also remarked that “the 75th year was a turning point in age-related changes for BMI”. Our study also shows a decrease in overweight and obesity prevalence between the two oldest classes (75–80 vs. 80+ years). This concurs with a study in France [45] where a decrease in obese men and women, and a decrease in overweight women only, were observed after the seventh decade. This observed decrease in obesity prevalence may be due to selective mortality, in that relatively fewer obese people survive to older ages [46].

In several countries around the world, studies on elderly people using anthropometric measurements have reported higher BMI values for women than for men. Mean BMI was found to be significantly higher in elderly women compared to men (28.7 kg/m^2 and 26.8 kg/m^2 respectively) in a Mexican population aged 60 years and more [40]. In a study among an elderly Brazilian population [47], the data measured show a higher mean BMI for women than for men

(28.2 kg/m^2 and 25.8 kg/m^2 respectively). Similar findings have been found in an Italian population [44]: for the whole group aged 65–84 years and in each 5-year age class, the mean BMI was significantly higher in women than in men (27.6 kg/m^2 and 26.4 kg/m^2 respectively). Differences by sex have also been found in several European countries, including France, where the mean BMI values for people aged 70–75 years were 27.6 kg/m^2 and 27.1 kg/m^2 for women and men, respectively [44]. It is reasonable to suggest that our data are in line with these studies, as they show that men are less likely to be obese than women. This difference by sex in BMI changes is well known: Inelmen et al. [43] in their review noticed an age- and gender-dependent decrease in body weight in the ageing process. A larger decrease in BMI with ageing is reported in women [48]. However, two other studies report a decrease in BMI with ageing in men only [44,49]. The gradual decrease in BMI observed in men by Perissinotto et al. [44] has reported to become statistically significant after the 75th year of age. Similarly, Lopez-Ortega and Arroyo showed a significant decrease in BMI at 75 years of age in men, but at 65 and 70 years of age in women [40]. Longitudinal studies have deepened these findings: in a 9-year follow-up, weight was found to decrease after 75 years of age in men and women, but with no change in BMI, while height decreased only in women [50]. In another longitudinal study, men and women between 75 and 80 years of age lost height with no change in weight or BMI [50]. These longitudinal study findings show that weight and/or height change with age, and possibly in a different way according to sex. These concurrent changes in weight and height do not necessarily appear in changes in BMI. Thus, age differences observed in cross-sectional studies could reveal generational effects rather than individual dynamic changes.

The use of a proxy respondent is likely to be linked to the subject's health status [51]. Participants who were unable to answer the questions by themselves were included in the study to avoid excessive gaps in the data. However, including people with a particularly poor health status does create bias [52]. Participants in our study who needed help to answer the questionnaire were more likely to be of normal weight than overweight. This could be due to the declarative bias from the proxy respondent, as reported in the study by Reither and collaborators [53] who found that "BMI from proxy reports was substantially lower than self-reported BMI."

Concerning chronic disease, Bamia et al.'s results show associations between self-rated health and several variables, including BMI. In this study, having a BMI below 30 kg/m^2 increases the probability of feeling in good health, the latter variable being a "proxy marker" of true health [54]: poor self-rated health is associated with a prevalence of diseases [55] and with their severity [56]. Recent literature shows that in several European countries, normal weight and overweight people aged 50 to 75 years could expect to live longer, and about 80% of these people would live those later years in good health [18]. The results of the trend analysis between number of diseases, chronic health conditions, and BMI indicated a linear relationship in both sexes between a high number of diseases and a high BMI [57]. Obesity, as addressed using the BMI, especially for people categorized as obese II or III, is known to increase the risk of a large number of chronic diseases and health complaints in older adults [58]. But, according to a ten-year follow-up study of middle-aged people (at baseline), the risk of developing a chronic disease also exists for people who are overweight but not obese [59]. Women differ from men: having a BMI $\geq$ 25 kg/m^2 is associated with an elevated risk of arthritis, in addition to risks of hypertension, dyslipidemia, and diabetes, which were also found in men [60].

Concerning physical limitations, in a longitudinal study on elderly people in France, obesity was associated with poorer motor performance, a higher risk of disability and faster motor decline [61]. A meta-analysis in the USA on subjects aged 60 years or more showed that a higher BMI was associated with poor physical function [62]. In a sample of older adults (> 70 years old) in the USA from the National Health and Nutrition Examination Survey III study [19], women in the underweight, overweight, and obese categories were significantly more likely to report functional limitations than women in the normal weight category. In comparison to women, men had fewer associations between BMI and functional limitations. For men and women, individuals in the highest BMI category (obese II) were approximately twice as likely to report functional limitations compared to individuals in the normal BMI category. A study from Hong Kong University on men and women aged 65 years or more and living at home showed that subjects in the two highest BMI categories (BMI 25 to 29.9 kg/m^2 and BMI $\geq$ 30 kg/m^2) had a significantly greater number of IADL (instrumental activities of daily living) impairments compared to the those in the lowest BMI categories (BMI < 18.5 kg/m^2 and BMI 18.5 to 22.9 kg/m^2). Those with a BMI > 30 kg/m^2 had the worst walking performance, and subjects with a BMI in the 18.5 to 24.9 kg/m^2 range had optimal performance [63]. Following Hergenroeder et al. [64], mobility measures showed that performance was similar in normal weight and overweight individuals; however, obese individuals performed less well than the other weight groups.

Sedentary behavior is usually defined as sitting time in a day [65,66]. The majority of studies using self-reported measures have centered on capturing daily TV-viewing time as a proxy marker of overall sedentary behavior [67,68]. The association between watching TV and obesity is known in adults: men and women aged 15 years or more who watch TV for at least 4 hours a day are nearly two and half times more likely to be obese than those who watch TV for 1 hour a day or less [69]. A correlation between more time spent in sedentary occupations and increasing BMI in older adults has been confirmed [66,70], and is independent of the level of physical activity [66,68]. Our results are in line with these studies. Therefore, regarding our hypothesis, public policies aiming to change behavior relative to time spent watching TV could be effective among the elderly.

According to our results, another lever that could be promoted among old people is exercise. Several studies on men and women [68] or women only [49], aged 65 years or over have analyzed sedentary behavior and physical activity in relation to BMI. In these studies [65], "active people" are defined as following health guidelines [68] or walking more than one hour a day [49,65]. An active lifestyle is negatively correlated with BMI in women aged 65 years or more: elderly women who walk less than one hour a day have higher BMI values than those who walk more than two hours a day [49].

An individual's diet and his/her weight (and by extension his/her BMI) are generally linked. Public messages on healthy eating are focused on the benefits of adopting a varied diet. Dietary variety is often defined as the number of different foods consumed over a given period [71,72]. From the answers to our questionnaire, we were able to establish an index of dietary variety for each person based on their daily consumption of vegetables, fruits, dairy products, meat products, fish, and eggs. If we consider a recent Japanese study showing that in women aged 65 to 74 years, low food diversity was associated with a BMI ≥ 25 kg/m^2 [73], we would expect people having a varied diet to be of normal weight rather than overweight. Our results were unable to confirm this correlation, all other things being equal.

Among the data in our corpus, we chose "family contacts" and "living as a couple" as indicative of social capital. A recent study on a population of Australian adults ranging in age from 16 years to more than 60 years [25] demonstrated that compared to single people, couples were significantly less likely to be within a normal weight range. Similar findings had previously been reported for several European countries including France, showing a higher BMI for married people of 17–74 years of age, both men and women. Results from studies on the transition from a marital status are contradictory: in a sample of the Swedish population aged 18–75 years [74], divorced or widowed women had a higher risk of developing obesity compared to those who remained married. In contrast, in a study on Americans aged 51–70 years, both men and women [75], entry into marriage was associated with weight gain and exit from marriage with weight loss. Another study on adults aged 50 years and over in Serbia also showed a correlation between being married and a high BMI: single men and women were less likely to be obese compared to married people, and single women were also less likely to be overweight [27]. In accordance with the majority of these data, and especially those concerning elderly people, we have expected a higher BMI to be associated with "living as a couple". However, our results did not show any effect of this variable. Similarly, according to Wu et al. [76], who observed in healthy elderly people "that the greater the number of kin ties in a person's social network, the greater their odds of obesity", we would expect a high frequency of family contacts to be linked to a higher risk of obesity, but our results did not show any effect for the "family contacts" variable. This could be due to the possibly multiple behavior patterns that underlie this variable, while conversely, this variable alone certainly cannot give a sufficient indication of the quality of relationships that a person experiences around him/her. Following Arezzo et al. [77], "social capital is a multidimensional concept [which] cannot be adequately proxied by only one measure".

Relationships between BMI and socio-economic factors are widely addressed in the literature. Income and education are often used as socio-economic indicators. Using these two indicators, a recent study in Germany [78] on adults aged 25 to 69 years showed that the highest socio-economic groups had the lowest prevalence of obesity. Devaux and Sassi [79] also showed that obesity and overweight in OECD countries tend to be more prevalent in disadvantaged socio-economic groups, a fact confirmed in France: the less educated an individual is, the greater the risk of obesity, with a more significant gap among the female population [80]. Regarding people of age 50 years and more, large-scale surveys [81,82] have shown that individuals with less education and a lower income were more likely to be frail and to have a high BMI [81], and that low-income people are more likely to be obese than others [82]. In line with the literature, our study also showed that educated participants are more likely to be of normal weight than overweight, and overweight rather than obese, when compared to participants with no qualifications, this correlation being mainly due to women. Likewise, women on a low income are more likely to be overweight than of normal weight.

Strengths and limitations of the study

An original feature of our approach was to compare normal-weight and overweight people on the one hand, and obesity with overweight on the other hand. Most studies using BMI categories as a dependent variable in logistic models take normal weight as a reference, and compare overweight or obesity to this reference. By using overweight as the reference, comparisons can take the gap between overweight and obesity into account. This question is crucial in the elderly population, where the overweight range may be considered as optimal for several health outcomes, leading some authors to put forward an "obesity paradox" hypothesis for the elderly population [16,83–86].

Strength of this study is the use of nested coding, which allows comparisons between a given modality and the one just preceding it, in ordinal variables with more than two modalities. For the "age" variable, this procedure produced detailed insights into the differences between the oldest ages, that is, when comparing individuals aged 80 years or over to individuals just 5 years younger.

A third strong point of the study is that the survey from which the data are extracted is representative of the French population living at home. The results can therefore be extrapolated to the whole population. Thanks to the *ceteris paribus* approach (all other things being equal), we have observed that some lifestyle factors (which can be modified by a change in the individual's behavior) are significantly correlated with weight status and some are not (especially dietary variety). Physical exercise and time spent watching TV seem to be effective levers to be targeted to prevent or reduce overweight and obesity.

However, this study also has five major limitations. The first arises from the use of the BMI. The advantages of this indicator applied to the elderly population have been extensively described [86], but it is not able to measure body composition in the elderly precisely because it cannot distinguish between fat mass and lean mass [87]. A combination of height and weight with other indicators, such as waist circumference or waist-to-hip ratio would be preferable, as proposed recently [88]. Furthermore, we have used self-reported rather than measured BMI. Weight underestimation and height overestimation biases, which result in an underestimation of BMI, are well known, especially among older people [89], but also among carers [53]. This is the second limitation. Nevertheless, many authors have shown that there is significant and substantial agreement between self-reported and assessed height, weight, and BMI, even in late life [90,91]. Regarding height and weight reported by carers (who represent less than 10% of our sample), a recent study has shown that proxies reported height and weight accurately [92].

The third major limitation of this study is the cross-sectional approach. The age effects found in this study cannot be extrapolated to a dynamic change that might occur in a given aging individual. Follow-up studies are needed to gain accurate knowledge of the modifications that actually result from the aging process.

The fourth limitation of the study concerns the way exercising was assessed in the study. The question asked to the participant was about practicing a sport, but a person can be physically active without practicing any sport. Daily living can involve moderate to vigorous physical activity, such as climbing stairs, walking, gardening, or doing the housework. The way the question was asked may have masked some physically active kinds of behavior.

The fifth limitation is the definition chosen for "dietary variety". The data in the questionnaire used in this survey were not precise enough to obtain a true indication of food variety. For example, a vegan or vegetarian diet may include a wide variety of food even if meat, fish, eggs and dairy products are excluded. However, there are few elderly vegetarians in France: only 2 or 3% were reported to eat a vegetarian diet in a study published in 2009, concomitant to the data we used [93]. According to a recent study [94], the proportion of vegetarian and vegan subjects in France amounts to 3.4% of adults and elderly people. This proportion drops to 1.7% when only people aged 65 years or over are considered. This marginal proportion of vegetarian/vegan people has been confirmed more recently [95].

Conclusion

Obesity is a very complex and multifactorial chronic disease. Body weight can be affected by environmental and socioeconomic conditions, genetic factors, lifestyle, etc. Our study highlighted some of them for the elderly population living at home in France. The growing prevalence of overweight and obesity among older adults is a major public health concern and could negatively affect life expectancy in the next few years. It is therefore important to identify health-promoting factors, such as exercise or less TV time, as suggested by our results. But because older adults are often portrayed as less likely to change long-standing health behavior, health promotion for this age group has lagged behind that of other age groups. Therefore, there is an urgent need for public health measures to prevent obesity among the elderly. Some have recently been implemented in France, through the national *Bien vieillir* program, designed to promote a healthy diet, exercise, and social relationships to maintain elderly people's autonomy and capacities. It is too early to tell whether these measures will have a positive impact on weight. Further studies are required to better analyze changes in behavior and their consequences for obesity or overweight, and by extension for people's lives and health.

Conflict of interest: The authors declare that they have no conflict of interest.

References

1. Eknoyan G (2006) A history of obesity, or how what was good became ugly and then bad. Adv Chronic Kidney Dis 13:421–7

2. Chauliac M, Hercberg S (2012) Changing the food environment: the French experience. Adv Nutr 3:605s–10s
3. World Health Organization (2000) Obesity: preventing and managing the global epidemic. WHO Technical Report Series 894, 268 p
4. Barreto SM, Passos VM, Lima-Costa MF (2003) Obesity and underweight among Brazilian elderly: the Bambui Health and Aging Study. Cad Saude Publica 19:605–12
5. Douketis JD, Paradis G, Keller H, et al (2005) Canadian guidelines for body weight classification in adults: application in clinical practice to screen for overweight and obesity and to assess disease risk. Can Med Assoc J 172:995–8
6. Chumlea WC, Guo SS, Kuczmarski RJ, et al (2002) Body composition estimates from NHANES III bioelectrical impedance data. Int J Obes Relat Metab Disord 26:1596–609
7. Guo SS, Zeller C, Chumlea WC, et al (1999) Aging, body composition, and lifestyle: the Fels Longitudinal Study. Am J Clin Nutr 70:405–11
8. Gallus S, Lugo A, Murisic B, et al (2015) Overweight and obesity in 16 European countries. Eur J Nutr 54:679–89
9. Paraponaris A, Saliba B, Ventelou B (2005) Obesity, weight status and employability: empirical evidence from a French national survey. Econ Hum Biol 3:241–58
10. Gaddey HL, Holder K (2014) Unintentional weight loss in older adults. Am Fam Physician 89:718–22
11. Wallace JI, Schwartz RS (2002) Epidemiology of weight loss in humans with special reference to wasting in the elderly. Int J Cardiol 85:15–21
12. Ostbye T, Pomerleau J, Speechley M, et al (1995) Correlates of body mass index in the 1990 Ontario Health Survey. CMAJ 152:1811–7
13. Fauziana R, Jeyagurunathan A, Abdin E, et al (2016) Body mass index, waist-hip ratio and risk of chronic medical condition in the elderly population: results from the Well-being of the Singapore Elderly (WiSE) Study. BMC Geriatr 16:1–9
14. Schäfer I, Hansen H, Schön G, et al (2012) The influence of age, gender and socio-economic status on multimorbidity patterns in primary care. First results from the multicare cohort study. BMC Health Serv Res 12:1–15
15. Mathus-Vliegen EM, Basdevant A, Finer N, et al (2012) Prevalence, pathophysiology, health consequences and treatment options of obesity in the elderly: a guideline. Obes Facts 5:460–83
16. Flegal KM, Kit BK, Orpana H, et al (2013) Association of all-cause mortality with overweight and obesity using standard body mass index categories: a systematic review and meta-analysis. JAMA 309:71–82
17. Janssen I, Mark AE (2007) Elevated body mass index and mortality risk in the elderly. Obes Rev 8:41–59
18. Stenholm S, Head J, Aalto V, et al (2017) Body mass index as a predictor of healthy and disease-free life expectancy between ages 50 and 75: a multicohort study. Int J Obes 41:769–75
19. Davison KK, Ford ES, Cogswell ME, et al (2002) Percentage of body fat and body mass index are associated with mobility limitations in people aged 70 and older from NHANES III. J Am Geriatr Soc 50:1802–9
20. Friedmann JM, Elasy T, Jensen GL (2001) The relationship between body mass index and self-reported functional limitation among older adults: a gender difference. J Am Geriatr Soc 49:398–403
21. Baumgartner RN, Wayne SJ, Waters DL, et al (2004) Sarcopenic obesity predicts instrumental activities of daily living disability in the elderly. Obes Res 12:1995–2004
22. Pedrero-Chamizo R, Gómez-Cabello A, Melendez A, et al (2015) Higher levels of physical fitness are associated with a reduced risk of suffering sarcopenic obesity and better perceived health among the elderly. The EXERNET multi-center study. J Nutr Health Aging 19:211–7
23. Powell K, Wilcox J, Clonan A, et al (2015) The role of social networks in the development of overweight and obesity among adults: a scoping review. BMC Public Health 15:1–13
24. Tymoszuk U, Kumari M, Batterham R, et al (2019) Social support and trajectories of body mass index and waist to hip ratio from mid-adulthood to old age. J Epidemiol Community Health 73:111–6
25. Schoeppe S, Vandelanotte C, Rebar AL, et al (2018) Do singles or couples live healthier lifestyles? Trends in Queensland between 2005–2014. PLoS One 13:e0192584
26. Sobal J, Rauschenbach B, Frongillo EA (2003) Marital status changes and body weight changes: a US longitudinal analysis. Soc Sci Med 56 1543–55
27. Grujic V, Dragnic N, Jovanovic VM, et al (2017) Predictors of overweight and obesity among adults aged 50 years and above: Serbian national health survey. Vojnosanit Pregl 74:38–45
28. Harvey JA, Chastin SF, Skelton DA (2015) How sedentary are older people? A systematic review of the amount of sedentary behavior. J Aging Phys Act 23:471–87
29. Du HD, Bennett D, Li LM, et al (2013) Physical activity and sedentary leisure time and their associations with BMI, waist circumference, and percentage body fat in 0.5 million adults: the China Kadoorie Biobank study. Am J Clin Nutr 97:487–96
30. Bouvier G (2011) L'enquête Handicap-Santé, présentation générale. Document de travail (F1109)
31. Ravaud JF (2014) Les enquêtes en population générale sur le handicap : un outil d'observation essentiel de la statistique publique. Inform Soc 3:40–9
32. Renaut S (2012) Les apports de l'enquête Handicap-Santé. Gerontol Soc 35:55–74
33. Bussiere C, Sicsic J, Pelletier-Fleury N (2014) The effects of obesity and mobility disability in access to breast and cervical cancer screening in france: results from the national health and disability survey. PLoS One 9:e104901
34. Palazzo C, Ravaud JF, Trinquart L, et al (2012) Respective contribution of chronic conditions to disability in France: results from the national disability-health survey. PLoS One 7:e44994
35. Dahl AK, Fauth EB, Ernsth-Bravell M, et al (2013) Body mass index, change in body mass index, and survival in old and very old persons. J Am Geriatr Soc 61:512–8
36. Cox B, van Oyen H, Cambois E, et al (2009) The reliability of the Minimum European Health Module. Int J Public Health 54:55–60
37. Thind A, Mohani A, Banerjee K, et al (2008) Where to deliver? Analysis of choice of delivery location from a national survey in India. BMC Public Health 8:29
38. Matta J, Carette C, Lange CR, et al (2018) Épidémiologie de l'obésité en France et dans le monde. Presse Med 47:434–8
39. Peralta M, Ramos M, Lipert A, et al (2018) Prevalence and trends of overweight and obesity in older adults from 10 European countries from 2005 to 2013. Scand J Public Health 46:522–9
40. López-Ortega M, Arroyo P (2016) Anthropometric characteristics and body composition in Mexican older adults: age and sex differences. Br J Nutr 115:490–9
41. Amarya S, Singh K, Sabharwal M (2014) Health consequences of obesity in the elderly. J Clin Gerontol Geriatr 5:63–7
42. Flegal KM, Kruszon-Moran D, Carroll MD, et al (2016) Trends in obesity among adults in the United States, 2005 to 2014. JAMA 315:2284–91
43. Inelmen EM, Sergi G, Coin A, et al (2003) Can obesity be a risk factor in elderly people? Obes Rev 4:147–55
44. Perissinotto E, Pisent C, Sergi G, et al (2002) Anthropometric measurements in the elderly: age and gender differences. Br J Nutr 87:177–86

45. Charles MA, Eschwège E, Basdevant A (2008) Monitoring the obesity epidemic in France: the Obepi surveys 1997–2006. Obesity 16:2182–6
46. Zamboni M, Mazzali G, Zoico E, et al (2005) Health consequences of obesity in the elderly: a review of four unresolved questions. Int J Obes (Lond) 29:1011–29
47. Canaan Rezende FA, Queiroz Ribeiro A, Priore SE, et al (2015) Anthropometric differences related to genders and age in the elderly. Nutri Hosp 32:757–64
48. Hughes VA, Frontera WR, Roubenoff R, et al (2002) Longitudinal changes in body composition in older men and women: role of body weight change and physical activity. Am J Clin Nutr 76:473–81
49. Gomez-Cabello A, Pedrero-Chamizo R, Olivares PR, et al (2011) Prevalence of overweight and obesity in non-institutionalized people aged 65 or over from Spain: the elderly EXERNET multi-centre study. Obes Rev 12:583–92
50. Dey DK, Rothenberg E, Sundh V, et al (1999) Height and body weight in the elderly. I. A 25-year longitudinal study of a population aged 70 to 95 years. Eur J Clin Nutr 53:905–14
51. Davin B, Joutard X, Paraponaris A, et al (2009) Endogénéité du statut du répondant dans les enquêtes sur la santé. Revue économique 60:275–91
52. Davin B, Joutard X, Paraponaris A (2019) “If you were me”: proxy respondents’ biases in population health surveys. ffhalshs-02036434f:1–20
53. Reither EN, Utz RL (2009) A procedure to correct proxy-reported weight in the National Health Interview Survey, 1976–2002. Popul Health Metr 7:1–10
54. Bamia C, Orfanos P, Juerges H, et al (2017) Self-rated health and all-cause and cause-specific mortality of older adults: individual data meta-analysis of prospective cohort studies in the CHANCES Consortium. Maturitas 103:37–44
55. Wu S, Wang R, Zhao Y, et al (2013) The relationship between self-rated health and objective health status: a population-based study. BMC Public Health 13:320
56. Meng Q, Xie Z, Zhang T (2014) A single-item self-rated health measure correlates with objective health status in the elderly: a survey in suburban Beijing. Front Public Health 2:1–9
57. Neto L, de Souza J, Barbosa AR, et al (2016) Diseases and chronic health conditions, multimorbidity and body mass index in older adults. Rev Bras Cineantropom Desempenho Hum 18:509–19
58. Patterson RE, Frank LL, Kristal AR, et al (2004) A comprehensive examination of health conditions associated with obesity in older adults. Am J Prev Med 27:385–90
59. Field AE, Coakley EH, Must A, et al (2001) Impact of overweight on the risk of developing common chronic diseases during a 10-year period. Arch Internal Med 161:1581–6
60. Kim IH, Chun H, Kwon JW (2011) Gender differences in the effect of obesity on chronic diseases among the elderly Koreans. J Korean Med Sci 26:250–7
61. Artaud F, Singh-Manoux A, Dugravot A, et al (2016) Body mass index trajectories and functional decline in older adults: Three-City Dijon cohort study. Eur J Epidemiol 31:73–83
62. Kim S, Leng XI, Kritchevsky SB (2017) Body composition and physical function in older adults with various comorbidities. Innov Aging 30:1–9
63. Woo J, Leung J, Kwok T (2007) BMI, body composition, and physical functioning in older adults. Obesity 15:1886–94
64. Hergenroeder AL, Wert DM, Hile ES, et al (2011) Association of body mass index with self-report and performance-based measures of balance and mobility. Phys Ther 91:1223–34
65. Gomez-Cabello A, Pedreto-Chamizo R, Olivares PR, et al (2012) Sitting time increases the overweight and obesity risk independently of walking time in elderly people from Spain. Maturitas 73:337–43
66. Gennuso KP, Gangnon RE, Matthews CE, et al (2013) Sedentary behavior, physical activity, and markers of health in older adults. Med Sci Sports Exerc 45:1493–500
67. Atkin AJ, Gorely T, Clemes SA, et al (2012) Methods of measurement in epidemiology: sedentary behaviour. Int J Epidemiol 41:1460–71
68. Inoue S, Sugiyama T, Takamiya T, et al (2012) Television viewing time is associated with overweight/obesity among older adults, independent of meeting physical activity and health guidelines. J Epidemiol 22:50–6
69. Vioque J, Torres A, Quiles J (2000) Time spent watching television, sleep duration and obesity in adults living in Valencia, Spain. Int J Obes 24:1683
70. Gomez-Cabello A, Vicente-Rodriguez G, Pindado M, et al (2012) Increased risk of obesity and central obesity in sedentary postmenopausal women. Nutr Hosp 27:865–70
71. Bernstein MA, Tucker KL, Ryan ND, et al (2002) Higher dietary variety is associated with better nutritional status in frail elderly people. J Am Diet Assoc 102:1096–104
72. Waijers PM, Feskens EJ, Ocke MC (2007) A critical review of predefined diet quality scores. Br J Nutr 97:219–31
73. Ishikawa M, Moriya S, Yokoyama T (2017) Relationship between diet-related indicators and overweight and obesity in older adults in rural Japan. J Nutr Health Aging 21:759–6574
74. Oliveira AJ, Rostila M, de Leon AP, et al (2013) The influence of social relationships on obesity: sex differences in a longitudinal study. Obesity 21:1540–7
75. Wilson SE (2012) Marriage, gender and obesity in later life. Econ Human Biol 10:431–53
76. Wu YH, Moore S, Dube L (2018) Social capital and obesity among adults: longitudinal findings from the Montreal neighborhood networks and healthy aging panel. Prev Med 111:366–70
77. Arezzo MF, Giudici C (2017) Social capital and self perceived health among European older adults. Soc Indic Res 130:665–85
78. Hoebel J, Kuntz B, Kroll LE, et al (2019) Socioeconomic Inequalities in the rise of adult obesity: a time-trend analysis of National Examination Data from Germany, 1990–2011. Obes Facts 12:344–56
79. Devaux M, Sassi F (2011) Social inequalities in obesity and overweight in 11 OECD countries. Eur J Public Health 23:464–9
80. de Saint Pol T (2009) Evolution of obesity by social status in France, 1981–2003. Econ Human Biol 7:398–404
81. Harttgen K, Kowal P, Strulik H, et al (2013) Patterns of frailty in older adults: comparing results from higher and lower income countries using the Survey of Health, Ageing and Retirement in Europe (SHARE) and the Study on Global AGEing and Adult Health (SAGE). PLoS One 8:e75847
82. Salmasi L, Celidoni M (2017) Investigating the poverty-obesity paradox in Europe. Econ Human Biol 26:70–85
83. Oreopoulos A, Kalantar-Zadeh K, Sharma AM, et al (2009) The obesity paradox in the elderly: potential mechanisms and clinical implications. Clin Geriatr Med 25:643–59
84. Childers DK, Allison DB (2010) The ‘obesity paradox’: a parsimonious explanation for relations among obesity, mortality rate and aging? Int J Obes 34:1231
85. Strandberg TE, Stenholm S, Strandberg AY, et al (2013) The “obesity paradox, ” frailty, disability, and mortality in older men: a prospective, longitudinal cohort study. Am J Epidemiol 178:1452–60
86. Ben-Yacov L, Ainembabazi P, Stark A (2017) Is it time to update body mass index standards in the elderly or embrace measurements of body composition? Eur J Clin Nutr 71:1029–32

87. Baumgartner RN, Stauber PM, McHugh D, et al (1995) Cross-sectional age differences in body composition in persons 60+ years of age. J Gerontol A Biol Sci Med Sci 50:M307–16
88. Ji M, Zhang S, An R (2018) Effectiveness of A Body Shape Index (ABSI) in predicting chronic diseases and mortality: a systematic review and meta-analysis. Obes Rev 19:737–59
89. Nyholm M, Gullberg B, Merlo J, et al (2007) The validity of obesity based on self-reported weight and height: implications for population studies. Obesity (Silver Spring) 15:197–208
90. Dahl AK, Hassing LB, Fransson EI, et al (2010) Agreement between self-reported and measured height, weight and body mass index in old age — a longitudinal study with 20 years of follow-up. Age Ageing 39:445–51
91. Ng SP, Korda R, Clements M, et al (2011) Validity of self-reported height and weight and derived body mass index in middle-aged and elderly individuals in Australia. Aust NZ J Public Health 35:557–63
92. Dobranowski K, Lloyd M, Côté P, et al (2018) Validity of proxy-reported height and weight to derive body mass index in adults participating in Special Olympics. J Appl Res Intellect Disab 31:136–43
93. Lecerf JM (2009) Particularités du senior végétarien. Médecine des maladies métaboliques 3:380–5
94. Allès B, Baudry J, Méjean C, et al (2017) Comparison of sociodemographic and nutritional characteristics between self-reported vegetarians, vegans, and meat-eaters from the Nutrinet-Sante study. Nutrients 9:1023
95. Dauchet L, Jung YJ (2019) Association entre régimes végétariens et pathologies chroniques : une approche épidémiologique. Cah Nutr Diet 54:318–25

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Palaeoneurology and the Emergence of Language

Paléoneurologie et origine du langage

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Abstract The origin of language has been much debated over the years. Recent research has centred the controversies on two main ideas. Language, as defined by the Basic Property formulated by Chomsky, is a characteristic unique to *Homo sapiens* that developed in our species in the past 300,000 years. Other scientists argue that the Basic Property is a derived characteristic shared with other hominin species, such as *H. neanderthalensis* and the last common ancestor of both modern humans and Neandertals, which evolved over a long period of time, perhaps as long as two million years. Palaeoneurology, which studies the phenotype of the brain in past populations, may have left this complex topic aside because of the difficulty of deducing brain morphology from endocasts (imprints of the neurocranium) and inferring function from brain morphology. In this article, we review the various hypotheses on the evolution of language, highlighting the potential of palaeoneurology to help understand this complex aspect of human evolution, and provide an updated interpretation of previously published endocranial phenotypic data from fossil populations. This brings additional support to a long chronology framework for the origin of language in the hominin lineage: the basic property for modern language may have been in place from the last common ancestor of *H. sapiens* and *H. neanderthalensis*.

Keywords Palaeoneurology · Basic property · *Homo neanderthalensis* · *Homo sapiens* · Middle Pleistocene hominins

Résumé L'origine du langage a suscité de nombreuses controverses au fil des ans. Des recherches récentes ont centré les débats sur deux idées principales. Le langage, tel que défini par la propriété de base de Chomsky, serait une caractéristique unique d'*H. sapiens* qui se serait développée au sein de notre espèce durant les derniers 300 000 ans. D'autres scientifiques soutiennent l'idée que la propriété de base serait une caractéristique dérivée partagée avec d'autres espèces d'hominines, telles qu'*H. neanderthalensis* et le dernier ancêtre commun aux humains modernes et aux Néandertaliens, et qui aurait évolué sur une longue période de temps, potentiellement sur deux millions d'années. La paléoneurologie, qui étudie le phénotype du cerveau dans les populations passées, peut avoir négligé ce sujet complexe en raison des difficultés à déduire la morphologie du cerveau à partir du moulage endocrânien (empreinte du neurocrâne) et à inférer la fonction à partir de la morphologie du cerveau. Dans ce manuscrit, nous passons en revue les différentes hypothèses concernant l'évolution du langage, nous mettons en évidence le potentiel de la paléoneurologie pour aider à comprendre cette question complexe dans l'évolution humaine et nous fournissons une interprétation à jour des données phénotypiques endocrâniennes précédemment publiées provenant de populations fossiles. Nous apportons un soutien supplémentaire à un cadre chronologique long pour l'origine du langage dans la lignée humaine : la propriété de base du langage moderne dans les populations d'hominines semble avoir précédé l'apparition de la population ancestrale aux *H. sapiens* et *H. neanderthalensis*.

Mots clés Paléoneurologie · Propriété de base · *Homo neanderthalensis* · *Homo sapiens* · Hominines du Pléistocène moyen

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In the evolution of the genus *Homo*, an area of constant debate concerns the classification of fossil specimens within much discussed *Homo* taxa [1–4] and the abilities of those hominin species. One of the major unresolved questions concerns the emergence and evolution of language faculties.

The only talking hominin

There are different hypotheses regarding the evolution of language within the genus *Homo*. One of the oldest hypotheses argues that language emerged at a late stage in modern humans, perhaps as late as 100,000 years ago (ka) [5–6]. This hypothesis was originally developed from the idea that the production of differentiated vowels would have been impossible without a large pharyngeal cavity. The descent of the larynx was also seen as a unique *H. sapiens* characteristic, which -*de facto*- limited the emergence of modern language to our species [7]. The ideas of a descended larynx as a prerequisite for producing differentiated vowels and as a unique *H. sapiens* feature have both been repeatedly contested ever since [8–9]. However, this hypothesis is still strongly supported because it is also rooted in the 'cultural modernity' hypothesis, which holds that modern humans acquired full modern human behaviour at least 100 ka after their first appearance [10]. Advanced modern behavioural traits, which include a new techno-complex (Later Stone Age, LSA in Africa and Upper Palaeolithic in Europe) and symbolism, as demonstrated by the earliest prehistoric art [11], seem to have been fully acquired by modern humans by 50–40 ka [12]. Before that date there is little in the archaeological record linked to modern humans that shows symbolic behaviour. The earliest trace of symbolic behaviour for the *H. sapiens* species can be traced back to ca 80 ka in Blombos cave (South Africa) [13] and Taforalt (Morocco) [14]. The presence of this behavioural package is, in turn, often used to infer the emergence of modern language.

More recently the 'Why Only Us' hypothesis [15] uses the 'Basic Property' of human language as a landmark to infer the origin of language in hominin populations. Basic Property is described by Chomsky [16] as the 'Merge' operation, which builds a "*discrete infinity of structured expressions that are interpretable in a definite way by the conceptual-intentional system of thought and action, and by a sensory-motor system for externalisation*" (p. 201). In other words, the Basic Property refers to the way thoughts are linked with sounds and signs. For Berwick and Chomsky (15), language—as defined by the Basic Property, is also restricted to *H. sapiens*, but it must have arisen within its clade earlier than previously thought. The San populations split from the other modern human populations around 160 ka [17] and were mostly genetically isolated until 3000 years ago. Despite this genetic isolation, the modern Sans possess a fully modern human language faculty. Therefore, the Basic Property for modern language had to have appeared between the origin of the first modern humans, which by the time of Berwick and Chomsky's publication (2017) was thought to be around 200 ka, but can now be placed at around 300 ka [18–20], and the first identified split within *H. sapiens* populations at around 160 ka [17].

The 'Why Only Us' hypothesis relies first on the scarcity of archaeological evidence of symbolic behaviour within the Denisovan/Neandertal lineage to infer that the Basic Property must have developed within the modern human clade only after the split between the two lineages. The new date estimates for the time of the split between those lineages, 700–500 ka instead of the traditional 400 ka [21–22], supports this hypothesis by allowing enough time to the *H. sapiens* lineage to develop genetic innovations that would ultimately lead to the acquisition of the Basic Property, and hence, of a fully modern human language faculty [23]. Additionally, the genetic differences identified between the Denisovan/Neandertal lineage and the modern human ones, notably in the *FOXP2* genomic region [24–25] are also seen, in the 'Why Only Us' hypothesis, as evidence of the different language faculties between the two clades. While Berwick and Chomsky [23] acknowledge that it is unclear whether FOXP2 plays a role in the emergence of the Basic Property, they rely on the fact that some segments of the FOXP2 transcription factor gene of an Altaic Neandertal individual appears to have introgressed from modern humans [25], supporting the idea that both lineages accumulated genetic differences in a key part of the genome concerning language faculties and language acquisition.

A long chronology for the development of modern language faculties

At the other end of the spectrum, researchers argue for a much longer chronology in the development of modern language faculties (i.e. Basic Property). This 'Gradual Hypothesis' is, yet again, primarily based on the interpretation of hints of symbolic behaviour in the archaeological record, which in the view of the supporters of a more gradual evolution of language, does not support cultural modernity. A number of recent studies have indeed modified the paradigm regarding the appearance of symbolic behaviour by demonstrating that hominins within the *H. neanderthalensis* lineage were capable of expressing advanced modern behavioural traits as defined by Klein [12]. The most spectacular discovery is the dating to ~176 ka of annular constructions of broken stalagmites which were made 336 m deep into the Bruniquel Cave (Southwest France) [26]. Similarly, the debated [27–28] dating of cave art in the Iberian Peninsula to ~64 ka [29] points to Neandertal authorship. This new chronology establishes that before the arrival of *H. sapiens* in Europe, hominins had already developed advanced symbolic behaviour. Symbolic behavioural faculties in *H. neanderthalensis* are also demonstrated by funerary practices [30], although the evidence has been heavily criticised [31], and the new direct dating of Neandertal hominin remains at the Grotte du Renne [32] demonstrates that the Neandertal occupation was indeed contemporary with the Châtelperronian Upper Palaeolithic techno-complex found at the site. Given this new archaeological evidence, it seems possible that symbolism was not limited to the *H. sapiens* clade alone, and that the Neandertals and possibly the common ancestor of both lineages may have been capable of similar behaviour. If these advanced behaviours are used as proxies for the Basic Property for modern language, then both the Neandertals and their ancestors would have had a language faculty that "*involves a cognitive architecture that maps sounds (or gestures) into meaning through a series of combinatorial structures*" [33, p. 52]. One should nevertheless keep in mind that the evidence describing advanced symbolic behaviour in Neandertals remains sparse and cannot compare quantitatively with later archaeological evidence associated with Upper Palaeolithic humans.

The Gradual Hypothesis also uses the most recent genomic studies to strengthen its theoretical claim. First, it stresses the fact that both lineages interbred at least three times during their isolated genomic history. The mitochondrial DNA (i.e. mtDNA) retrieved from 'classic' (i.e. 130–40 ka) Neandertal specimens is closer to that of modern humans than it is to the mtDNA sequenced from Denisovan and Middle Pleistocene fossils from Europe that are widely considered to be early Neandertals (i.e. Sima de los Huesos), indicating some gene flow between the two lineages during the mid-Middle Pleistocene [34]. Neandertals and *H. sapiens* interbred when the latter first came into the Levant around 100–120 ka [25,35] and the modern human fossils from Peștera cu Oase in Romania, which date back to 42–37 ka, probably had a recent Neandertal ancestor (i.e. 4 to 6 generations [36]). Moreover, while the Neandertal and modern human clades show genetic distinctiveness, the actual number of differences appears to be relatively small. Prüfer and colleagues [37] showed that only 31,389 single nucleotide substitutions and 4113 short insertions or deletions distinguished modern humans from their nearest extinct relatives, among which only about three thousands of those fixed changes could have potentially influenced gene expression [37]. Therefore, one could consider that with such an intricate genetic history between the two lineages, it is less likely that the two would have had completely distinct language faculties.

The final idea put forward by supporters of the Gradual Hypothesis is co-evolution of tool-knapping and language faculties [38–39]. This implies that the evolution of the Basic Property for modern language could have originated within the genus *Homo* with the Mode 2 technology (i.e. Acheulean) whose earlier appearance in the African archaeological record is documented at 1.75 million years ago [40]. This idea relies on the assumption that the transmission of skills necessary to master elaborate lithic technology demands language [33]. Experimental studies have given contrasting results when testing this hypothesis. In 2013, Uomini and Meyer showed that the pattern of cerebral blood flow lateralisation was similar when participants were asked to knap Acheulean tools and to generate cued words [41]. Another study, focusing on the Oldowayen techno-complex, which appeared around 2.5 million years ago in the archaeological record, gives further support to Uomini and Meyer's results. It shows that reliance on stone tools would have triggered selection for teaching and language. One of the outcomes of this selection would have been the appearance of Acheulean, the Mode 2 technology being the first techno-complex requiring more advanced faculties in both language and teaching for its transmission [42]. However, Putt and colleagues [43] in a similar study suggest that selection from reliance on stone tools favoured the development of the prefrontal and temporal cortices, which offered a more complex toolkit to the hominins but did not play a significant role in the evolution of language.

Towards a new paradigm?

The lack of scientific consensus, which may be explained by the difficulties of evaluating traits that can only be studied through proxies (anatomical or symbolic), has led to a situation where the study of language evolution is often considered as out of reach for current research capacities. The first aim of the Globularity hypothesis (i.e. Globularisation Leads to our Brain's Language-Readiness) developed by Boeckx [44], is to offer an updated framework for the study of language evolution. The globularity hypothesis distinguishes between language and language-readiness, in other words, the anatomical and physiological prerequisites for language acquisition and use are not sufficient and inputs from cultural evolution studies are necessary to understand the complexity of grammatical systems that need to be learned by children. The Globularity hypothesis aims to focus on the neurobiological properties that would need to be linked to the anatomical and physiological preconditions for a 'language-ready brain'. This hypothesis sets out to investigate the phenotypes of both brain and braincase, given their tightly correlated developmental trajectories, in order to draw inferences from skull size and shape changes about the organ that generates language. For instance, Boeckx [44] links the formation of a fronto-parietal-temporal loop that would provide an indirect pathway for language [45–46] to the expansion of the parietal region, which could have had an impact on the connection between areas of the brain believed to be part of this language loop (i.e. Broca's and Wernicke's regions, see below). The expansion of the parietal region is part of the globularisation process within the hominin lineage [47–48] that may have played a role in the formation of a language network. The Globularity hypothesis supports a rather late evolution of the Basic Property within the modern human lineage, as one of its components relies on the hypothesis of self-domestication [49–50] which would have led to the appearance of the modern human phenotype. This is congruent with morphometric studies on encephalisation trajectories within the *Homo* lineage, where *H. sapiens* appears to present a different globularisation trajectory, possibly triggered by the expansion of the parietals [47], which may have happened late in the evolution of modern humans [51]. However, the unique approach to language evolution consisting of linking the study of brain and neurocranium phenotypes is important for any advances in the field.

Language evolution and palaeoneurology

Palaeoanthropology has long been studying the phenotypes of the calvarium and the brain, through the study of casts of the inner surface of the neurocranium (i.e. endocasts) of fossil specimens [52–55]. However, apart from a few exceptions [56–58], the implications of specific anatomical features for language evolution are often overlooked. First, the object of the study in palaeoneurology, the endocast, is a schematic representation of the brain's anatomy, and may not be regarded as a reliable source of information. Its morphology must be considered carefully, especially when discussing function. Secondly, there are few studies combining data on the morphology of the endocast and of the neurocranium. To address the former, Kochiyama and colleagues [59] estimated the possible shape of the actual brain of fossil Neandertals and Early *H. sapiens* in order to compare it with the brain morphology of living populations. Their results confirmed that both Early and extant *H. sapiens* presented a larger cerebellum than the Neandertals [60]. The cerebellum is linked to higher cognition, including language [61–62], and the morphological differences identified between the two species may indicate distinct language faculties. Gunz and colleagues [63] went further by deriving an index of endocranial shape based on the actual morphologies of living people's brains using MRI scans. They then estimated this shape index in fossil specimens and compared it with the shape of the neurocranium and with gene expression data. Their results show that introgressed Neandertal alleles correlate with reduced globularity of the endocranium shape in modern humans, thus demonstrating the potential of their approach. Nevertheless, clarifying the correlation between morphology and function will require further work, and traditional approaches in palaeoneurology should also be considered as they can bring interesting insights regarding language evolution.

These approaches rely on the study of areas of the brain that are traditionally identified as playing a part in the classic language loop: the Wernicke–Geschwind model [64–65]. This model describes how different areas of the brain are involved in language comprehension and language production [66]. One of the major issues regarding the Wernicke–Geshwind model lies in the fact that the definitions of the regions involved in this language loop are still much debated and the usefulness of the model itself is sometimes questioned. For instance, Tremblay and Dick [67] showed that scientists did not agree on the actual anatomical definition of the Broca and Wernicke areas. They conducted a survey in which scientists were asked to choose between seven different definitions for each area. While 73% of the scientists recognised Broca's area in two similar definitions, four definitions of the Wernicke area were needed to reach a similar percentage (i.e. 70%, see Fig. 1). Alternatives to this model are, however, not easy to implement (see, for instance, the fronto-parietal-temporal loop discussed by Boeckx [44]), while the anatomical regions referred to in the Wernicke–Geschwind model can be linked to well-known areas of the brain as defined by Brodmann [68]. Broca's area generally encompasses areas 44 and 45, while Wernicke's area most often refers to area 39, part of areas 40 and 22. In palaeoneurology, Broca's area may cover approximately the morphology of the third frontal convolution (i.e. 3Fc), which encompasses areas 44 and 45 as part of area 10. Wernicke's area is more difficult to define on endocasts, but part of it, the angular and supramarginal gyri, correspond to Brodmann's areas 39 and 40, respectively and can be identified (see, Fig. 1 and [54,56,69]). The development and definition of the 3Fc and of the angular and supramarginal gyri as observed in palaeoneurology correspond to a certain extent to the most common definitions of the Broca and Wernicke areas (see Fig. 1 and [67]). Therefore, and despite the current debates on the Wernicke–Geschwind model [67], those anatomical regions and their bilateral variations as observed on endocasts remain the most direct source of anatomical information for palaeoanthropologists discussing language evolution in fossil populations.

Mounier and colleagues [70] used parsimony to analyse a coded morphological database of fossil hominins from the genus *Homo* which considered both ecto and endocranial morphologies. The aim of the analysis was to test whether the anatomy of the endocast contributed to the phylogenetic differential definition of *H. neanderthalensis* from *H. sapiens*. However, the morphological features identified as responsible for the separation of the two species are mostly located on the ectocranial and not on the endocranial surface.

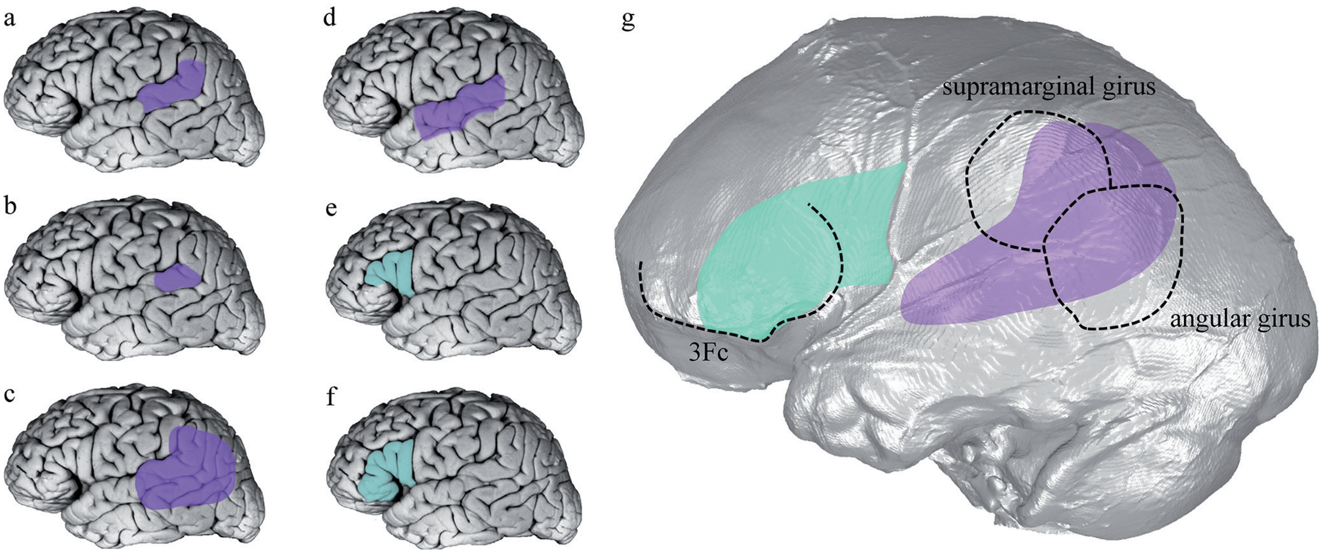

Fig. 1 (a to f) Most common anatomical definitions of Wernicke's area (a to d) and Broca's area (e and f) on the brain. These definitions of each area have been endorsed by 70% (Wernicke, respectively 26%, 23%, 12% and 9%) and 73% (Broca, respectively 50% and 23%) of the respondents to the Tremblay and Dick survey [67]. (g) Anatomical region of the endocast linked with Broca's area (green): 3Fc (third frontal convolution) and Wernicke's area (violet): angular gyrus and supramarginal gyrus on the endocast of a modern Australian (AUS047, Duckworth Collection). Despite the uncertainties regarding the definitions of both areas on the brain, the use of the 3Fc, angular and supramarginal gyri appears as the most reasonable proxy to observe changes related to those areas in palaeoneurology / *(a à f) Définitions anatomiques les plus courantes de la zone de Wernicke (a à d) et de la zone de Broca (e et f) sur le cerveau. Ces définitions de chaque zone ont été approuvées par 70 % (Wernicke, respectivement 26 %, 23 %, 12 % et 9 %) et 73 % (Broca, respectivement 50 % et 23 %) des répondants à l'enquête de [67]. (g) Région anatomique de l'endocrâne liée à la zone de Broca (vert) : 3Fc (troisième circonvolution frontale) et région de Wernicke (violet) : gyrus angulaire et gyrus supramarginal sur l'endocrâne d'un Australien moderne (AUS047, Duckworth Collection). Malgré les incertitudes concernant les définitions des deux zones du cerveau, l'utilisation de la 3Fc, des gyri angulaire et supramarginal apparaît comme le proxy le plus raisonnable pour observer les changements liés à ces zones en paléoneurologie*

Amongst the 35 endocranial features considered in the study, 10 are related to either Broca (characters #14—Definition and development of the relief of the head of 3Fc, #15—Definition and development of the relief of the foot of the 3Fc, #16—Orientation of the anterior and posterior ramus of the Sylvian valley, #17—Lateral development of the pars triangularis, #18—Sagittal development of the pars triangularis, #19—Maximum length position between pars triangularis, and #20—Position of the base of the pars triangularis relative to the temporal pole) or Wernicke areas (#22—Definition and projection of the supra-marginal gyrus, #23—Form of the supra-marginal gyrus, #24—Definition of the lobule of the angular gyrus). None of the endocranial characters considered in the cladistic analysis were identified as a full apomorphy for the Neandertal and *H. sapiens* clades, but four, #1 (cranial capacity), #16, #22 and #30 (position of the occipital lobes), are apomorphies for both clades. Focusing on the 10 characters that describe morphologies linked to the language loop, we note that some are variable within and outside taxa of the genus *Homo*, but others mark the emergence of important clades. For instance, three characters describing the 3Fc, hence Broca's area (i.e. #14 well-developed head of the third frontal convolution, #16 upward and frontward orientation of the anterior and posterior ramus of the Sylvian valley, and #17 well-developed *pars triangularis*), are newly emerged morphological features that separate Neandertals, modern humans and their last common ancestor from *H. erectus sensulato* and most of the Middle Pleistocene fossils (Fig. 2). This is also true for Wernicke's area: both the lobule of the angular gyrus (#24) and the supramarginal gyrus (#22) become strongly developed and well defined just before the split between Neandertals and modern humans. A recent study [71] found that the area of the endocast where both features can be observed appears slightly more spread out in *H. sapiens*. However, they did not study the angular and supramarginal gyri in detail but focused instead on the shape of the parietal lobe. Moreover, a well-defined and projected supramarginal gyrus constitutes a true synapomorphy for both the Neandertal and modern human clades (Fig. 2).The definition and development of the relief of the head of 3Fc (#14), the lateral development of the pars triangularis (#17), the maximum length position

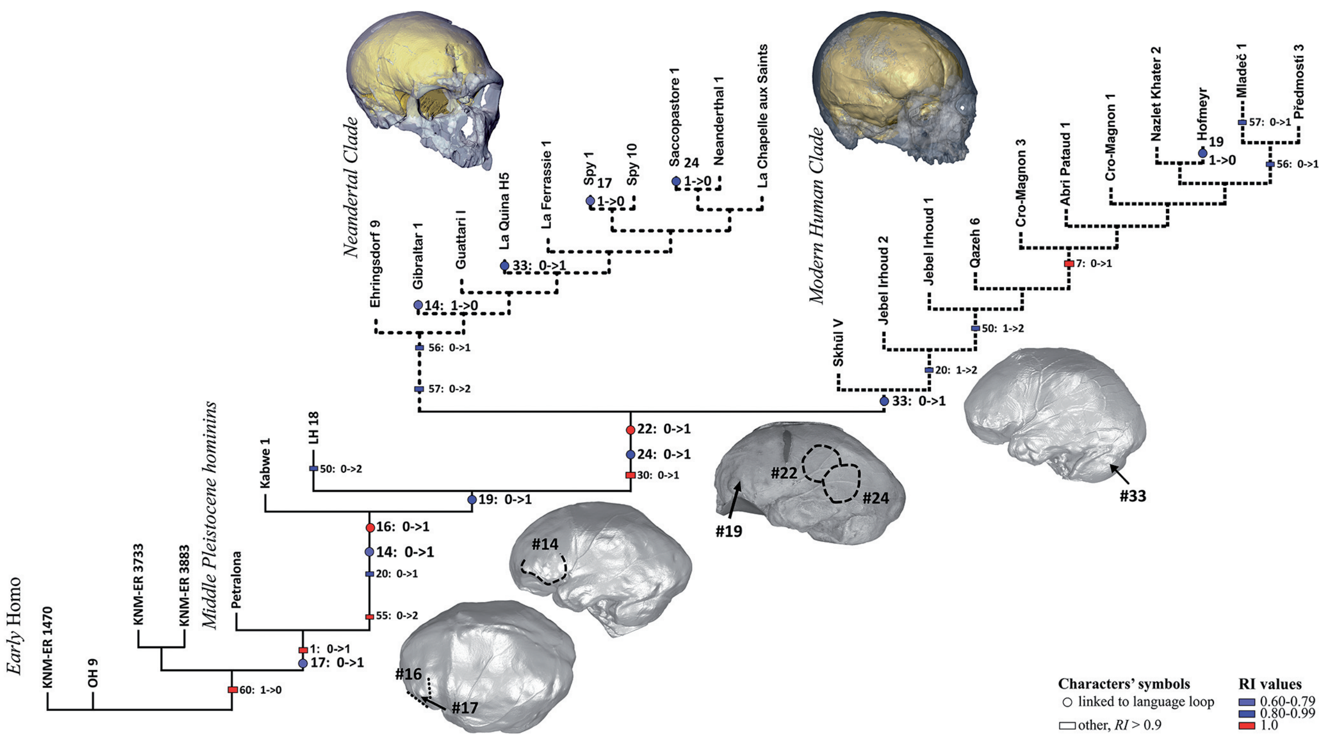

Fig. 2 Cladogram of the genus *Homo* modified from Mounier and colleagues [70] presenting the most important changes along the branch of the tree (true synapomorphies –RI = 1, and characters with RI > 0.8) along with the appearance of derived features related to the classic Wernicke–Geschwind model throughout the Middle Pleistocene and before the split between the modern and Neandertal lineages (#14 and #17 respectively RI = 0.667 and RI = 0.75 due to reversions). #33 is not linked to the language loop but has been linked to the evolution of language [59]. The endocast used to display the morphological features are, from top to bottom: Kabwe 1 (oblique view, left side), Kabwe 1 (norma lateralis), Irhoud 2 (norma lateralis) and AUS 047. Character descriptions: #1, Cranial capacity; #7, Number of ramifications of the middle meningeal system; #14, Definition and development of the relief of the head of 3Fc; #16, Orientation of the anterior and posterior ramus of the Sylvian valley; #17, Lateral development of the pars triangularis; #19, Maximum length position between pars triangularis; #20, Position of the base of the pars triangularis relative to the temporal pole; #22, Definition and projection of the supra-marginal gyrus; #24, Definition of the lobule of the angular gyrus; #30, Position of the occipital lobes; #33, Width of the sulcus separating the cerebellar lobes; #50, Presence of a tuber parietale; #55, Form of the outline of the planum occipital in norma occipitalis; # 56, Presence of a suprainiac fossa; #57, Definition of the torus occipitalis transversus; #60, Form of the outline of the superior border of the temporal squama / *Cladogramme du genre* Homo *modifié de Mounier et al*. [70] *présentant les changements les plus importants le long de la branche de l'arbre (vraies synapomorphies –RI = 1, et caractères avec RI > 0,8) ainsi que l'apparition de caractéristiques dérivées liées au classique modèle de Wernicke-Geschwind tout au long du Pléistocène moyen et avant la scission entre les lignées modernes et néandertaliennes (# 14 et 17 respectivement RI = 0,667 et RI = 0,75 en raison des inversions). # 33 n'est pas lié à la boucle linguistique, mais a été lié à l'évolution du langage (e.g.* [59]*). L'endocrâne utilisé pour afficher les caractéristiques morphologiques est de haut en bas : Kabwe 1 (vue oblique, côté gauche), Kabwe 1 (normalateralis), Irhoud 2 (normalateralis), et AUS 047. Descriptions des caractères : # 1, Capacité crânienne ; # 7, Nombre de ramifications du système méningé moyen ; # 14, Définition et développement du relief de la tête de la troisième circonvolution centrale ; # 16, Orientation du ramus antérieur et postérieur de la scissure de Sylvius ; # 17, Développement latéral de la pars triangularis ; # 19, Position de la longueur maximale entre les pars triangularis ; # 20, Position de la base de la pars triangularis par rapport au pôle du lobe temporal ;# 22, Définition et projection de la supra-gyrus marginal ; # 24, Définition du lobule du gyrus angulaire ; # 30, Position des lobes occipitaux ; # 33, Largeur du sulcus séparant les lobes cérébelleux ; # 50, Présence d'un tuber pariétale ; # 55, Forme du contour du planum occipital in normaoccipitalis ; # 56, Présence d'une fosse suprainiaque ; # 57, Définition du torus occipitalis transversus ; # 60, Forme du contour du bord supérieur de l'écaille de l'os temporal*

between pars triangularis (#19) and the definition of the lobule of the angular gyrus (#24) are not true synapomorphies in this analysis, as they undergo reversion in individual specimens within the Neandertal (i.e. Gibraltar 1, Spy 1 and Saccopastore 1) and *H. sapiens* (i.e. Hofmeyr) clades. Those reversions prevent morphologies that could yield information regarding the language loop from appearing as derived features common to Neandertals and modern humans. However, it should be noted that the study did not focus on these particular anatomical traits, and that the endocast sample was not chosen for this purpose. More specimens could have been added to the study if it had focused on morphologies linked to the language loop. Instead, the state of preservation of the endocasts considered by Mounier and colleagues [70] is sometimes unsatisfactory, for instance the left side of the calvarium of Hofmeyr and Gibraltar 1 is virtually absent, and the reported observations of characters #14 (definition and development of the relief of the head of 3Fc), #17 (lateral development of the pars triangularis), #19 (maximum length position between pars triangularis) and #24 (definition of the lobule of the angular gyrus) are necessarily based on some degree of interpolation. Therefore, these reversions should not prevent us from highlighting the underlying patterns, which show the appearance, throughout the Middle Pleistocene hominin fossil record, of anatomical features related to areas of the brain which have been described as playing a role in language [66]. Finally, Mounier and colleagues [70] identify an additional character which is not a true synapomorphy, but which plays a role in the definition of the modern human and the Neandertal clades. Character #33 defines the size of the sulcus separating the cerebellar lobes, and in most Neandertals the sulcus is wider than in most modern humans. It is linked to higher cognition, including language [61–62], in spite of not being part of the classic language loop. This indicates a possible increase in the size of the cerebellar lobes in modern humans [59–60], which could have had an impact on *H. sapiens* language faculties [59,72].

It is interesting to note that many of the characters identified in the sequence of appearance, during the Middle Pleistocene, of anatomical features related to the language loop on hominin endocasts are focused on the 3Fc (i.e. #14, #16, #17 and #19). In 2014, Balzeau and colleagues [56] quantified and analysed the bilateral variation in size and shape of the 3Fc within *Pan*, *Australopithecus* and *Homo* specimens (including an expanded Neandertal sample, see Fig. 3): the study demonstrated that the 'Broca's cap' identified in hominins was due to a size reduction of the 3Fc in the left hemisphere when compared to the right one. The left 3Fc is indeed shorter but presents a similar width making its shape more compact, hence increasing its morphological distinctiveness. We have expanded our Neandertal samples since our original study [56]. Figure 3 presents the comparison of the size of the third frontal convolution and the endocranial volume, expressed respectively as their square-root and their cube-root. In addition, the mean surface (in mm^2) of this anatomical area in the Neandertal sample (167.7, SD = 32.7, N = 11) is larger than the ones observed in both fossil *H sapiens* (133.5, SD = 30.6, N = 8) and in the *H erectus* sample (110.6, SD = 24.4, N = 12). The small sample sizes of the groups analysed make it difficult to identify statistical correlations within our data. Nevertheless, the observed global variation throughout human evolution, as illustrated by the mean values and by the distribution of the specimens for each sample in figure 3, appears to show a size gradient for this anatomical area between hominin species. When only the hominin sample is considered, there is a significant correlation between 3Fc and the endocranial volume (RMA regression, $r = 0.19$, $P = 0.008$). Moreover, the gradient of the degree of asymmetry as seen directly on the endocasts and partly observed through morphometric data on small fossil samples [56], that is, the distinctiveness of the morphology of the 3Fc on the left hemisphere, sets Neandertals and modern humans apart from the rest of the sample. The sparseness of the fossil record prevents us from performing a more detailed comparative morphometric analysis of the departure from symmetry of the third frontal convolution in hominin species. Nevertheless, our morphometric data showing the increase in size of this anatomical area in recent hominin species concords with the repeated observation of a well-defined Broca's area in *H. sapiens*, Neandertals and a few Middle Pleistocene fossils (i.e. *H. heidelbergensissensulato*) when compared to other fossil hominins and *Pan* specimens [56]. Although these results should not be interpreted as directly inferring speech capacities, nor as a direct characterisation of the functional area related to speech, they are nevertheless based on morphological observations which constitute the best available proxy for analysing Broca's cap in fossil hominins [56,69]. Similarly, and as demonstrated above, other anatomical features of the endocast appear to be poorly delimited in hominins or even absent in great apes [54–55]. In particular, the reliefs of the angular and supramarginal gyri are only identifiable in Neandertals, modern humans and some Middle Pleistocene fossils [54,70]. Their definition is too faint to allow any reproducible quantification on endocasts and these characters were not considered by Balzeau and colleagues [56].

Therefore, both analyses of the endocast morphology—through different methodological approaches— identify a clear separation of modern humans and Neandertals from other hominid species, despite known differences between these taxa (e.g. the relative contribution of the frontal, parieto-temporal and occipital lobes [73]). In this context, the morphologies responsible for such a split in the hominid clade are linked to the classic Wernicke–Geschwind model and it could be argued that they form a morphological

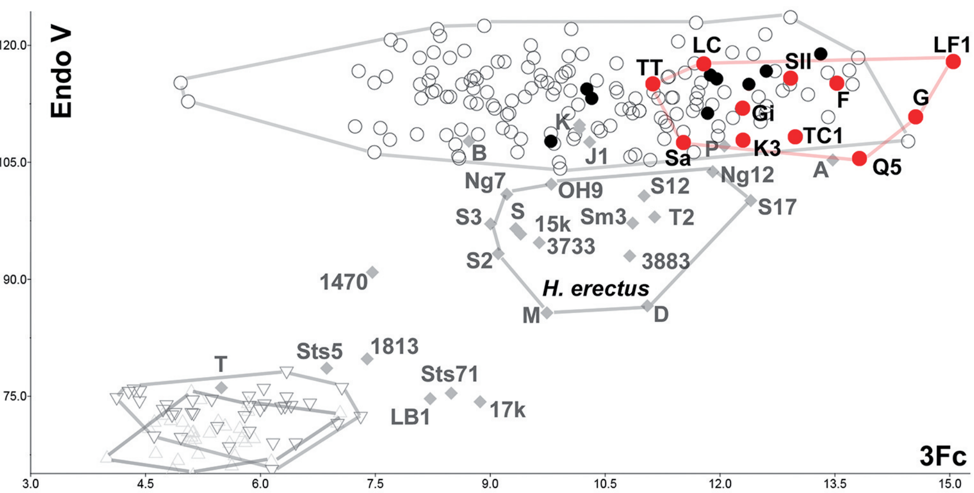

Fig. 3 Bivariate plot of the size of the third frontal convolution (square root, noted 3Fc, in mm) and of the endocranial volume (cube root, noted Endo V, in mm) in *Pan paniscus* (triangles), *Pan troglodytes* (inverted triangles), *H. sapiens* (circles), fossil *H. sapiens* (black circles), fossil hominins (black diamonds: T: Taung, 17k: KNM-WT 17000, 1470: KNM-ER 1470, 1813: KNM-ER 1813, 3733: KNM-ER 3733, 3883: KNM-ER 3883, 15k: KNM-WT 15000, OH 9, D: Dmanisi 9002, T2: Trinil 2, S2: Sangiran 2, S17: Sangiran 17, M: Mojokerto, Ng7: Ngandong 7, Ng12: Ngandong 12, Sm3: Sambungmacan 3, S3: Zhoukoudian Ckn. E 1.PA.16, S12: Zhoukoudian Ckn. L 2.PA.100, LB 1: Liang Bua 1, SV: Skhūl V, Ar: Arago, B: Bodo, K: Kabwe 1, JB1: Jebel Irhoud 1, P: Petralona, S: Salé) and Neandertals (red circle, F: Feldhofer, LC: La Chapelle-aux-Saints 1, LF1: La Ferrassie 1, Gu: Guattari, Gi: Gibraltar, K3: Krapina 3, Q5: La Quina H5, Sa: Saccopastore, TC1: Tabun C1, TT: Teshik Tash, SII: Spy 10). Modified from *Balzeau et al*. [56] / *Graphique bivarié de la taille de la troisième circonvolution frontale (racine carrée, noté 3Fc) et du volume endocrânien (racine cubique, noté Endo V) chez* Pan paniscus *(triangles)*, Pan troglodytes *(triangles inversés)*, H. sapiens *(cercles)*, H. sapiens *fossiles (cercles noirs), hominines fossiles (diamants noirs : T : Taung, 17k : KNM-WT 17000, 1470 : KNM-ER 1470, 1813 : KNM-ER 1813, 3733 : KNM-ER 3733, 3883 : KNM-ER 3883, 15k : KNM-WT 15000, OH 9, D : Dmanisi 9002, T2 : Trinil 2, S2 : Sangiran 2, S17 : Sangiran 17, M : Mojokerto, Ng7 : Ngandong 7, Ng12 : Ngandong 12, Sm3 : Sambungmacan 3, S3 : Zhoukoudian Ckn.E 1.PA.16, S12 : Zhoukoudian Ckn.L 2.PA.100, LB 1 : Liang Bua 1, SV : Skhūl V, Ar : Arago, B : Bodo, K : Kabwe 1, JB1 : JebelIrhoud 1, P : Petralona, S : Salé) et Néandertaliens (cercle rouge, F : Feldhofer, LC : La Chapelle-aux-Saints 1, LF1 : La Ferrassie 1, Gu : Guattari, Gi : Gibraltar, K3 : Krapina 3, Q5 : La Quina H5, Sa : Saccopastore, TC1 : Tabun C1, TT : TeshikTash, SII : Spy 10). Modifié à partir de Balzeau et al*. [56]

substrate of characteristics present in both Neandertals and modern humans that are possibly linked to Chomsky's Basic Property for language. Indeed, the 3Fc and the angular gyrus have been repeatedly associated with language processing, one controlling for muscles related to speech [74] and the other having a role in the transformation of visual representations into an auditory code [75]. The function of the supramarginal gyrus, and despite its position on the brain (Brodmann's area 40), is less clear; it has nevertheless been described as being involved with language comprehension [76]. The only highlighted difference between Neandertals and modern humans concerns the cerebellum which, from about 100,000 years ago, gradually became larger in *H. sapiens* [51,59,70,72]. The cerebellum plays a role in higher cognition and possibly language, but is not part of the classic language loop and it is unclear whether it influenced language faculties. Nevertheless, the development of these anatomical features throughout the Middle Pleistocene and their presence in both *H. sapiens* and *H. neanderthalensis* suggest that both species would have had similar language faculties despite the fact that their general brain structure presents anatomical differences.

Origin of language—more questions than answers

The literature review presented in this paper shows a complex picture of the evolution of language. It remains difficult to decipher which hominin population developed the Basic Property which gave hominins modern language, and when. The study of endocasts, which is often overlooked when discussing the evolution of language, may nevertheless bring new insights to the debate. The identification of an endocranial anatomical substrate possibly linked to language and common to *H. neanderthalensis*, *H. sapiens* and their ancestor [56,70] must be discussed within the wider debate surrounding the origin of language. In recent years, palaeogenomics has profoundly transformed the status of *H. neanderthalensis*, which now stands much closer to modern humans, given the accumulating evidence regarding interbreeding between the modern and Neandertal lineages [25,34–36]. Moreover, evidence of complex behaviour (e.g. advanced modern behaviour [12]) outside of the modern human clade [26,29–30], along with experimental studies showing possible co-evolution of tool-knapping and language faculties [41–42], supports the possibility of common, or at least close, language faculties between both lineages.

However, one should keep in mind that the same evidence is sometimes used to demonstrate the exact opposite: genomics data, despite interbreeding, show that the lineages were separated [23], evidence of advanced modern behaviour outside of the modern clade is much discussed [31] and experimental studies on tool-knapping may reach a different conclusion [43]. This is also the reason that palaeoneurology can be of importance in helping to resolve the debate surrounding the origin of language, even though demonstrating the presence of the morphological traits required to develop the Basic Property for modern language does not demonstrate the presence of the ability itself, as it cannot be observed in the fossil record [77].

The origin of language remains a difficult topic, but new approaches [59,63], and the study of both the calvarium and endocranial morphologies, as advocated by Boeckx [44] may bring a more robust answer in the near future, and palaeoneurology through the study of endocasts will certainly play a role in this.

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References

1. Argue D, Groves CP, Lee MSY, et al (2017) The affinities of *Homo floresiensis* based on phylogenetic analyses of cranial, dental, and postcranial characters. J Hum Evol 107:107–33
2. Dembo M, Matzke NJ, Mooers AØ, et al (2015) Bayesian analysis of a morphological supermatrix sheds light on controversial fossil hominin relationships. Proc R Soc B 282:20150943
3. Wood B, Lonergan N (2008) The homini fossil record: taxa, grades and clades. J Anat 212:354–76
4. Mounier A, Caparros M (2015) The phylogenetic status of *Homo heidelbergensis* – a cladistic study of Middle Pleistocene hominins. BMSAP 27:110–34
5. Berwick R, Hauser M, Tattersall I (2013) Neanderthal language? Just-so stories take center stage. Front Psychol 4:671
6. Bolhuis JJ, Tattersall I, Chomsky N, et al (2014) How could language have evolved? PLoS Biol 12:e1001934
7. Lieberman PH, Klatt DH, Wilson WH (1969) Vocal Tract Limitations on the Vowel Repertoires of Rhesus Monkey and other Nonhuman Primates. Science 164:1185–87
8. Fitch WT, Reby D (2001) The descended larynx is not uniquely human. Proc Biol Sci 268:1669–75
9. Boë LJ, Sawallis TR, Fagot J, et al (2019) Which way to the dawn of speech?: Reanalyzing half a century of debates and data in light of speech science. Sci Adv 5:eaaw3916
10. Conard N (2010) Cultural modernity: Consensu or conundrum? Proc Natl Acad Sci USA 107:7621–22
11. Aubert M, Lebe R, Oktaviana AA, et al (2019) Earliest hunting scene in prehistoric art. Nature 576:442–45
12. Klein RG (2008) Out of Africa and the evolution of human behavior. Evol Anthropol 17:267–81
13. Errico (d') F, Henshilwoodc C, Vanhaerend M, et al (2005) *Nassarius kraussianus* shell beads from Blombos Cave: evidence for symbolic behaviour in the Middle Stone Age. J Hum Evol 48:3–24
14. Bouzouggar A, Barton N, Vanhaeren M, et al (2007) 82,000-year-old shell beads from North Africa and implications for the origins of modern human behavior. Proc Natl Acad SciUSA 104:9964–69
15. Berwick RC, Chomsky N (2016) Why only us. MIT Press, Cambridge, MA, 224 p
16. Chomsky N (2017) The language capacity: architecture and evolution. Psycho Bull Rev 24:200–3
17. Mallick S, Li H, Lipson M, et al (2016) The Simons Genome Diversity Project: 300 genomes from 142 diverse populations. Nature 538:201–6
18. Mounier A, Mirazón Lahr M (2019) Deciphering African late middle Pleistocene hominin diversity and the origin of our species. Nat Commun 10:3406

19. Schlebusch CM, Malmström H, Günther T, et al (2017) Southern African ancient genomes estimate modern human divergence to 350,000 to 260,000 years ago. Science 358:652–55
20. Hublin JJ, Ben-Ncer A, Bailey SE, et al (2017) New fossils from Jebel Irhoud, Morocco and the pan-African origin of *Homo sapiens*. Nature 546:289–92
21. Meyer M, Arsuaga JL, de Filippo C, et al (2016) Nuclear DNA sequences from the Middle Pleistocene Sima de los Huesos hominins. Nature 531:504–7
22. Mounier A, Mirazón Lahr M (2016) Virtual Ancestor Reconstruction: revealing the ancestor of modern humans and Neandertals. J Hum Evol 91:57–72
23. Berwick RC, Chomsky N (2017) Why only us: Recent questions and answers. J Neurolinguist 43:166–77
24. Sankararaman S, Mallick S, Patterson N, et al (2016) The combined landscape of Denisovan and Neanderthal ancestry in present-day humans. Curr Biol 26:1241–47
25. Kuhlwilm M, Gronau I, Hubisz MJ, et al (2016) Ancient gene flow from early modern humans into Eastern Neanderthals. Nature 530:429
26. Jaubert J, Verheyden S, Genty D, et al (2016) Early Neanderthal constructions deep in Bruniquel Cave in southwestern France. Nature 534:111–14
27. White R, Bosinski G, Bourrillon R, et al (2020) Still no archaeological evidence that Neanderthals created Iberian cave art. J Hum Evol 144:102640
28. Hoffmann DL, Standish CD, García-Diez M, et al (2020) Response to White et al's reply: 'Still no archaeological evidence that Neanderthals created Iberian cave art'. J Hum Evol 144:102810
29. Hoffmann DL, Standish CD, García-Diez M, et al (2018) U-Th dating of carbonate crusts reveals Neandertal origin of Iberian cave art. Science 359:912–15
30. Rendu W, Beauval C, Crevecoeur I, et al (2013) Evidence supporting an intentional Neandertal burial at La Chapelle-aux-Saints. Proc Natl Acad Sci USA 111:81–6
31. Dibble HL, Aldeias V, Goldberg P, et al (2015) A critical look at evidence from La Chapelle-aux-Saints supporting an intentional Neandertal burial. J Archaeol Sci 53:649–57
32. Welker F, Hajdinjak M, Talamo S, et al (2016) Palaeoproteomic evidence identifies archaic hominins associated with the Châtelperronian at the Grotte du Renne. Proc Natl Acad Sci USA 113:11162–67
33. Dediu D, Levinson SC (2018) Neanderthal language revisited: not only us. Curr Opin Behav Sci 21:49–55
34. Posth C, Wißing C, Kitagawa K, et al (2017) Deeply divergent archaic mitochondrial genome provides lower time boundary for African gene flow into Neanderthals. Nat Commun 8:16046
35. Vernot B, Tucci S, Kelso J, et al (2016) Excavating Neandertal and Denisovan DNA from the genomes of Melanesian individuals. Science 352:235–39
36. Fu Q, Hajdinjak M, Moldovan OT, et al (2015) An early modern human from Romania with a recent Neanderthal ancestor. Nature 524:216–19
37. Prüfer K, Racimo F, Patterson N, et al (2014) The complete genome sequence of a Neanderthal from the Altai Mountains. Nature 505:43–49
38. Corballis MC (2014) The gradual evolution of language. Humana Mente J Philos S 27:39–60
39. Stout D, Toth N, Schick K, et al (2008) Neural correlates of Early Stone Age toolmaking: technology, language and cognition in human evolution. Philos T R Soc B 363:1939–49
40. Lepre CJ, Roche H, Kent DV, et al (2011) An earlier origin for the Acheulian. Nature 477:82–85
41. Uomini NT, Meyer GF (2013) Shared Brain Lateralization Patterns in Language and Acheulean Stone Tool Production: a Functional Transcranial Doppler Ultrasound Study. PLoS One 8: e72693
42. Morgan TJH, Uomini NT, Rendell LE, et al (2015) Experimental evidence for the co-evolution of hominin tool-making teaching and language. Nat Commun 6:6029
43. Putt SS, Wijeakumar S, Franciscus RG, et al (2017) The functional brain networks that underlie Early Stone Age tool manufacture. Nat Hum Behav 1:0102
44. Boeckx C (2017) The language-ready head: Evolutionary considerations. Psychon Bull Rev 24:194–99
45. Friederici AD (2012) The cortical language circuit: from auditory perception to sentence comprehension. Trends Cogn Sci 16:262–68
46. de Diego-Balaguer R, Martinez-Alvarez A, Pons F (2016) Temporal attention as a scaffold for language development. Front Psychol 7:44
47. Bruner E, Manzi G, Arsuaga JL (2003) Encephalization and allometric trajectories in the genus *Homo*: Evidence from the Neandertal and modern lineages. Proc Natl Acad Sci USA 100:15335–40
48. Neubauer S, Gunz P, Hublin J-J (2010) Endocranial shape changes during growth in chimpanzees and humans: A morphometric analysis of unique and shared aspects. J Hum Evol 59:555–66
49. Theofanopoulou C, Gastaldon S, O'Rourke T, et al (2017) Self-domestication in *Homo sapiens*: Insights from comparative genomics. PLoS One 12:e0185306
50. Zanella M, Vitriolo A, Andirko A, et al (2019) Dosage analysis of the 7q11.23 Williams region identifies BAZ1B as a major human gene patterning the modern human face and underlying self-domestication. Sci Adv 5:eaaw7908
51. Neubauer S, Hublin JJ, Gunz P (2018) The evolution of modern human brain shape. Sci Adv 4:eaao5961
52. Bruner E (2018) Human paleoneurology: Shaping cortical evolution in fossil hominids. J Comp Neurol 527:1753–65
53. Holloway RL (2008) The human brain evolving: A personal retrospective. Annu Rev Anthrop 37:1–19
54. Grimaud-Hervé D (1997) L'évolution de l'encéphale chez *Homo erectus* et *Homo sapiens*. Exemples de l'Asie et de l'Europe. CNRS Editions, Paris, 405 p
55. Holloway RL, Broadfield DC, Yuan MS (2004) The Human Fossil Record. Brain Endocasts: The Paleoneurological Evidence. Wiley, Hoboken, New Jersey, 315 p
56. Balzeau A, Gilissen E, Holloway RL, et al (2014) Variations in size, shape and asymmetries of the third frontal convolution in hominids: Paleoneurological implications for hominin evolution and the origin of language. J Hum Evol 76:116–28
57. Albessard-Ball L, Balzeau A (2018) Of tongues and men: a review of morphological evidence for the evolution of language. J Lang Evol 3:79–89
58. Beaudet A (2017) The emergence of language in the hominin lineage: Perspectives from fossil endocasts. Front Hum Neurosci 11:427
59. Kochiyama T, Ogihara N, Tanabe HC, et al (2018) Reconstructing the Neanderthal brain using computational anatomy. Sci Rep 8:6296
60. Bruner E (2008) Comparing endocranial form and shape differences in modern humans and Neandertals: a geometric approach. Paleo Anthropology 2008:93–106
61. Schmahmann JD, Sherman JC (1998) The cerebellar cognitive affective syndrome. Brain 121:561–79
62. Stoodley CJ, Schmahmann JD (2009) Functional topography in the human cerebellum: a meta-analysis of neuroimaging studies. Neuroimage 44:489–501
63. Gunz P, Tilot AK, Wittfeld K, et al (2019) Neandertal introgression sheds light on modern human endocranial globularity. Curr Biol 29:120–27.e5
64. Geschwind N (1970) The organization of language and the brain. Science 170:940–44

65. Wernicke C (1908) The symptom-complex of aphasia. In: Church A (ed) Diseases of the nervous system. Appleton, New York, pp 265–324
66. Toga AW, Thompson PM (2003) Mapping brain asymmetry. Nat Rev Neurosci 4:37
67. Tremblay P, Dick AS (2016) Broca and Wernicke are dead, or moving past the classic model of language neurobiology. Brain Lang 162:60–71
68. Brodmann K (1909) Vergleichende Lokalisationslehre der Großhirnrinde: in ihren Prinzipien dargestellt auf Grund des Zellenbaues. Barth, Leipzig, Germany, 324 p
69. Keller SS, Crow T, Foundas A, et al (2009) Broca's area: Nomenclature, anatomy, typology and asymmetry. Brain Lang 109:29–48
70. Mounier A, Balzeau A, Caparros M, et al (2016) Brain, calvarium, cladistics: A new approach to an old question, who are modern humans and Neandertals? J Hum Evol 92:22–36
71. Pereira-Pedro AS, Bruner E, Gunz P, et al (2020) A morphometric comparison of the parietal lobe in modern humans and Neanderthals. J Hum Evol 142:102770
72. Weaver AH (2005) Reciprocal evolution of the cerebellum and neocortex in fossil humans. Proc Natl Acad Sci USA 102:3576–80
73. Balzeau A, Holloway RL, Grimaud-Hervé D (2012) Variations and asymmetries in regional brain surface in the genus *Homo*. J Hum Evol 62:696–706
74. Binder J (2000) The new neuroanatomy of speech perception. Brain 123:2371–72
75. Price CJ (2000) The anatomy of language: contributions from functional neuroimaging. J Anat 197:335–59
76. Leichnetz GR (2011) Supramarginal gyrus. In: Kreutzer JS, DeLuca J, Caplan B (eds) Encyclopedia of Clinical Neuropsychology. Springer New York, New York, pp 2439–40
77. Bruner E, Bondioli L, Coppa A, et al (2016) The endocast of the one-million-year-old human cranium from Buia (UA 31), Danakil Eritrea. Am J Phys Anthropol 160:458–68

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NOTE / *NOTE*

Taphonomie et diagnose sexuelle primaire à partir de l'os coxal : du terrain au laboratoire

Taphonomic Processes and Primary Sexual Determination from The Coxal Bone: From the Field to the Laboratory

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Résumé Une grande partie des analyses ostéologiques repose sur la détermination du sexe de l'individu étudié. Les méthodes fondées sur l'os coxal – dont le dimorphisme est commun à toute l'espèce humaine – permettent d'obtenir des résultats très probants. Cependant, la structure de l'os coxal, principalement composée d'os spongieux, le rend fragile. Ainsi, comme de précédentes études l'ont démontré, on observe une conservation différentielle des parties qui le composent liée à des raisons taphonomiques mais également aux manipulations du terrain au laboratoire. Cette étude s'est appuyée sur 302 individus issus de la fouille du cimetière médiéval et moderne de La Ciotat, sélectionnés en fonction de deux critères : la présence d'au moins un élément de l'os coxal et le fait qu'ils aient été lavés au préalable. Elle a permis de confirmer la faible conservation de l'os coxal. De plus, l'application des méthodes de détermination du sexe morphoscopique et de la DSP a mis en évidence l'absence de parties spécifiques, plus fragiles. Nous avons également testé la corrélation entre le sexe estimé de l'individu et l'état de conservation de l'os coxal. La prise de données directement lors de la phase terrain s'avère une étape incontournable pour garantir la diagnose sexuelle primaire du maximum d'individus.

Mots clés Os coxal · Diagnose sexuelle · Conservation · Terrain · Laboratoire

Abstract Much of osteological analysis focuses on determining the sex of the individual being studied. Because sexual dimorphism of the os coxae is shared by all *Homo sapiens*, analysis of this bone produces convincing determinations of sex. Apart from its reliability, however, its structure is mainly composed of cancellous bone and is therefore fragile. Thus, as previous studies have shown, the different parts of the os coxae are not uniformly preserved for taphonomic reasons, but also as a consequence of their handling from the time of excavation to laboratory study. This study was based on 301 individuals from the excavation of the medieval and modern cemetery of La Ciotat, previously selected on the basis of two criteria: the presence of at least one of the two ossa coxae, and the fact that they had been washed beforehand. The Anatomical Preservation Index established by S. Bello confirmed the poor state of preservation of the ossa coxae. The use of morphological sex determination and Diagnose Sexuelle Probabiliste (DSP) methods also revealed that the most fragile parts of the bone were frequently absent. A correlation between sex and state of preservation was also calculated. Finally, to ensure the reliability of primary sex determination in the maximum number of individuals, we stress the importance of collecting data and observations during excavation, owing to the significant loss of information that occurs between field excavation and laboratory study.

Keywords Coxal bone · Sex assessment · Preservation · Field recovery · Laboratory analysis

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Introduction

La détermination du sexe est une étape cruciale de l'analyse d'une série ostéologique, qu'il s'agisse de discuter de pratiques mortuaires, de recrutement, d'état sanitaire, etc. Il est admis, depuis plusieurs décennies, que l'os coxal, qui exprime à lui seul la quasi-totalité du dimorphisme sexuel du bassin osseux, est l'élément le plus pertinent pour une diagnose sexuelle fiable dans la mesure où ce dimorphisme est commun à toute l'espèce humaine et pas seulement à une population en particulier [1]. En France, deux méthodes sont utilisées en routine, notamment sur le matériel anthropologique issu de fouilles archéologiques : la méthode morphoscopique développée par Bruzek [2] et la diagnose sexuelle probabiliste [3,4]. Toutefois, ces méthodes nécessitent une bonne conservation de l'os coxal pour garantir la fiabilité de la diagnose. Or, cet élément osseux est fragile et sa préservation variable d'un site à l'autre [5]. En effet, le rapport entre os compact et os spongieux n'est pas favorable à sa conservation [6]. Les parties les plus sensibles aux dégradations taphonomiques sont les extrémités de l'aile iliaque, le corps du pubis et l'épine sciatique [7–9], autant d'éléments entrant dans les critères pris en compte dans les méthodes sus-citées. À titre d'illustration, sur 860 os coxaux issus de caveaux d'époques médiévale et moderne de Grenoble Saint-Laurent, 533 n'ont pu être exploités [10].

Pour pallier cette limite, la diagnose sexuelle secondaire [5] qui permet d'approcher avec une marge d'erreur connue la détermination du sexe de sujets ne présentant pas d'os coxal a été proposée. Les fonctions discriminantes établies sont propres à la série ostéologique étudiée et tiennent compte, par conséquent, de ses spécificités. Cependant, pour paramétrer ces fonctions, il est nécessaire qu'un nombre suffisant de sujets féminins et masculins ait bénéficié d'une diagnose primaire à partir de l'os coxal.

Afin d'augmenter les chances de déterminer le sexe d'un sujet exhumé sur une fouille archéologique, nous sommes nombreux à avoir envisagé d'effectuer la détermination sexuelle sur le terrain. Une première expérience de ce type a été tentée par Guillon [11] sur le cimetière médiéval de Tournedos à Porte-Joie (Eure, Normandie) portant sur 751 individus. Le choix de procéder sur le terrain à la diagnose sexuelle sur les os coxaux apparaissant les plus fragiles a été fait sur la fouille d'un second cimetière médiéval de cette même commune ; les résultats de cette expérience ont été publiés par Berthon et al. [12]. Malheureusement, il était trop tard pour que leurs conclusions puissent être mises à profit lors de la fouille préventive du cimetière Saint-Jacques à La Ciotat [13,14] dont il sera question ici.

Dans le cadre de cette opération archéologique, la détermination du sexe *in situ* sur les os coxaux, en appliquant la méthode morphoscopique [2], a été prescrite dans le cahier des charges auquel devait répondre l'opérateur. Cette prise de données en cours de fouille a été envisagée comme une première information, au même titre que l'évaluation de la classe d'âge des défunts consignée dans les fiches de terrain en vue d'obtenir une esquisse du recrutement dans les zones fouillées, l'un des enjeux étant la localisation d'une aire d'ensevelissement réservée à l'hôpital contigu du cimetière. En outre, il avait été prévu d'emblée que l'étude anthropologique post-fouille ne pourrait porter que sur un échantillon de 400 individus afin de dégager des pistes de réflexion sur le contexte funéraire et orienter d'autres études anthropologiques.

La préparation de la collection anthropologique issue des fouilles de La Ciotat se poursuivant, plusieurs travaux universitaires ont été engagés[1]. Dans l'un d'eux, la détermination sexuelle d'un échantillon de 302 individus adultes pourvus d'un bassin a été effectuée en appliquant les méthodes morphoscopique et probabiliste en prévision d'une diagnose sexuelle secondaire. Cette nouvelle approche offrait l'opportunité de quantifier la perte d'informations entre la phase terrain et l'étude en laboratoire, de comparer les résultats obtenus et d'évaluer l'impact des dégradations subies selon le sexe. Bien que les protocoles appliqués sur le terrain diffèrent sensiblement (pas de DSP *in situ*), il nous a semblé que les enjeux en termes de résultats et de moyens à déployer sur les fouilles archéologiques sont suffisamment importants pour rendre compte à notre tour de cette expérience et la confronter à celle de Berthon et al. [12].

Matériel

L'opération archéologique du carré Saint-Jacques à La Ciotat a été réalisée en 2009. Elle a permis d'exhumer sur un peu plus de 1 000 m^2 1 245 individus (933 adultes et 312 immatures) en dépôt primaire. Ce cimetière enclos attenant à l'hôpital Saint-Jacques a été créé *ex nihilo* en 1581 et abandonné en 1831. Les défunts y étaient inhumés dans des fosses ou dans des cercueils disposés en rangées plus ou moins bien organisées. Trois phases d'occupation séparées par des remblais ont pu être distinguées, ce qui permet d'inscrire chaque sépulture dans une période précise.

Les recoupements entre sépultures sont nombreux, et les squelettes complets sont rares. De fait, une évaluation de la représentation globale de chaque sujet a mis en évidence que 243 individus étaient complets ou subcomplets, 505 moyennement représentés (par au moins la moitié de leurs ossements) et 497 incomplets (par moins de la moitié de leurs ossements), ceux-ci étant représentés, en réalité, par quelques os ou esquilles [13]. Au final, 529 individus adultes

[1] Notamment les travaux doctoraux de Perrin [15].

ou de taille adulte possédaient au moment de la fouille au moins un os coxal.

L'étude anthropologique préliminaire réalisée sur un échantillon de 400 individus dans le cadre de la post-fouille de l'opération a permis d'examiner 324 adultes ou grands adolescents. Parmi ceux-ci, 224 étaient pourvus d'au moins un os coxal au moment de la fouille, et une diagnose sexuelle a pu être réalisée sur le terrain sur 203 d'entre eux (90 %). En post-fouille, 131 (58 %) des sujets en question ont pu de nouveau être déterminés avec la méthode morphoscopique, et seulement 49 (22 %) ont pu bénéficier d'une DSP. Aucun désaccord n'a été relevé par les auteurs de l'étude entre le terrain et le laboratoire pour la méthode morphoscopique [13]. En revanche, dans neuf cas (18 %), la détermination probabiliste s'est avérée en contradiction avec ces résultats.

Dans le cadre de notre étude, nous avons retenu 302 individus parmi les 529 adultes en position primaire que contenait notre collection. Notre sélection de départ était fondée sur trois critères simples, les squelettes devaient avoir été au moins lavés, posséder au moins un élément d'os coxal et appartenir aux classes d'âge adultes et grands immatures. Cependant, le sexage des grands immatures n'a pas été possible en raison de leur fusion inachevée. C'est pourquoi notre échantillon d'étude ne contient que des individus adultes.

Méthodes

Dans un premier temps, nous avons travaillé à l'échelle de l'os coxal (n = 604). Afin d'évaluer l'état de ces os après lavage et conditionnement, nous avons appliqué l'indice de conservation anatomique (ICA) [16,17] appréciant la conservation de l'os selon six stades auquel a été ajouté un septième stade « non identifiable » réservé aux pièces trop fragmentées pour permettre une telle évaluation (Tableau 1, Fig. 1).

La méthode morphoscopique [2] est fondée sur l'observation de cinq caractères morphologiques (surface préauriculaire, grande échancrure ischiatique, arc composé, bord inférieur du pubis et rapport ischiopubien) composés pour certains d'entre eux de sous-critères. Comme l'a mentionné Bruzek [2], le nombre de scores corrects obtenus varie sensiblement en fonction du sexe et de l'échantillon de référence pris en compte. Par ailleurs, l'état de conservation des os conduit souvent à privilégier le segment sacro-iliaque, ce qui est moins pénalisant que s'il s'était agi du complexe ischiopubien où le nombre d'erreurs ou d'indéterminés est important, au point que l'écart entre le nombre de déterminations correctes obtenues pour chacun des sexes, les deux échantillons de référence réunis, s'avère statistiquement significatif (80 % de réussite pour les sujets d'une morphologie masculine et 93 % pour les sujets d'une morphologie féminine, p = 0,00012 ; d'après les données de Bruzek [2], tableau 4 série B).

Au moment de la fouille, seule la méthode morphoscopique a été appliquée lors du démontage des squelettes, la mise en œuvre de la DSP sur le terrain ayant été jugée trop complexe. Seuls les résultats obtenus (masculin, féminin, indéterminé) ont été reportés sur la fiche de sépulture par les quatre archéoanthropologues en charge de l'enregistrement sur le terrain (G.L. Georget, J. Hernot, R. Lisfranc, C. Rigeade), ce qui ne permet pas d'évaluer *a posteriori* comment les différents critères de cette méthode ont été pris en compte ou d'apprécier l'érosion de chacun des segments anatomiques en question. Des fiches de conservations ont également été remplies *a posteriori* à partir de données manuscrites prises lors de la fouille. Malgré cela, compte tenu de l'état de conservation général du matériel anthropologique, il peut être avancé sans risque que, dans bien des cas, seul le complexe sacro-iliaque a dû être pris en compte.

En laboratoire, en revanche, afin d'évaluer la possibilité d'appliquer la méthode de Bruzek selon l'état de conservation de l'os coxal, nous avons calculé dans combien de cas une attribution sexuelle par caractère était possible. Celle-ci se décline selon trois modalités : sujets d'une morphologie masculine, sujets d'une morphologie féminine, indéterminé. Nous avons distingué également trois modalités de non-attribution à une forme sexuelle : caractère absent, non observable, non identifiable (Tableau 2).

Tableau 1 Cotation de l'état de conservation des os coxaux inspirée de *l'ICA* [13] / *Scores for os coxae preservation inspired by the API* [13]

Stade	Conservation (%)	État de conservation global de la pièce après remontage
0	0 %	L'os n'est pas conservé
1	Non identifiable	L'os est trop fragmentaire pour en estimer la représentation
2	0 % < ICA < 25 %	Moins du quart de la pièce est conservé
3	25 % ≤ ICA < 50 %	Au moins le quart de l'os est présent, mais moins de la moitié de la pièce est conservée
4	50%	La moitié de la pièce est conservée
5	50 % < ICA < 75 %	Plus de la moitié de l'os est présente, mais moins des trois quarts de la pièce sont conservés
6	75 % ≤ ICA < 100 %	Au moins trois quarts de l'os sont conservés, mais la pièce n'est pas complète
7	100 %	La pièce est intégralement conservée

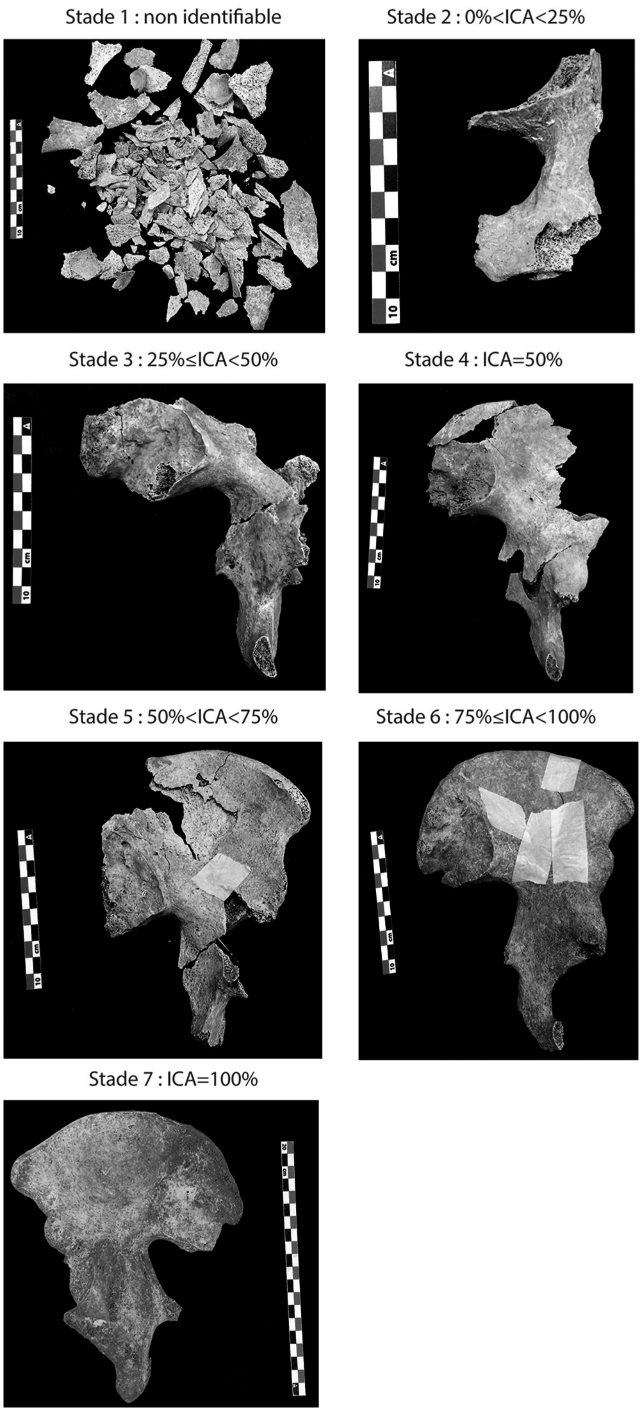

Fig. 1 Stade de conservation de l'os coxal (DAO : Cindy Dentz) / *Stages of os coxae preservation (CAD: Cindy Dentz)*

La diagnose sexuelle probabiliste [3] repose sur la prise de dix mesures. Nous avons calculé pour chacune d'elles le

Tableau 2 Stades de cotation des sous-caractères de la méthode de Bruzek [2] / *Scoring sexualization based on five characters of the method developed by Bruzek* [2]

Sexe évalué	**Critère d'évaluation**
Féminin	La partie présente des caractères typiquement féminins
Masculin	La partie présente des caractères typiquement masculins
Indéterminé	La partie ne présente pas un dimorphisme assez fort
Absent	La partie nécessaire à l'évaluation du caractère est absente
Non observable	La partie est présente mais trop fragmentaire pour pouvoir être étudiée
Non identifiable	L'os coxal est trop fragmentaire pour pouvoir isoler la partie intéressante

nombre de fois où cet enregistrement était possible sur les 604 os coxaux[2] de notre échantillon et, par la suite, comparé les fréquences en fonction du sexe en ne tenant compte que des os coxaux qui ont pu bénéficier d'une diagnose sexuelle.

Un de nos objectifs consistait également à évaluer si la dégradation de l'os coxal est sexe-dépendante, ce qui peut, le cas échéant, introduire un biais dans les études de sex-ratio. Une fois la diagnose sexuelle effectuée sur chaque os coxal exploitable, que le sexe soit donné par la méthode morphoscopique ou métrique, nous avons vérifié par un test exact de Fisher si les valeurs obtenues pour chaque stade d'ICA par sexe s'avéraient significativement différentes. Nous avons également comparé les mesures exploitables en fonction du sexe. Par ailleurs, nous avons calculé la fréquence des caractères morphoscopiques présents par sexe et par côté et appliqué un test exact de Fisher afin de savoir si le sexe de l'individu joue sur la conservation de certaines parties anatomiques.

Dans un second temps, nous avons changé d'échelle pour travailler à celle de l'individu (n = 302) afin d'évaluer l'impact des dégradations osseuses qui se produisent entre la phase de terrain et les études menées en laboratoire. Nous avons comparé, par un tableau de contingence, les résultats des diagnoses sexuelles effectuées à chacune de ces phases d'étude et calculé les pourcentages de concordance.

Résultats

À l'échelle de l'os coxal

Sur la totalité de notre série, les stades de l'ICA cotés après lavage et, si nécessaire, consolidation et reconditionnement des os indiquent que 51,3 % seulement des os coxaux sont

[2] Il s'agit du nombre total d'os coxaux pris en compte dans l'étude. Cet effectif inclut les os coxaux au stade de conservation 0, c'est-à-dire non conservés.

représentés par au moins 50 % de l'os (Fig. 2), ce que Bello considère comme « bien conservé ». D'ailleurs, le stade 7 qui correspond à un os coxal complet se démarque de façon flagrante des autres valeurs. Les os coxaux dont la conservation n'a pas pu être évaluée (stade 1) ne représentent, quant à eux, que 3,6 % de l'échantillon.

Par os coxal, quel que soit le côté considéré, l'attribution d'une forme sexuelle (féminine, masculine ou indéterminée) à chacun des critères de la méthode morphoscopique est rarement possible pour la *margo inferior ossis pubis* et pour le rapport ischium/pubis. En effet, il s'agit d'une région particulièrement fragile en raison de la finesse de la branche pubienne. De même, l'évaluation de la forme de la grande incisure ischiatique requiert la conservation de presque la totalité de la longueur de l'os et celle de l'arc composé, la conservation de l'ilium. Or, la mauvaise conservation de ces éléments avait déjà été mise en évidence par Sauter et Privat [18]. Globalement, l'attribution à une forme sexuelle est possible dans moins de 50 % des cas quel que soit le critère observé (Fig. 3), ce qui explique que de nombreux adultes n'aient pas bénéficié d'une diagnose sexuelle.

Nous pouvons constater de fortes disparités dans le nombre de mesures de la DSP qu'il a été possible de prendre sur notre échantillon (Fig. 4). Sans grande surprise, la fréquence des mesures se fondant sur la partie ischiopubienne est basse (PUM, SPU, ISMM), de même que les mesures qui requièrent une conservation complète de la crête iliaque (DCOX, SCOX). En revanche, les mesures appartenant à la zone sacro-iliaque et au sourcil acétabulaire ont pu être fréquemment enregistrées (IIMT, SS, SA, SIS, VEAC). La largeur est moins fréquemment mesurable, car les bords latéraux et médiaux de la crête iliaque sont plus fragiles que son sommet, et l'ischium, pris en compte dans les mesures de longueur, est une partie plutôt résistante.

La conservation des os coxaux en fonction du sexe

Si l'on tient compte des os coxaux pour lesquels le sexe a pu être attribué ($n = 319$), le test non paramétrique de Fisher ne révèle pas de différence de conservation entre les os coxaux attribués au sexe masculin ou féminin, même pour le stade de conservation 6 (Fig. 5) où l'on compte deux fois plus de sexe masculin que féminin.

Concernant la méthode de diagnose sexuelle probabiliste [3], il n'y a pas non plus de différences statistiquement significatives entre la fréquence des mesures prises sur les os coxaux féminins et masculins (Fig. 6), mais toutes les valeurs féminines sont inférieures aux valeurs masculines comme l'avait mentionné Bello dans sa thèse [17]. En revanche, pour la méthode morphoscopique, la présence des critères anatomiques exploitables apparaît, dans notre échantillon, significativement différente entre les deux sexes pour l'arc composé du côté gauche et la *margo inferior ossis pubis* du côté droit (Tableau 3).

À l'échelle de l'individu

Sur notre corpus de 302 individus, 275 individus (91 %) ont bénéficié d'une diagnose sexuelle sur le terrain avec la méthode morphoscopique, pour seulement 168 (56 %)

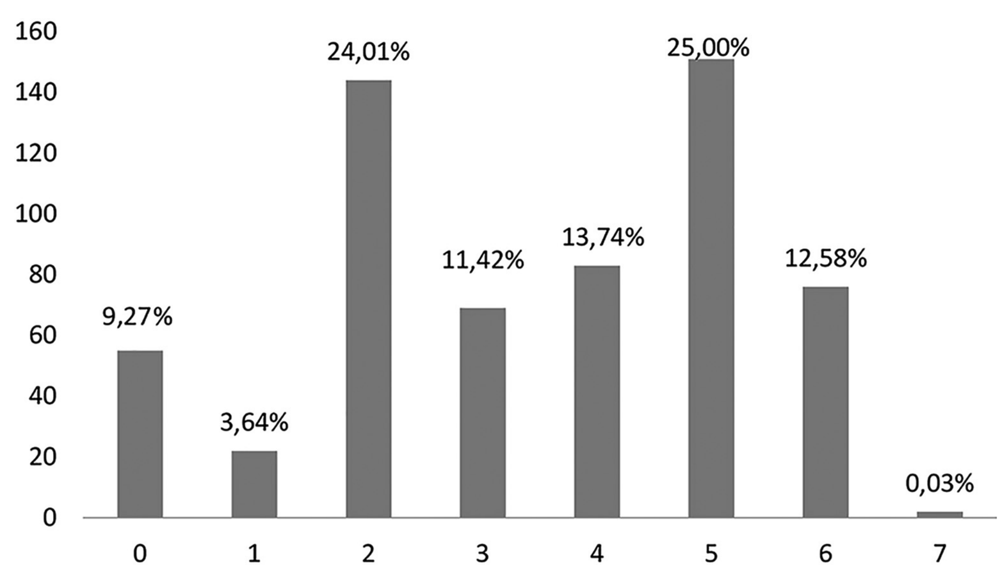

Fig. 2 Répartition des huit stades de conservation des os coxaux de notre corpus ($n = 602$) (0 : absent, 1 : non identifiable, 2 : 0 % < ICA < 25 %, 3 : 25 % ≤ ICA < 50 %, 4 : 50 %, 5 : 50 % < ICA < 75 %, 6 : 75 % ≤ ICA < 100 %, 7 : 100 %) / *Distribution of the 8 stages of preservation of the os coxae from our corpus (N = 602) (0: absent, 1: unidentifiable, 2: 0% < ICA < 25%, 3: 25% ≤ ICA < 50%, 4: 50%, 5: 50% < ICA < 75%, 6: 75% ≤ ICA < 100%, 7: 100%)*

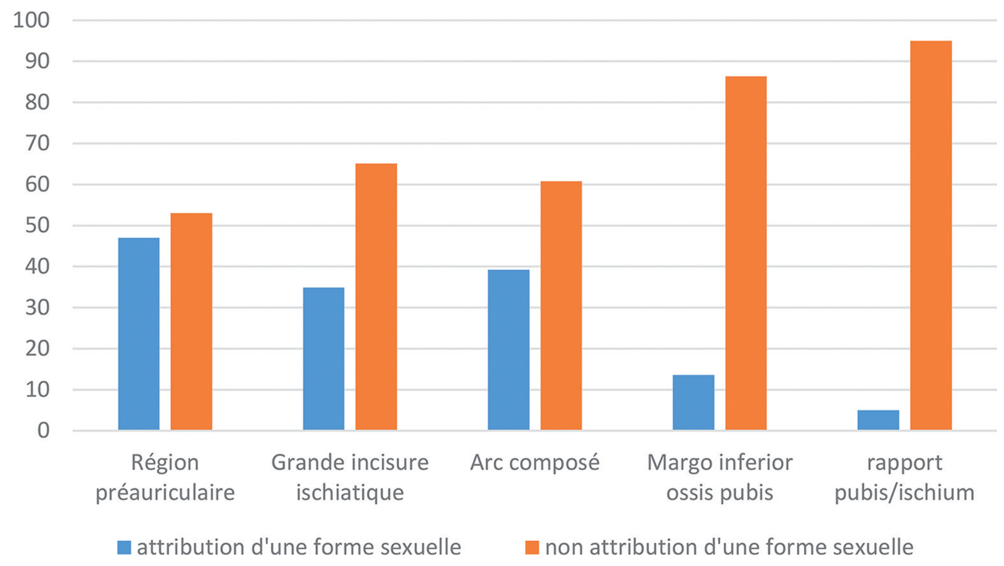

Fig. 3 Attribution en pourcentage d'une forme sexuelle par critère anatomique (*n* = 525) / *Percentage attribution of a sexual form by anatomical criteria (N = 525)*

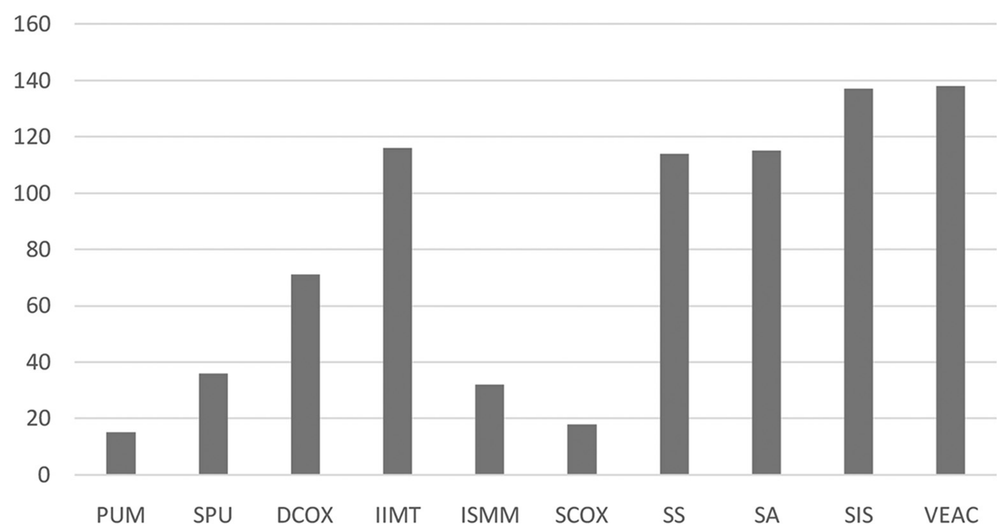

Fig. 4 Effectif des mesures de la DSP [1]. PUM : longueur acetabulosymphysaire, SPU : largeur cotylopubienne, DCOX : longueur de l'os coxal, IIMT : hauteur de l'échancrure ischiatique, SCOX : largeur de l'ilium, SS : longueur spinosciatique, SA : longueur spinoauriculaire, SIS : largeneur cotylosciatique, VEAC : diamètre acétabulaire verticale / *Number of measurements taken according to DSP* [1]. *PUM: acetabulo-sympyseal pubic length, SPU: cotylo-pubic width, DCOX: coxal length, IIMT: greater sciatic notch height, SCOX: iliac breadth, SS: spino-sicatic length, SA: spino-auricular length, SIS: cotylo-sciatic breadth, VEAC: vertical acetabular diameter*

en laboratoire quelle que soit la méthode, ce qui représente une perte de 35 % d'informations entre le terrain et le laboratoire. Les nombreuses manipulations ayant eu lieu entre le terrain et la reprise de l'étude ont par conséquent entraîné une érosion importante des parties anatomiques déterminantes pour la diagnose sexuelle (sont inclus ici les individus de sexe indéterminé, car ils ont bénéficié d'une diagnose sexuelle).

Nous avons pu comparer la concordance des sexes attribués sur le terrain et *a posteriori* par la méthode morphoscopique et la DSP. Il s'avère que 21,5 % des déterminations sont en désaccord (Tableau 4). Par ailleurs, la diagnose sur le terrain conduit à classer neuf sujets comme étant de sexe indéterminé alors que ceux-ci ont pu être attribués à l'un des deux sexes en laboratoire.

Pour 121 individus (40 %), la DSP a pu être appliquée sur au moins un os coxal, tandis que cinq d'entre eux seulement n'ont pas bénéficié de la méthode morphoscopique (non observable). Enfin, quelle que soit la méthode, le sexe a pu être déterminé sur 173 individus (57,4 %).

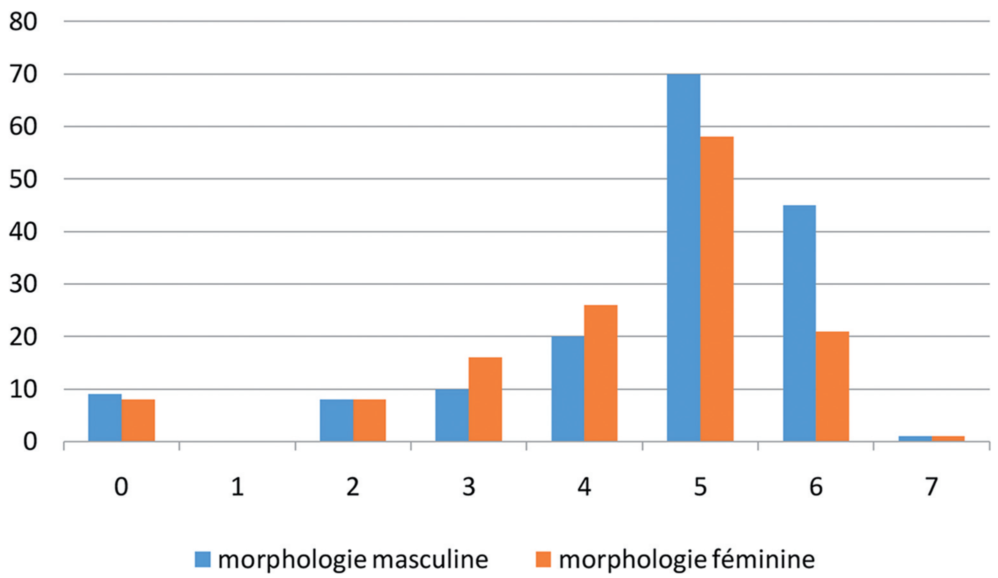

Fig. 5 Fréquence des huit stades de conservation de l'os coxal (0 : absent, 1 : non identifiable, 2 : 0 % < ICA < 25 %, 3 : 25 % ≤ ICA < 50 %, 4 : 50 %, 5 : 50 % < ICA < 75 %, 6 :75 % ≤ ICA < 100 %, 7 : 100 %) selon la morphologie masculine ou féminine, par individu (n = 302) / *Frequency of the 8 stages of os coxae preservation (0: absent, 1: unidentifiable, 2: 0% < ICA < 25%, 3: 25% ≤ ICA < 50%, 4: 50%, 5: 50% < ICA < 75%, 6: 75% ≤ ICA < 100%, 7: 100%) according to male or female morphology, per individual (N = 302)*

Tableau 3 Répartition en pourcentage des individus non observables en fonction du sexe par côté / *Percentage distribution of unobservable individuals according to sex for each side*

	Région préauriculaire		**Grande incisure ischiatique**		**Arc composé**		**Margo inferior ossis pubis**		**Rapport pubis/ischium**	
	N	**p Fisher**	**N**	**p Fisher**	**N**	**p Fisher**	**N**	**p Fisher**	**N**	**p Fisher**
Os coxal droit										
Morphologie féminine	58	0,490	39	0,155	45	0,143	6	0,017	4	0,428
Morphologie masculine	47		60		69		25		9	
Os coxal gauche										
Morphologie féminine	59	0,789	45	0,333	38	0,007	10	0,058	3	0,326
Morphologie masculine	53		60		73		28		11	

Tableau 4 Concordance des diagnoses sexuelles entre le terrain et le laboratoire / *Concordance of sexual diagnosis between field and laboratory*

Terrain	**Labo**				
	Sexe féminin	**Sexe masculin**	**Indéterminé**	**Non observable**	**Total**
Sexe féminin	63	9	3	64	139
Sexe masculin	12	74	4	46	136
Indéterminé	2	8	0	17	27
Total	77	91	7	127	302

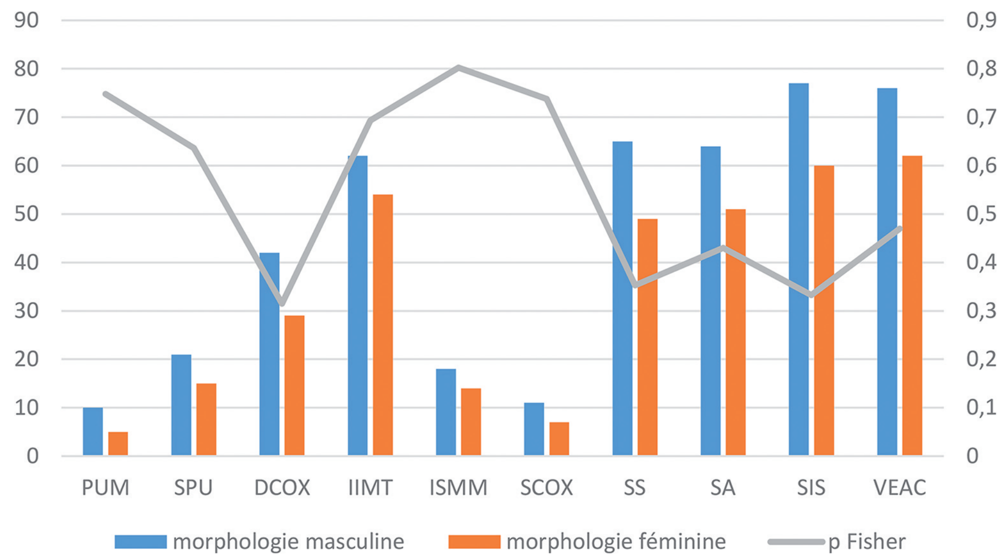

Fig. 6 Pourcentage des mesures de la DSP qui ont pu être prises en fonction de la morphologie masculine ou féminine et valeur du *p* du test de Fisher. PUM : longueur acetabulosymphysaire, SPU : largeur cotylopubienne, DCOX : longueur de l'os coxal, IIMT : hauteur de l'échancrure ischiatique, SCOX : largeur de l'ilium, SS : longueur spinosciatique, SA : longueur spinoauriculaire, SIS : largeneur cotylosciatique, VEAC : diamètre acétabulaire verticale / *Percentage of DSP measurements that could be taken based on male or female morphology and Fisher's test P-value. PUM: acetabulo-sympyseal pubic length, SPU: cotylo-pubic width, DCOX: coxal length, IIMT: greater sciatic notch height, SCOX: iliac breadth, SS: spino-sicatic length, SA: spino-auricular length, SIS: cotylo-sciatic breadth, VEAC: vertical acetabular diameter*

Discussion

Notre étude confirme le problème de la conservation différentielle des différentes parties constituant l'os coxal, mais, à ces altérations découlant de la constitution de l'os, il faut ajouter celles de nos pratiques. Nous avons noté que du terrain au laboratoire les os coxaux ont subi de sévères pertes de substance osseuse, ce qui réduit inévitablement le nombre d'individus pouvant bénéficier d'une diagnose sexuelle primaire. Les multiples manipulations (dégagement, prélèvement, conditionnement, transport, lavage puis reconditionnement) sont largement responsables de ce résultat. Ce constat a déjà été établi et commenté notamment dans le cas d'études paléopathologiques [19–21].

On peut également noter au passage que l'indice de conservation anatomique [16,17] apporte une appréciation globale ne garantissant en rien la « mesurabilité » de l'os. Au niveau de l'enjeu — obtenir au moins quatre variables clés de la DSP —, cet indice n'apparaît pas suffisant pour évaluer les potentialités d'une série. Pour pallier cette limite, une attention particulière portée à l'os coxal sur le schéma de conservation serait souhaitable. L'os coxal devrait être représenté par les trois parties anatomiques détachées les unes des autres (ilium, ischium, pubis) afin de permettre une cotation précise des zones conservées pour chaque élément. Une autre solution, plus directe et produisant une donnée viable et durable, serait d'appliquer systématiquement la DSP sur le terrain.

La perte irrémédiable de 35 % d'informations au cours de ces différentes manipulations constatée pour le site de La Ciotat est plus importante qu'à Porte-Joie (Eure, Normandie) où les os coxaux semblent plus résistants. Pour ces raisons au moins, on ne peut que souscrire à l'application des méthodes de détermination du sexe sur l'os coxal dès la phase de terrain [12]. Encore faut-il que les informations collectées soient de qualité comparable. Les mauvaises concordances entre le terrain et le laboratoire semblent dans les deux cas avoir la même origine : le fait de s'affranchir, sur le terrain, de reporter les cotations conduit au non-respect du principe de majorité qui garantit la fiabilité de la méthode morphoscopique.

Concernant les mesures impliquées dans la DSP, il est intéressant de noter que, hormis IIMT, les distances les plus discriminantes sont celles qui sont le moins souvent mesurables, ce qui explique en partie que l'attribution à un sexe n'est pas toujours possible. La perte de la branche pubienne, notamment, diminue considérablement les chances de succès. On se retrouve alors avec le corps de l'os qui permet les mesures SIS, SA, SCOX, VEAC, SPU et SS.

Par ailleurs, il a été établi dans de précédentes études [8,17] que l'os coxal d'un individu masculin est plus robuste que celui d'un individu féminin. Cette robustesse s'apprécie particulièrement dans la zone acétabulaire. De plus, cette zone offre des résultats probants —bien que moins fiables que certaines autres parties plus fragiles de l'os coxal — et se conserve bien. Des mesures impliquant cette zone mériteraient une attention particulière.

Notre étude a également montré que la variabilité de la conservation de l'os coxal pourrait être liée, en partie, au sexe de l'individu. Toutefois, les différences identifiées pour deux variables (arc composé et *margo inferior ossis pubis*) ne s'observent que d'un seul côté. Dans la mesure où les défunts sont inhumés sur le dos, on ne peut imputer ce biais aux pratiques funéraires, ce qui nous oriente plutôt vers un biais propre à l'échantillon. Cette observation mériterait d'être vérifiée par une étude tenant compte de l'âge des individus, l'ostéoporose ayant forcément un impact sur la conservation de l'os coxal chez les sujets féminins.

Conclusion

La détermination du sexe d'un individu conditionne la plupart des études menées sur une série ostéologique, qu'il s'agisse des pratiques mortuaires ou de l'approche anthropobiologique. Bien que plusieurs méthodes permettent actuellement une diagnose sexuelle fiable, la fragilité intrinsèque de l'os coxal limite fréquemment le nombre d'individus dont le sexe est déterminé. La perte de substance osseuse et la fragmentation au cours des différentes étapes du processus de fouilles archéologiques et du traitement du matériel s'ajoutent aux altérations taphonomiques et anthropiques antérieures.

A contrario de ce que nous avions envisagé lors de la programmation de la fouille de La Ciotat, la méthode morphoscopique introduit des aléas liés à la lisibilité de l'os sur le terrain et à la saisie de nombreuses cotes. Il semble par conséquent préférable de privilégier la DSP. Pour peu que les critères et mesures soient précisément consignés, l'effort consenti sur le terrain nous paraît largement compensé par le gain d'informations obtenues. Et, dès lors que chacun des paramètres entrant dans la détermination du sexe a été consigné, il ne nous paraît pas nécessaire de revenir sur ces déterminations dans le cadre de la post-fouille sauf, bien entendu, lorsque la restauration d'une pièce osseuse permet de prendre de nouvelles mesures.

Notre étude, portant sur un nombre plus important de sujets que celle de Berthon et al. [12] et n'intégrant pas seulement les os coxaux les plus fragiles, vient renforcer leur constat, et nous ne pouvons que souscrire à leurs propositions. Au vu de cette convergence, la détermination du sexe *in situ* apparaît la meilleure solution. Les deux études incitent donc à prescrire dans le cahier des charges des opérations archéologiques la réalisation systématique de la diagnose sexuelle primaire sur le terrain, en privilégiant la DSP lorsque son application est possible.

Liens d'intérêts : Les auteurs déclarent ne pas avoir de liens d'intérêts.

Références

1. Bruzek J, Schmitt A, Murail P (2005) Identification biologique individuelle en paléoanthropologie. Détermination du sexe et de l'âge au décès à partir du squelette. In: Dutour O, Hublin JJ, Vandermeersch B (eds) Objets et méthodes en paléoanthropologie. CTHS, Paris, pp 217–45
2. Bruzek J (2002) A method for visual determination of sex, using the human hip bone. Am J Phys Anthropol 117:157–68
3. Murail P, Bruzek J, Houët F, et al (2005) DSP: a tool for probabilistic sex diagnosis using worldwide variability in hip-bone measurements. BMSAP 17:167–76
4. Bruzek J, Santos F, Dutailly B, et al (2017) Validation and reliability of the sex estimation of the human os coxae using freely available DSP2 software for bioarchaeology and forensic anthropology. Am J Phys Anthropol 164:440–9
5. Murail P, Bruzek J, Braga J (1999) A new approach to sexual diagnosis in past populations. Practical adjustments from Van Vark's procedure. Int J Osteoarchaeol 9:39–53
6. Denys C, Patou-Mathis M (2014) Manuel de la taphonomie. Errance, Arles, 271 p
7. Waldron T (1987) The relative survival of the human skeleton: implication for palaeopathology. In: Boddington A, Garland AN, Janaway RC (eds) Death, Decay and Reconstruction. Manchester University Press, Manchester, pp 55–64
8. Gaillard J (1960) Détermination sexuelle d'un os coxal fragmentaire. BMSAP 11:255–67
9. Walker PL (1995) Problems of preservation and sexism in sexing: some lessons from historical collections for paleodemographers. In: Saunders SR, Herring A (eds) Grave reflections: portraying the past through cemetery studies. Canadian Scholar's Press, Toronto, pp 31–47
10. Hervieu P (2010) Gestion funéraire et paléobiologique de sépulture collective : l'exemple de caveau au Moyen Âge et à l'époque moderne l'exemple des caveaux. Thèse de doctorat d'anthropologie biologique, université de la Méditerranée, Aix-Marseille-II
11. Guillon M (1997) Anthropologie de terrain et paléodémographie : études méthodologiques sur les grands ensembles funéraires : applications au cimetière médiéval de Tournedos-Portejoie (Eure). Thèse de doctorat en anthropologie biologique, université de Bordeaux-I
12. Berthon W, Thomas A, Thomann A, et al (2015) Faut-il mener une diagnose sexuelle in situ dans les grands ensembles funéraires ? Le cas du cimetière médiéval de Val-de-Reuil (Eure), « Le Chemin aux Errants ». BMSAP 27:26–41
13. Richier A (2011) L'îlot Saint-Jacques, du vignoble champêtre au cimetière paroissial. La Ciotat, Bouche du Rhône. Rapport final d'opération. Inrap Service régional de l'Archéologie, Aix-en-Provence, Vol 1
14. Richier A, Bizot B (2018) L'opération archéologique du cimetière de La Ciotat (Bouches-du-Rhône) : réussites et écueils. In: Carré F, Hincker V, Chapelain de Seréville-Niel C (eds) Rencontre autour des enjeux de la fouille des grands ensembles sépulcraux médiévaux, modernes et contemporains. Publication du Gaaf 7, Reugny, pp 145–54
15. Perrin M (2019) État sanitaire entre ancien régime et révolution industrielle : étude paléoépidémiologique de deux populations provençales, interactions bioculturelles. Thèse de doctorat en anthropologie biologique, Aix-Marseille Université, 550 p
16. Bello S, Signoli M, Rabino Massa E, et al (2002) Les processus de conservation différentielle du squelette des individus immatures : implications sur les reconstitutions paléodémographiques. BMSAP 14:245–62
17. Bello S (2001) Taphonomie des restes osseux humains. Effet des processus de conservation du squelette sur les paramètres

anthropologiques. Thèse de doctorat en anthropologie biologique, Aix-Marseille Université et Università degli Studi di Torino

18. Sauter MR, Privat F (1952) Une nouvelle méthode de détermination sexuelle de l'os coxal : l'indice cotylosciatique. Bull Soc Suisse Anthropol Ethno 28:12–3
19. Ardagna Y, Fort A, Sperendio E (2017) Les données métriques en anthropologie biologique : entre histoire et endommagement. BMSAP 29:177–84
20. Caffell A, Roberts C, Janaway R, et al (2001) Pressures on osteological collections: the importance of damage limitation. In: Williams E (ed) Human remains: conservation, retrieval and analysis. Proceedings of a conference held in Williamsburg, VA, Nov 7-11th 1999. Archaeopress, Oxford, pp 187–97
21. Caffell A, Roberts C, Janaway R, et al (2001) Human skeletal collections: the responsibilities of project managers, physical anthropologists and conservators, and the need for standardized condition assessment. In: WilliamsE (ed) Human remains: conservation, retrieval and analysis. Proceedings of a conference held in Williamsburg, VA, Nov 7-11th 1999. Archaeopress, Oxford, pp 199–208

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NOTE / *NOTE*

Stature Estimation from Hand and Foot Dimensions Reveals a Similar Allometric Relationship in Sudanese Arabs and Somalis

L'estimation de la stature à partir des dimensions du pied et de la main met en évidence une même relation allométrique chez les Soudanais arabes et les Somalis

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Abstract Population-specific anthropometric standards serve as a guide to forensic practitioners for identification purposes. However, few studies have observed on whether the relationship between stature and body parts differs among populations. Our aim is to first assess the validity of using hand and foot dimensions to estimate stature in two geographically similar but linguistically different populations, Sudanese Arabs and Somalis, and then secondly to assess whether the relationship between hand and foot dimensions and stature differ among these populations. Standard anthropometric measurements were used to assess sexual dimorphism. Regressions were performed to establish the relationship between body parts and stature and were compared among the populations to describe the allometry. Comparisons between regression coefficients reveal that 1) stature has the same relationship with hand and foot lengths in each population and 2) the relationship between stature/hand length and foot length is the same (isometric) in both populations. These results suggest a close affinity between the two groups. Hand and foot length can be used to estimate the stature of individuals but not to identify sex or differentiate one population from the other.

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Keywords Stature estimation · Sudanese Arabs · Somalis · Allometry

Résumé Des référentiels anthropométriques servent aux médecins légistes à établir le profil biologique des individus. Cependant peu d'études ont observé si la relation entre la stature et les dimensions des parties du corps sont différentes entre les populations. Cette étude évalue en premier lieu la validité de l'utilisation des dimensions des mains et des pieds pour estimer la stature de deux populations géographiquement similaires mais linguistiquement différentes, les Arabes soudanais et les Somaliens. Elle évalue ensuite si le même rapport est présent dans les deux populations. Des mesures anthropométriques standard ont été utilisées pour évaluer le dimorphisme sexuel. Des régressions ont été effectuées pour établir la relation entre les dimensions des parties du corps avec la stature et ont été comparées entre les populations pour décrire les processus allométriques. La comparaison des coefficients de régression révèle que : 1) la stature entretient la même relation avec les longueurs des mains et des pieds dans les deux populations ; 2) la relation entre le ratio stature/longueur des mains et la longueur des pieds est la même (isométrique) entre les populations. Ces résultats suggèrent une affinité étroite entre ces groupes. La longueur des mains et des pieds peut être utilisée dans l'estimation de la stature des individus, mais ne permet pas l'identification du sexe et la distinction entre les populations.

Mots clés Estimation de la stature · Soudanaises arabes · Somalies · Allométrie

Introduction

The relationship between stature and the size of body parts is an important factor for identification purposes. Mutilated bodies from catastrophes and terror attacks may have to be

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identified from a single body part. Forensic practice requires an accurate biological profile of victims to be established. Ancestry, sex, age and stature are the "Big Four" of identification in forensic anthropometry.

Adult stature results from complex interactions between genetic, epigenetic and environmental factors. Average adult stature differs between human populations [e.g. 1–5]. The differences in stature and the size of body parts of populations living in distinct latitude and climatic conditions show the influence of environmental factors [3,6]. This environmental conditioning can also be observed in populations with a similar phenotype, such as Pygmy populations from East and West Africa where the phenotype is acquired by a distinctive process and reveals convergent evolution [7]. On the other hand, populations living in similar environments exhibit different average adult statures. This is reported among Pygmies and Bantu-speaking neighbours [e.g. 8,9] and suggests a genetic difference [10].

As stature and body proportions vary between populations, the mathematical formulae predicting stature from body part sizes need to be population-specific. Identifying human remains using regression equations from different populations can cause misidentification. In other words, estimations made by extrapolating from the equation for a different population will affect forensic diagnosis and identification.

Anthropometric data suggest highly correlated relationships between stature and different anatomical parts in populations around the world. It is still unclear that whether this relationship is similar among different populations. From the perspective of forensic medicine, establishing the accuracy of regression equations is important. In anthropology, different relationships between stature and body parts could be attributed to changes in scaling, suggesting allometric differences between populations. Changes in scaling can be associated with particular environmental adaptations as suggested by Bergmann's and Allen's rules for our broadly distributed species [11].

Anthropometry has been established for Europeans and other populations in the world, but is notably lacking for populations in regions of armed conflict, and Sudan is no exception. The only body of work from this region is by Ahmed and his colleagues [12–15] who have published many regression equations to estimate stature from craniocephalic, lower limb and upper limb measurements of Sudanese Arabs. The majority of cranio-cephalic dimensions and all upper and lower limb measurements show correlations with stature. The coefficient of determination is very low for cranio-cephalic dimensions and the highest values correspond to tibia and foot length (no other lengths have been obtained for lower members). Based on correlation coefficients and coefficients of determination, Ahmed [12] suggests that some dimensions are more reliable than others to estimate stature. However, no tests have been performed to validate this suggestion. Ahmed and his colleagues have contributed to the knowledge on Sudanese morphology but no regional studies exist for comparison.

The aim of this study was to assess the relationship between stature and anthropometric measurements of hands and feet in two East African groups—Sudanese Arabs and Somalis. Correlations among traits were established for each population and linear regression formulae were constructed to assess the estimation of stature from the measurements of hands and feet. The populations were compared to establish any similarity between stature and hand or foot lengths between populations. The allometry was analyzed to compare scaling effects.

Material and Methods

The subjects recruited for the study were healthy adult Sudanese Arab and Somali volunteers (over 18 years of age) living in Khartoum, Sudan. The study was conducted in a dental referral clinic in Khartoum between September and November 2017. Prior informed consent was obtained from each individual participating in the study. Permission for the research was obtained from the Ethical Committee Board of the Khartoum Centre for Research and Medical Training in accordance with the guidelines of the Federal Ministry of Health of Sudan. We are aware that the sample size, especially for Somali people, is low for forensic medicine standards, but access to a Somali population is very limited. Both countries suffer from political instability, with a relatively small Somali student diaspora and migrants. To avoid comparing two populations with a different sample size, the number of Sudanese Arabs included in the study was made close to that of Somalis. Stature, weight and hand and foot lengths and widths were measured once by the same observer (N.A.) in 99 Sudanese Arabs (Female = 49, Male = 50) and 69 Somalis (Female = 28, Male = 41). We are aware that intra and inter-observer tests are needed for the method to be valid and that without these tests, measurements become observer-dependent. Our study therefore presents this limitation, which is the same as in almost all previous studies on Sudanese and other non-European populations [e.g. 12–15], since these avoid inter-observer variation (measurements taken only by one observer) and no intra-observer test is carried out. Furthermore, studies based on anthropometric measurements are extremely limited for these two populations, because of the historical reasons and the current political and social situation, hence, few data are available on Sudanese Arabs and even fewer on Somalis. Weights were measured with an electronic scale to the nearest 0.1 kg, height with a steel height gauge to the nearest 0.1 cm and hand and foot length with digital sliding callipers to the nearest 0.1 cm. All the measurements were taken using standard anthropometric points as described by Vallois [16].

The Shapiro–Wilk test was carried out to assess normality. As the proportion of normal distribution was low, sexual dimorphic differences were analyzed using the Mann–Whitney test (α = 0.05), which was also used to compare populations. Pearson's correlation coefficients were used to assess the correlations between stature and each hand and foot measurement.

Stature is one of the three main biological profiling characteristics that can be estimated from the anthropometry of body parts. Since height correlates with hand and foot length in both study populations (see below), regression analyses were made in order to observe a) whether stature has a similar relationship with hand length in both sexes, and b) whether the degree of relationship between stature and the latter measurement is the same in both populations. In other words, only comparison between regressions (and not between correlations) can be used to assess whether one relationship is more significant than another. The left size was used for regression analysis. The degree of significance of the difference in slope and interception of the *Y*-axis between two lines of regression can be obtained with covariance analysis (ANCOVA), called the "univariate general linear model" in SPSS (version18). This software also allows comparisons of regressions from variance analysis (ANOVA), in which a dummy variable is binary-coded (0 or 1) and another variable results from the product of the dummy variable and the independent variable accompanying covariates. The dummy variable serves to separate the two groups to be compared. To perform this analysis, a linear regression must be the starting point. In the resulting table, the dummy variable coefficient indicates the degree of significance of the difference intercepts with the *Y*-axis, while the coefficient of the product of this variable and the independent variable gives the comparison regression coefficients (slope) (Introduction to SAS. UCLA: Statistical Consulting Group; from http://stats.idre.ucla.edu/sas/modules/; accessed November 22, 2018).

A paired *t*-test (α = 0.05) was carried out to assess differences between real values for stature and the results obtained with the regression equations.

The relationship between stature (height) and body parts can also be investigated through allometric (scaling) analysis. Allometry is the study of the relationship of body size to

Table 1 Descriptive statistics by sex for Sudanese Arabs / *Statistiques descriptives par sexe chez les Soudanais*

Variable	Sex	Mean	SD	ES	Range	M–W
Age (years)	Male	27.1	6.83		18.2–52.8	
	Female	24.6	5.85		18.6–52.3	
Stature (cm)	Male	178.88	6.85	0.98	162–197	*
	Female	162.60	5.08	0.72	153–172	
Weight (kg)	Male	70.57	12.11	1.73	52–116	*
	Female	57.58	11.47	1.62	37–89	
Right hand length (cm)	Male	17.54	1.69	0.24	15–21.5	*
	Female	16.78	1.21	0.17	13–18.5	
Right hand width (cm)	Male	7.13	1.02	0.15	5.4–9	
	Female	7.03	0.47	0.07	5.5–8	
Left hand length (cm)	Male	17.52	1.66	0.24	14.7–21	
	Female	16.83	1.19	0.17	13–19	
Left hand width (cm)	Male	7.06	1.02	0.15	5–9	
	Female	6.90	0.49	0.07	5–7.9	
Right foot length (cm)	Male	24.47	2.07	0.3	20–28.7	*
	Female	22.68	1.47	0.21	18–25	
Right foot width (cm)	Male	7.71	1.49	0.21	5.5–12	
	Female	7.45	0.03	0.15	4.5–9	
Left foot length (cm)	Male	24.42	2.04	0.29	20.5–29	*
	Female	22.5	1.57	0.22	18–25.3	
Left foot width (cm)	Male	7.50	1.33	0.19	5–10.2	
	Female	7.34	1.05	0.15	5–8.8	

M–W: Mann–Whitney test; *: significant at $P < 0.05$

shape, or in other words the relationship between changes in body size and changes in a ratio between body parts [17]. If changes in body size are not followed by modifications in the ratio between body parts, the process is called isometric, where the shape remains the same when size changes. On the other hand, if changes in body size produce changes in the ratio between body parts, this is referred to as allometric, where changes in body size are accompanied by changes in shape (body proportion). Thus, stature corresponds to the main trait and any change in size in a body part has to be related to it. In allometric analysis, stature is considered as the independent variable.

Allometry is best assessed by comparing ln-transformed data [18]. In our study, hand length (HL) and foot length (FL) were considered for the allometric analysis. We regressed ln-stature with the ratio ln-HL or ln-FL/ln-stature. Least-square regressions were obtained by sex for Sudanese Arabs and Somalis. If the regression coefficient is significant, scaling of the traits is allometric; if regression coefficients are not significant, scaling is isometric. Changes in stature among adult individuals are expected to produce an isometric variation in HL and FL, in other words the ratio between these measurements and the stature should remain the same independently of changes in height. All statistical analyses were performed with SPSS (version 18).

Results

Sexual dimorphism is not expressed in the same way in the two populations. In Somalis, significant differences are observed in all measurements except weight, whereas in Sudanese Arabs, significant sexual dimorphism is recorded in height, weight, right hand length and foot length (Tables 1, 2). Comparisons between the populations suggest that there are no significant differences between males, but in females, significant differences are observed in weight, hand length as well as in foot length and width, with Sudanese Arabs showing higher values than Somalis except for weight.

Significant correlations were found between measurements of hands and feet in both populations ($P < 0.01$). In Sudanese Arabs, hand length and foot length were correlated with height. In Somalis, hand length was correlated with height in both males and females, whereas foot length was correlated with height only in females (Tables 3, 4).

Regression Coefficient

The regression equations are presented in table 5. Although the correlations between height and hand length and foot length are significant, the coefficient of determination (R^2)

Table 2 Descriptive statistics by sex for Somalis / *Statistiques descriptives par sexe chez les Somalies*

Variable	Sex	Mean	SD	SE	Range	M–W
Age (years)	Male	22.6	2.42		18.4–29	
	Female	24	5.65		18.3–53.1	
Stature (cm)	Male	176.1	7.77	1.21	162–194	*
	Female	162.93	5.00	0.95	155–173	
Weight (kg)	Male	66.1	13.43	2.1	48–107	
	Female	64.82	14.62	2.76	42–92	
Right hand length (cm)	Male	17.32	1.59	0.25	13–20	*
	Female	15.78	1.53	0.29	13–18.3	
Right hand width (cm)	Male	7.36	0.66	0.1	5.2–8.6	*
	Female	6.86	0.5	0.09	5.3–7.8	
Left hand length (cm)	Male	17.49	1.46	0.23	13.8–20.5	*
	Female	15.76	1.49	0.28	13.5–18.2	
Left hand width (cm)	Male	7.36	0.65	0.1	5.4–8.6	*
	Female	6.71	0.51	0.1	5.3–7.8	
Right foot length (cm)	Male	24.05	2.04	0.32	19.7–28.3	*
	Female	21.59	1.68	0.32	18.5–25	
Right foot width (cm)	Male	8.10	1.09	0.17	5.6–10.4	*
	Female	6.47	1.34	0.25	4.3–8.7	
Left foot length (cm)	Male	24.25	2.00	0.31	19.9–28.5	*
	Female	21.53	1.61	0.3	18.5–24.8	
Left foot width (cm)	Male	8.00	1.07	0.17	5.7–10	*
	Female	6.45	1.36	0.26	4.5–9	

M–W: Mann–Whitney test; *: significant at $P < 0.05$

Table 3 Pearson correlations by sex for Sudanese Arabs / *Corrélations (Pearson) par sexe chez les Soudanais*

Variable	Sex	S	W	RHL	RHW	LHL	LHW	RFL	RFW	LFL	LFW
Stature	Male		0.31	0.48	−0.16	0.44	−0.1	0.46	0.07	0.47	0.02
	Female		0.18	0.46	0.26	0.44	0.15	0.59	0.41	0.60	0.38
Weight	Male	*		0.28	0.03	0.21	−0.02	0.02	−0.04	0.05	−0.01
	Female	ns		0.28	0.29	0.28	0.24	0.13	0.32	0.14	0.32
Right hand length	Male	**	*		0.50	0.97	0.44	0.75	0.58	0.77	0.68
	Female	**	*		0.61	0.97	0.45	0.78	0.79	0.8	0.75
Right hand width	Male	ns	ns	**		0.50	0.94	0.48	0.58	0.47	0.66
	Female	ns	*	**		0.63	0.87	0.34	0.50	0.37	0.54
Left hand length	Male	**	ns	**	**		0.43	0.73	0.58	0.76	0.70
	Female	**	ns	**	**		0.45	0.77	0.79	0.79	0.76
Left hand width	Male	ns	ns	**	**	**		0.44	0.51	0.44	0.56
	Female	ns	ns	**	**	**		0.24	0.43	0.27	0.46
Right foot length	Male	**	ns	**	**	**	**		0.55	0.98	0.65
	Female	**	ns	**	**	**			0.74	0.98	0.68
Right foot width	Male	**	ns	**	**	**	**	**		0.56	0.83
	Female	**	*	**	**	**	**	**		0.79	0.94
Left foot length	Male	**	ns	**	**	**	**	**	**		0.66
	Female	**	ns	**	**	**	ns	**	**		0.75
Left foot width	Male	**	ns	**	**	**	**	**	**	**	
	Female	**	*	**	**	**	**	**	**	**	

S: stature; W: weight; RHL: right hand length; RHW: right hand width; LHL: left hand length; LHW: left hand width; RFL: right foot length; RFW: right foot width; LFL: left foot length; LFW: left foot width. * $P < 0.05$; **: $P < 0.01$; ns: non-significant / *S : stature ; W : poids ; RHL : longueur main droite ; RHW : largeur main droite ; LHL : longueur main gauche ; LHW : largeur main gauche ; RFL : longueur pied droit ; RFW : largeur pied droit ; LFL : longueur pied gauche ; LFW : largeur pied gauche. * : P < 0,05 ; ** : p < 0,01 ; ns: non significatif.*

is low. This means that only a small proportion of the observed variation in stature can be estimated by hand or foot length. Around 20% of the stature can be predicted from hand length in all the Sudanese Arabs and male Somalis and around 30% from hand length and foot length in female Somalis.

Comparisons among the regressions show that they do not differ between the sexes or between Sudanese Arabs and Somalis (Table 5, Figs 1, 2). In other words, the relationship between stature and hand length and foot length is similar in both sexes and in both populations. The regression equations were therefore obtained for the sexes pooled together (Table 5). A paired *t*-test showed no significant differences between the real values for stature and the results obtained with the regression equations (Table 6).

Allometry

Almost all the regressions are non-significant, suggesting that changes in height are not accompanied by any change in proportion and that the relationship is therefore isometric (Fig. 3). There are two significant regressions, one between stature and the foot length/height ratio in female Sudanese Arabs and the other between stature and the hand length/height ratio in female Somalis, which suggests an allometric relationship. However, detailed analysis of the data revealed that these two significant regressions are the product of a few extreme values in a small sample size (type I error); both regressions have a low coefficient of determination ($R^2 < 0.2$). Furthermore, the comparison of regressions for hand and foot measurements between sexes and populations fail to show any significant differences between them. Therefore, changes in size and shape follow the same scaling, so that the relationship is isometric.

Discussion and conclusions

The expansion of forensic studies in recent years has greatly increased the production of studies on anthropometry linked to the identification of the sex, age, stature and ancestry of individuals. In particular, hand and foot dimensions have been widely tested for use as proxies for stature in many different populations (see Asadujjaman et al. [19] for a

Table 4 Pearson correlations by sex for Somalis / *Corrélations (Pearson) par sexe chez les Somalies*

Variable	Sex	S	W	RHL	RHW	LHL	LHW	RFL	RFW	LFL	LFW
Stature	Male		0.46	0.48	0.22	0.43	0.29	0.24	0.22	0.29	0.26
	Female		0.36	0.43	0.15	0.52	0.28	0.59	0.37	0.57	0.49
Weight	Male	**		0.34	0.39	0.36	0.45	0.55	0.59	0.52	0.55
	Female	ns		0.34	0.19	0.34	0.45	0.32	0.21	0.35	0.34
Right hand length	Male	**	*		0.44	0.90	0.44	0.53	0.51	0.67	0.54
	Female	**	*		0.38	0.93	0.34	0.57	0.46	0.57	0.49
Right hand width	Male	ns	*	**		0.49	0.92	0.35	0.57	0.53	0.57
	Female	ns	ns	**		0.34	0.84	0.31	0.56	0.34	0.55
Left hand length	Male	**	*	**	**		0.54	0.54	0.57	0.71	0.62
	Female	**	*	**	**		0.32	0.66	0.4	0.65	0.41
Left hand width	Male	ns	**	**	**	**		0.32	0.59	0.50	0.91
	Female	*	*	**	**	**		0.34	0.5	0.36	0.47
Right foot length	Male	ns	**	**	*	**	*		0.69	0.84	0.61
	Female	**	**	**	*	**	**		0.49	0.94	0.39
Right foot width	Male	ns	**	**	**	**	**	**		0.74	0.95
	Female	ns	*	**	**	**	**	**		0.46	0.85
Left foot length	Male	ns	**	**	**	**	**	**	**		0.69
	Female	**	**	**	*	**	**	**	**		0.41
Left foot width	Male	ns	**	**	**	**	**	**	**		
	Female	*	*	**	*	**	**	**	**	**	

S: stature; W: weight; RHL: right hand length; RHW: right hand width; LHL: left hand length; LHW: left hand width; RFL: right foot length; RFW: right foot width; LFL: left foot length; LFW: left foot width. *: $P < 0.05$; **: $P < 0.01$; ns: non-significant / *S : stature, W : poids, RHL : longueur main droite, RHW : largeur main droite, LHL : longueur main gauche, LHW : largeur main gauche, RFL : longueur pied droit, RFW : largeur pied droit, LFL : longueur pied gauche, LFW : largeur pied gauche. * :* p *< 0,05 ; ** :* p *< 0,01 ; ns : non significatif.*

review on hand dimensions [e.g. 20–23]). Hand length and foot length are described as presenting the highest coefficients of correlation and determination. Of these two measurements, foot length has the highest coefficient of determination in linear regressions but it is never higher than 0.590 [24]. At present, it is not possible to draw any general inferences from the body of works on forensic anthropology about the relationship between stature and hand and foot length, since the determination coefficients sometimes differ widely between sexes for the same population or even between right and left sizes in the same sample of individuals [e.g. 13,24]. Furthermore, the majority of forensic studies are focused on a single population, and although some authors compare their results with previous works, raw data from different populations are rarely available. Studies covering more than one population therefore have limited possibilities for comparisons of average values and for inferring a higher or lower coefficient of correlation (see below). In other words, few studies have addressed comparisons of the pattern of relationships between stature and hand or foot length among different populations.

In the first published data on Sudanese Arabs, Ahmed [12–14] showed the potential of hand and foot measurements from Sudan to estimate stature. No data exist from Somalia. Our results, as indicated above, are based on the measurements taken only once and by one observer, so that intra and inter-observer variability have not been assessed (see Methods). However, for stature and hand and foot length, they are very close to those previously reported. We confirm that length measurements produce higher correlations with stature than width measurements and are therefore more suited to estimations of adult height in both groups, Sudanese Arabs and Somalis. However, the coefficient of determination is low, implying limited potential usefulness of regression equations to determine stature from hand or foot length. Figures 1, 2 show the dispersion of hand and foot length measurements for stature. Ahmed [12,13] reports higher coefficients of determination but the paired *t*-tests do not appear to be more accurate: in fact the paired *t*-test in our study shows an extremely small average difference when real values are compared to calculated values. This suggests that the equations presented in table 5, although limited in

Table 5 Comparisons between regression coefficients / *Comparaison entre les coefficients de régression*

	Features	Sex	Regression equation	R^2	SEE	IC95%	*P*	Sign
Sudanese Arabs	S - LHL	Male	S = 147.257 + 1.804 LHL	0.191			0.927	ns
		Female	S = 130.977 + 1.879 LHL	0.194				
		F-M	S = 118.619 + 3.03 LHL	0.195	0.625	1.241		
	S - LFL	Male	S = 140.303 + 1.58 LFL	0.220			0.529	ns
		Female	S = 118.525 + 1.959 LFL	0.364				
		F-M	S = 95.025 + 3.225 LFL	0.423	0.382	0.758		
Somalis	S - LHL	Male	S = 135.929 + 2.297 LHL	0.185			0.696	ns
		Female	S = 133.133 + 1.891 LHL	0.315				
		F-M	S = 111.435 + 3.534 LHL	0.406	0.522	1.042		
	S - LFL	Male	S = 148.777 + 1.127 LFL	0.084			0.478	ns
		Female	S = 124.566 + 1.782 LFL	0.329				
		F-M	S = 111.708 + 2.551 LFL	0.385	0.394	0.786		
Sudanese Arabs	S - LHL	Male	S = 147.257 + 1.804 LHL				0.595	ns
Somalis	S - LHL	Male	S = 135.929 + 2.297 LHL					
Sudanese Arabs	S - LHL	Female	S = 130.977 + 1.879 LHL				0.988	ns
Somalis	S - LHL	Female	S = 133.133 + 1.891 LHL					
Sudanese Arabs	S - LFL	Male	S = 140.303 + 1.58 LFL				0.532	ns
Somalis	S - LFL	Male	S = 148.777 + 1.127 LFL					
Sudanese Arabs	S - LFL	Female	S = 118.525 + 1.959 LFL				0.776	ns
Somalis	S - LFL	Female	S = 124.566 + 1.782 LFL					

S: stature; LHL: left hand length; LFL: left foot length; SEE: standard error of the estimate; *P*: *p*-value for comparison between regression equations (males *vs* females or Sudanese Arabs *vs* Somali); ns: non-significant / *S : stature ; LHL : longueur main gauche ; LFL : longueur pied gauche ; SEE : erreur type de l'estimation ;* p : p-*valeur de la comparaison entre les équations de régression (hommes–femmes ou Soudanais–Somalies) ; ns : non significatif*

Table 6 Paired *t*-test between real stature and stature estimated from regression equation / t-*test apparié entre la stature et la stature estimée avec les équations de régression*

	Features	Dif. Average	Correlation	Sign	Sig. *t*-test
Sudanese Arabs	S - LFL	0.00369	0.651	$P < 0.001$	0.996
Somalis	S - LFL	0.00291	0.62	$P < 0.001$	0.997
Sudanese Arabs	S - LHL	0.00498	0.441	$P < 0.001$	0.996
Somali	S - LHL	0.00136	0.637	$P < 0.001$	0.999

S: stature; LFL: left foot length; LHL: left hand length / *S : stature ; LFL : longueur pied gauche* ; *LHL : longueur main gauche*

their power to produce a stature estimation for individuals, can be used at the population level.

Our results also confirm that all measurements for Sudanese Arabs are highly correlated [14]. The strong correlation between upper and lower limb dimensions has also been observed in many other populations [e.g. 24–26]. Comparisons of regression coefficients show that those for hands and feet are similar irrespective of sex. This probably suggests that the dimensions of limb parts are highly integrated genetically and that establishing a single regression equation for each population would enable the size of different parts to be estimated, as stature maintains similar relationships with hands and feet independently of sex.

Sexual dimorphism was observed in almost all metric dimensions in the Somalis but in the Sudanese Arabs it was only present in height, weight and foot length. Sexual dimorphism does not contradict the suggestion that stature maintains the same relationship with other body parts in both

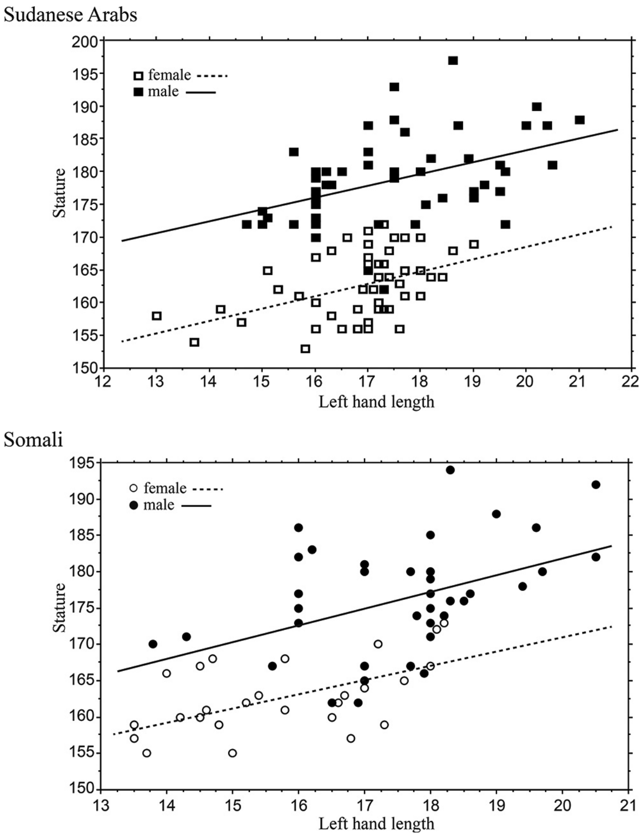

Fig. 1 Linear regressions between stature and left hand length in each population. Regressions do not differ between sexes in each population. Measurements in cm / *Régression linéaire entre la stature et la longueur de la main gauche dans chaque population. Les régressions ne sont pas différentes entre les sexes dans chaque population. Mesures en cm*.

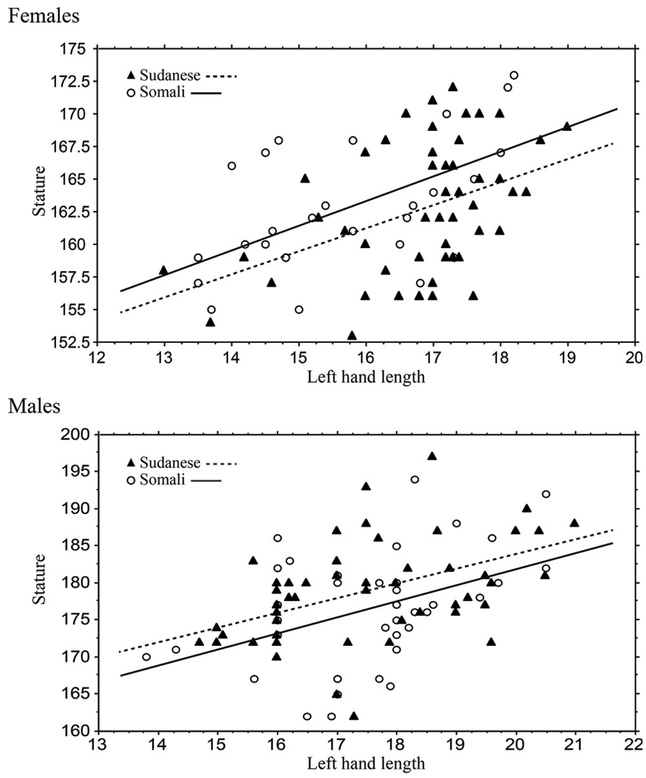

Fig. 2 Linear regressions between stature and left hand length by sex. The regression between populations do not differ and the relationship between stature and hand length is similar in the two populations. Measurements in cm / *Régression linéaire entre la stature et la longueur de la main gauche par sexe. Les régressions ne sont pas différentes entre les populations, la relation entre la stature et la longueur de la main est similaire chez les deux populations. Mesures en cm*.

sexes (isometry). Sexual differences along the same isometric scale have already been described for other traits in humans [e.g. 27,28]. Similar coefficients of regression for hand and foot length in both sexes in both populations suggest that sexual differences in dimensions are expressed along the same scale.

In some populations, stature, body part dimensions and/or body proportions are highly distinctive [7,29], which suggests that the relationships between stature and body parts expressed through correlation/regression coefficients is population-specific [30–32]. This is not the case between Sudanese Arabs and Somalis: the analysis of regression coefficients carried out in the present study suggests that the relationship between stature and hand and foot length is same in these two populations. It is worth emphasizing the importance of this analysis because some authors have advanced an interpretation of their results based only on the different raw values of the correlation coefficients without conducting any tests to assess the significance of the differences. Some studies even interpret differences between correlation coefficients as differences between populations [e.g. 15,33], so that a higher correlation coefficient is *incorrectly* interpreted as an indication of a more important relationship [e.g. 23]. Whether differences exist cannot be assessed from the raw values of coefficients: any comparison between coefficients has to be done following a statistical method (ANCOVA or the one used in this study). In other words, previous studies based only on correlation coefficients cannot determine whether differences exist among populations, so that the use of different correlations to estimate stature from body parts is not warranted at present.

Allometric analysis shows that both populations follow a variation in hand and foot length that expresses changes in height isometrically. This indicates that changes in stature are accompanied by proportional changes in hand and foot dimensions [e.g. 34,35].

Few studies have investigated genetic diversity in East Africa. In Sudan, the four main African language families are present, which suggests a complex history of migration

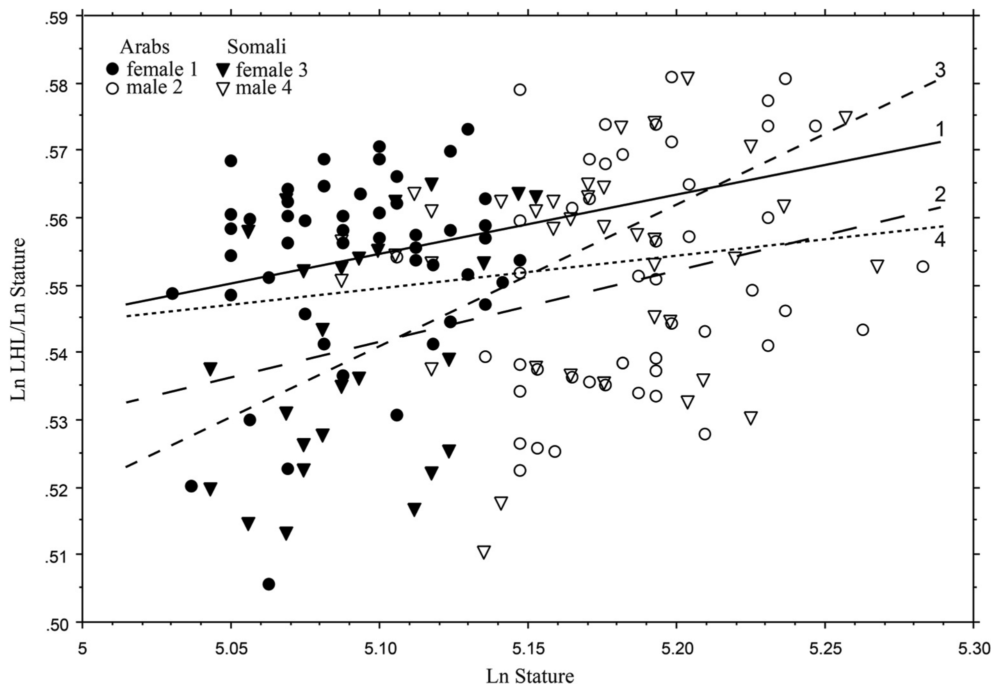

Fig. 3 Allometric relationships between stature and left hand length. The regressions are not significant, thus suggesting an isometric relationship between these two characteristics. In female Somalis, the regression is significant at α = 0.05, but is due to two extreme values: further comparison between regressions fails to reveal any difference among them, suggesting that all relationships follow an isometric scaling / *Relation allométrique entre la stature et la longueur de la main gauche. Les régressions ne sont pas significatives, ce qui suggère un rapport isométrique entre ces deux caractéristiques. Chez les femmes somalies, la régression est significative à α = 0,05, mais cela est dû aux deux valeurs extrêmes ; la comparaison entre les régressions ne révèle aucune différence entre elles, ce qui suggère que toutes les relations suivent un rapport isométrique.*

and admixture. Babiker et al. [36] have analyzed 15 microsatellites in several ethnic groups from Sudan, and compared them to published results from neighbouring populations including Somalis. They reported the Somali people as the most genetically distinct from other northeast African groups. Dobon et al. [37] observed that Sudanese Arabs and Ethiopians share the same polymorphisms and are clearly distinct from other groups. This study was based on an analysis of 200,000 single-nucleotide polymorphisms from the region. A language link also exists, as Sudanese Arabs and Ethiopians speak languages that are included in the Afro-Asiatic family. A genetic study of the Y chromosome in the region has revealed a strong correlation between genetic and linguistic structure [38]. Since Somalis also speak a language that belongs to the Afro-Asiatic family, the strong link between genetic and linguistic traits could predict a close affinity between Somalis and Sudanese Arabs. Like the genetic studies, our study on body measurements also point to a close affinity between these two populations.

To summarize, hand and foot lengths can be used in estimations of the stature of individuals of Sudanese Arab and Somali origin, but any prediction requires caution because of the low values of the coefficient of determination. The regressions expressing the relationship between stature and hand and foot lengths are similar in both populations and sexes, suggesting a close affinity among these groups. The identification of sex and differentiation of one population from the other is not possible using hand and foot anthropometry alone.

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References

1. Deniker J (1908) La taille en Europe. BMSAP série V 9:456–62
2. Czekanowski J (1922) Forschungen im Nil-Kongo-Zwischengebeit. Anthropologische Beobachtungen. Wissenschaftliche ergebnisse der Deutschen Zentral-Afrika-Expedition 1907–1908. Ethnographie-Anthropologie IV. Klinkhardt and Biermann, Leipzig, pp 143–473
3. Hiernaux J (1968) La diversité humaine en Afriques subsaharienne. Recherches biologiques. Institut de sociologie de l'Université Libre de Bruxelles, Bruxelles, 262 p

4. Eveleth PB, Tanner JM (1990) Worldwide variation in human growth, 2nd edn. Cambridge University Press, Cambridge, 497 p
5. Stulp G, Barrett L (2014) Evolutionary perspectives on human height variation. Biol Rev 91:206–34
6. Hiernaux J, Froment A (1976) The correlations between anthropo-biological and climatic variables in sub-Saharan Africa: revised estimates. Hum Biol 48:757–67
7. Ramirez Rozzi FV, Koudou Y, Froment A, et al (2015) Growth pattern from birth to adulthood in African pygmies of known age. Nat Commun 6:7672
8. Schebesta P (1938) Die Bambuti-Pygmaen vom Ituri. I.-Geschichte, Geographie, Unwelt, Demographie und Anthropologie der Ituri-Bambuti, belgisch Congo. G. van Campenhout, Bruxelles, 438 p
9. Pagezy H (1978) Morphological, physical and ethoecological adaptations of Oto and Twa women living in the equatorial forest (Tumba Lake, Zaire). J Hum Evol 7:683–92
10. Becker NS, Verdu P, Froment A, et al (2011) Indirect evidence for the genetic determination of short stature in African pygmies. Am J Phys Anthropol 145:390–401
11. Ruff CB (1994) Morphological adaptation to climate in modern and fossil hominids. Yearb Phys Anthropol 37:65–108
12. Ahmed AA (2013) Estimation of stature from the upper limb measurements of Sudanese adults. Forensic Sci Int 228:e1–e7
13. Ahmed AA (2013) Estimation of stature using lower limb measurements in Sudanese Arabs. J Forensic Leg Med 20:483–8
14. Ahmed AA (2014) A study of the anthropometric correlations between upper limb measurements for personal identification in Sudanese population. Homo 65:489–98
15. Ahmed AA, Taha S (2016) Cephalo-facial analysis to estimate stature in a Sudanese population. Leg Med (Tokyo) 20:80–6
16. Vallois HV (1965). Anthropometric techniques. Curr Anthropol 6:127–44
17. Gould SJ (1977) Ontogeny and phylogeny. Belknap Press of Harvard University Press, Cambridge, 501 p
18. Gingerich PD, Smith BH, Rosenberg K (1982) Allometric scaling in the dentition of primates and prediction of body weight from tooth size in fossils. Am J Phys Anthropol 58:81–100
19. Asadujjaman M, Babor Ali Molla M, Nahid Al Noman S (2019) Stature estimation from hand anthropometric measurements in Bangladeshi population. J Forensic Leg Med 65:86–91
20. Saxena SQ (1984) A study of correlations and estimation of stature from hand length, hand breadth and sole length. Anthropol Anz 42:271–76
21. Sanli SG, Kizilkanat ED, Boyan N, et al (2005) Stature estimation based on hand length and foot length. Clin Anat 18:589–96
22. Zeybek G, Ergur I, Demiroglu Z (2008) Stature and gender estimation using foot measurements. Forensic Sci Int 181:54e1–54e5
23. Uhrová P, Beňuš R, Masnicová S, et al (2015) Estimation of stature using hand and foot dimensions in Slovak adults. Leg Med 17:92–97
24. Kanchan T, Menezes RG, Moudgil R, et al (2010) Stature estimation from foot length using universal regression formula in a North Indian population. J Forensic Sci 55:163–6
25. Krishan K, Sharma A (2007) Estimation of stature from dimensions of hands and feet in a North Indian population. J Forensic Leg Med 14:327–32
26. Ozaslan A, Koc S, Ozaslan I, et al (2006) Estimation of stature from upper extremity. Mil Med 171:288–91
27. Velemínská J, Bigoni L, Krajíček V, et al (2012) Surface facial modelling and allometry in relation to sexual dimorphism. Homo 63:81–93
28. Fischer B, Mitteroecker P (2017) Allometry and sexual dimorphism in the human pelvis. Anat Rec 300:698–705
29. Ruff CB, Niskanen M, Junno JA, et al (2005) Body mass prediction from stature and bi-iliac breadth in two high latitude populations, with application to earlier higher latitude humans. J Hum Evol 48:381–92
30. Krishan K, Kanchan T, Sharma A (2012) Multiplication factor versus regression analysis in stature estimation from hand and foot dimensions. J Forensic Leg Med 19:211–4
31. Rastogi P, Nagesh KR, Yoganarasimha K (2008) Estimation of stature from hand dimensions of north and south Indians. Leg Med (Tokyo) 10:185–9
32. Hasegawa I, Uenishi K, Fukunaga T, et al (2009) Stature estimation formulae from radiographically determined limb bone length in a modern Japanese population. Leg Med (Tokyo) 11:260–6
33. Akhlaghi M, Hajibeygi M, Zamani N, et al (2012) Estimation of stature from upper limb anthropometry in Iranian population. J Forensic Leg Med 19:280–4
34. Cheverud JM (1982) Relationships among ontogenetic, static, and evolutionary allometry. Am J Phys Anthropol 59:139–49
35. Pélabon C, Bolstad GH, Egset CK, et al (2013) On the relationship between ontogenetic and static allometry. Am Nat 181:195–212
36. Babiker HMA, Schlebusch C, Hassan HY, et al (2011) Genetic variation and population structure of Sudanese populations as indicated by 15 Identifiler sequence-tagged repeat (STR) loci. Investig Genet 2:12
37. Dobon B, Hassan HY, Laayouni H, et al (2015) The genetics of East African populations: a Nilo-Saharan component in the African genetic landscape. Sci Rep 5:9996
38. Hassan HY, Underhill PA, Cavalli-Sforza LL, et al (2008) Y-chromosome variation among Sudanese: restricted gene flow, concordance with language, geography, and history. Am J Phys Anthropol 137:316–33

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NOTE / *NOTE*

Life, Health and Death in the Steppe: A Bioarchaeological Study of Bronze Age and Iron Age Pastoralist Populations of the Volga—Don Region, Russia*

Transitions bioculturelles et évolution de l'état sanitaire des populations pastorales des steppes de la Volga et du Don (Russie) de l'âge du Bronze à l'âge du Fer

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Abstract Major socio-economic, political and climatic changes have shaped the Eurasian steppe region during the Bronze and Iron Ages (3rd millennium BC—4th century AD), yet little is known about the bio-cultural impacts of these permutations on the life, health and death of the pastoralist populations who inhabited this area. This research represents the first attempt to adopt a holistic approach that includes osteoarchaeology, palaeopathology and environmental data to explore the evolution of the health status, diet, and lifestyles of these prehistoric pastoralist communities in the Volga–Don steppe region. The analysis of 385 skeletons derived from 155 kurgans suggests that, despite changes in pastoral mobility and sedentary lifestyles, there was no major change in the diet of Bronze and Iron Age populations, and children from the different cultures were exposed to various stressors. Evidence of interpersonal violence was observed in both the Bronze and Iron Age groups. A diversification of injuries and the appearance of conditions that were almost absent during the Bronze Age indicate that the overall health of Iron Age populations may have deteriorated. Various levels of health-related care to people with disabling diseases and severe injuries, and evidence of surgery, provide insights into the social dimensions of care among these prehistoric pastoralist societies.

Keywords Paleopathology · Eurasia · Pastoralism · Nomads · Bioarchaeology · Osteoarchaeology

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Résumé Les steppes de l'Eurasie ont été marquées par d'importants changements socio-économiques, politiques et climatiques entre l'âge du Bronze et l'âge du Fer (III^e millénaire avant J.-C.–IV^e siècle après J.-C.), mais l'impact de ces mutations sur la santé et les modes de vie des populations pastorales qui habitaient les steppes eurasiennes est méconnu. Cette recherche représente la première tentative d'investigation de l'évolution de l'état sanitaire, du régime alimentaire et des modes de vie des communautés pastorales qui habitaient les steppes de la Volga et du Don de l'âge du Bronze à l'âge du Fer, par l'adoption d'une approche holistique intégrant les données ostéoarchéologiques, paléopathologiques et paléoenvironnementales. L'analyse de 385 squelettes issus de 155 kourganes suggère une absence de changement majeur de régime alimentaire malgré les mutations de modes de vie mobile et sédentaire, et révèle l'importance des épisodes de stress pendant l'enfance tout au long de la période étudiée. Des indices de violence interpersonnelle sont présents à la fois dans les groupes de l'âge du Bronze et dans ceux de l'âge du Fer. Une diversification des traumatismes et l'apparition de maladies qui étaient pratiquement absentes pendant l'âge du Bronze suggèrent une dégradation de l'état sanitaire des populations à l'âge du Fer. Différents degrés de la pratique du soin et de la préservation de la santé d'individus blessés ou atteints de maladies handicapantes, ainsi que des soins chirurgicaux, témoignent de la vie sociale au sein de ces sociétés pastorales.

Mots clés Paléopathologie · Eurasie · Pastoralisme · Nomades · Bioarchéologie · Ostéoarchéologie

Throughout the world, today's mobile pastoralist communities have to make major adaptive adjustments in the face of burning modern challenges such as climatic, socio-political and economic changes [1–3]. In particular, modern semi-nomadic pastoralist groups who inhabit the flat grassland landscapes of Eurasia have had to formulate efficient adaptive responses since the steppe environment and livestock are highly sensitive to climate change [3–5]. Tracing the large-scale effects of multifactorial shifts on the fluctuations that occur in the health status and lifestyle of modern humans is, however, challenging [6]. Biocultural analyses of past societies, that integrate palaeopathological and contextual data, can enable such changes to be explored on a deep time-scale [7]. The present article derived from a PhD research that investigated the evolution of the health status, diet and lifestyle of prehistoric Eurasian pastoralist communities from the Volga–Don region during a period of significant change between the 3rd and the 1st millennium BC [8]. Placed at the geosocial crossroads between Europe, Central Asia and the Caucasus, in present-day southern Russia, the Volga–Don region is the western arm of the vast Eurasian steppe belt (Fig. 1).

The Eurasian steppe biome, an arid zone of treeless plains and plateaux covered by herbaceous plants, already existed about 5000 years ago, during the Bronze Age (3300–1200/800 BC) and the Iron Age (600 BC–400 AD), when communities adopted a mobile lifestyle based on pastoralism. From the end of the 4th millennium BC, carts and wagons emerged in the steppe and horses were increasingly domesticated [10]. In comparison with a shepherd on foot, wheeled vehicles and packed horses would have considerably improved mobility across the steppe. However, steppe communities abandoned this way of life to settle in permanent houses for circa 600 years during the Late Bronze Age (1800–1200 BC), and then re-adopted a form of mobile pastoralism at the beginning of the Iron Age [11–13]. The reason why they changed their settlement patterns is still unknown [11]. For a long time, scholars believed that the steppe populations settled so that they could cultivate plants, but pollen and macrobotanical analyses have demonstrated that crop-based agriculture throughout the Bronze Age was very weak [11,14,15]. It has also been suggested that these transformations could be linked with major climatic and socio-political changes [12,13,16]. Global climatic fluctuations of the Mid- to Late- Holocene are believed to have greatly impacted upon the vegetation cover, the availability of water resources and biodiversity of the steppe [17–19]. It is considered that martial activities increased during the Middle

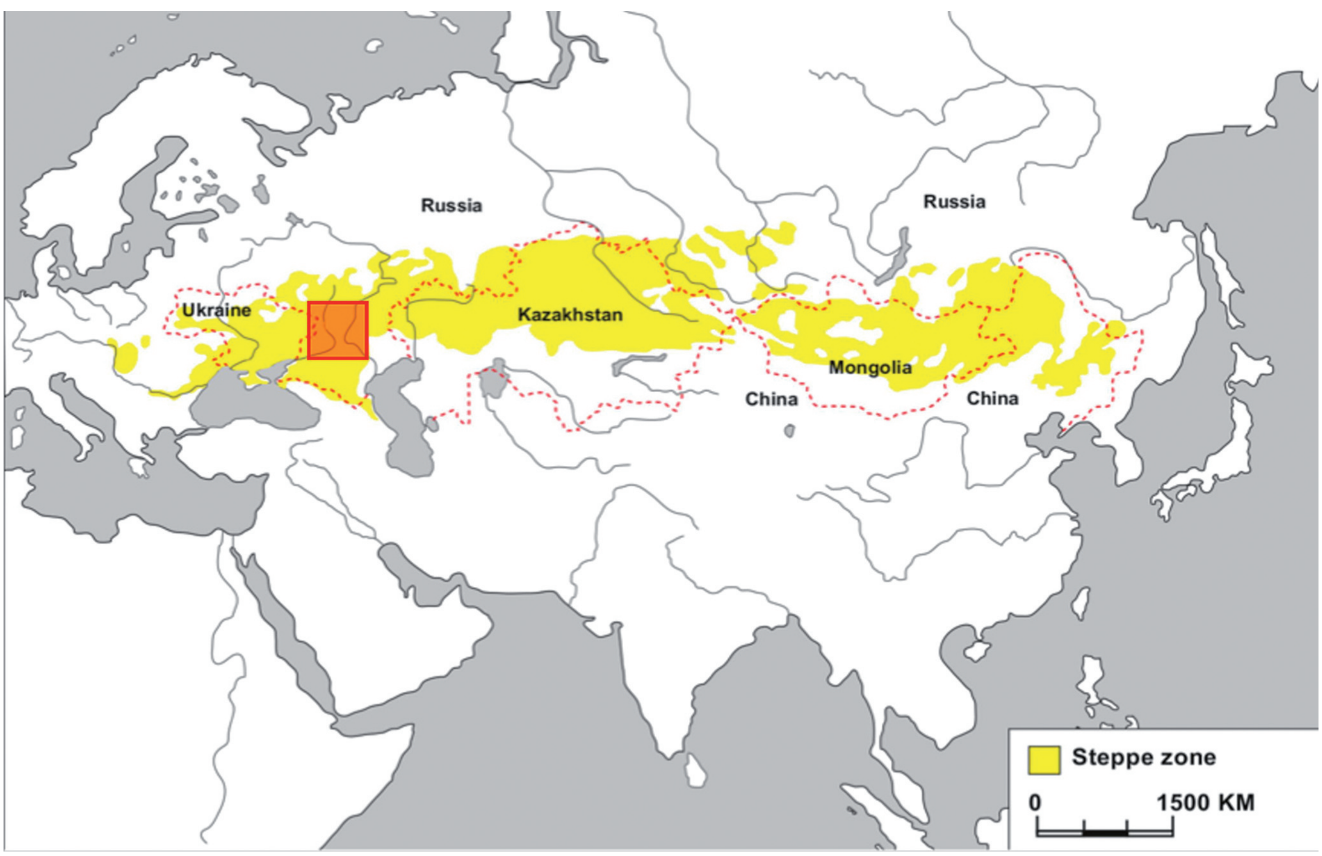

Fig. 1 Map of Eurasia (adapted from Hanks [9]) showing the limits of the steppe (in yellow) and the Volga–Don region under study (red rectangle) / *Carte de l'Eurasie (adaptée de Hanks* [9]*) délimitant les steppes (en jaune) et la région de la Volga et du Don étudiée (rectangle rouge)*

Bronze Age when weapons and goods became more frequent in burials, whereas weapons were rarely placed in the Early and Late Bronze Age burials. The substantial number and frequency of weapons found in graves of the highly mobile Iron Age populations seem to indicate regular participation in conflicts and warfare [11,12]. Detail about the mortuary practices of each culture is provided in the PhD research from which this paper derives [8].

Pastoralism, defined as the use of extensive grazing on rangelands for livestock production, is based on a constant and dynamic balance between people, pasture and domesticated animals in arid and semi-arid environments [20]. This fragile but flexible and efficient balance is constantly adapting to seasonality, water sources and rainfalls, herd composition, socio-political, cultural and economic factors [3,21]. However, sudden or prolonged imbalance caused by external or internal elements (i.e. droughts, diseases, conflicts, cultural behaviours) can potentially impact on the health status of people and their domesticated animals and this was probably the case for the Bronze and Iron Age Eurasian pastoralists. Nevertheless, the bioarchaeology of prehistoric mobile pastoralist societies from the Eurasian steppe, and across the world, have been largely understudied [22].

Bioarchaeology is a relatively new field in Russia where physical anthropology and archaeology evolved as separate branches of science. Palaeopathological analyses of osteological materials are rare in comparison with the large number of archaeological excavations of kurgans (burials mounds) undertaken every year. Since the collapse of the Soviet Union, however, interdisciplinary research undertaken on skeletal materials derived from kurgans have demonstrated the potential wealth of information that can be gained from the combination of anthropological and archaeological data [e.g. 23–28]. However, relatively few palaeopathological studies have been undertaken on large samples of skeletal remains derived from prehistoric sites in Russia. The overarching aim of the research was to provide a deeper understanding of the bio-cultural changes experienced by those members of the mobile pastoralist populations of the Volga–Don steppe region from the Bronze Age to the Iron Age interred within kurgans. The present note is focusing on the palaeopathological aspects of the PhD research.

Materials and methods

Materials

The study includes the analysis of 385 human skeletons derived from 155 kurgans, 343 graves and 23 sites of the Volga–Don territories of Southern Russia (oblasts of Samara, Volgograd, Astrakhan and Rostov), and dated to the Bronze and the Iron Ages (Table 1). The osteological and palaeopathological study of human skeletons was undertaken at the Department of Physical Anthropology of the Peter the Great Museum of Anthropology and Ethnography, the Kunstkamera, in St. Petersburg, Russia. The corpus of skeletal remains derived from excavations undertaken in the 1990s at the site of Krasnosamarskoe [29], and from excavations undertaken by Soviet archaeologists V. P. Shilov and S. I. Kapochina between 1956 and 1964 [8].

Methods

Standard osteological methods based on the pelvis were used for adult sex [30–33] and age-at-death determination [34–36].

Table 1 Details of the number of individuals from each period / *Détails des effectifs par chronoculture*

Chronology	**Datation**	**Cultures**	**Total**
Early Bronze Age (EBA)	3300–2600 BC	Yamnaya	32
Middle Bronze Age (MBA)	2800–2200/2100 BC	Poltavka	78
	2800–2100 BC	Catacomb	
	2100–1800 BC	Potapovka	
Late Bronze Age (LBA)	1800–1200 BC	Srubnaya	79
Total			189
Early Iron Age (EIA)	600–350 BC	Sauromatian	71
	350–100 BC	Early Sarmatian	
Middle Iron Age (MIA)	100 BC–AD 150	Middle Sarmatian	47
Late Iron Age (LIA)	AD 150–400	Late Sarmatian	45
IA n/d*	n/d	n/d	33
Total			196
Total			**385**

*IA n/d: Cultural group not determined / *Groupe culturel indéterminé*

The age-at-death of juveniles was primarily estimated on the basis of the stages of tooth calcification and the dental development sequence [37–39], as well as diaphyseal lengths of long bones and epiphyseal fusion data [40–41].

Several indicators of physiological disruption or perturbation due to biological, psychosocial, or environmental stress have been observed in the Bronze and Iron Age populations of the Volga–Don region including: non-specific indicators of physiological stress (Cribra Orbitalia (CO), Porotic Hyperostosis (PO) and Dental Enamel Hypoplasia (DEH)), non-specific infections (periosteal new bone formation, osteomyelitis and endocranial lesions), and metabolic disorders (scurvy, rickets, residual rickets and osteomalacia). In addition, respiratory tract infections, dental diseases (caries, periapical cavities, periodontal disease, Ante-Mortem Tooth Loss (AMTL), calculus, extensive dental wear and interproximal dental grooves), joint disease (osteoarthritis, seronegative spondylarthropathies and rheumatoid arthritis, diffuse idiopathic skeletal hyperostosis), and trauma (skull trauma, injuries of the appendicular skeleton, osteochondritis dissecans, amputation and trepanation) were recorded. Details on the population profile, methods and statistics for each lesion type (breakdowns by individual, bone/tooth, sex and age categories) are provided in the PhD research [8]. Prevalence is reported by numbers of individuals in the present note, unless specified otherwise. Nonparametric chi-square tests of independence were undertaken to check the significance ($P < 0.05$) of observed intra-group and extra-group differences. A Fisher's exact test of independence was used when the theoretical values in each group were small (< 5).

Dental diseases and diet

The overall trends for dental diseases indicate that no major change in diet is likely to have occurred during the Bronze Age and the Iron Age of the Volga–Don steppe populations. The dentition of all groups displayed low levels of caries, periapical lesions and ante-mortem tooth loss, as well as very high levels of calculus, periodontal disease and extensive dental wear (Table 2). Low levels of caries have been recorded in hunting-gathering and pastoral societies who predominantly consumed meat, dairy products and fish. The results of dental caries (≤ 0.9% of the teeth affected in each group) are comparable to pastoral economies of Northern Kazakhstan and Inner Mongolia, as well as the hunting-gathering economy of the mid-Holocene Cis-Baikal populations (Fig. 2). Diets rich in protein can also result in increased calculus deposits and dental calculus can have protective effects against the formation of caries [46,47]. Therefore, it is likely that the Bronze Age and Iron Age steppe populations from the Volga–Don region had a non-cariogenic diet largely based on the consumption of animal proteins, such as meat, dairy products and fish. Crop-based agricultural products were probably not a major component of their diet. In addition, the relatively high levels of extensive dental wear in the dentition of skeletons from all cultures may have been caused by the consumption of coarse and fibrous foods such as dry meat and coarse cheese, and uncooked plants. The presence of interproximal grooves in the premolars and molars of Bronze Age (6.9%, 7/101) and Iron Age (3.6%, 5/139) individuals indicates that teeth may have also been used for non-masticatory purposes.

Table 2 Summary of frequencies of dental diseases in the adult Bronze and Iron Age populations (by number of teeth observable for caries, calculus and extensive dental wear, and by tooth positions for periapical lesions and ante-mortem tooth loss – AMTL) / *Résumé des fréquences des lésions dentaires au sein des populations adultes de l'âge du Bronze et de l'âge du Fer (par nombre de dents observables pour les caries, le tartre, et l'attrition dentaire sévère, et par alvéole dentaire pour les abcès et les pertes dentaires ante-mortem–AMTL)*

Cultures	**Caries**		**Periapical lesions**		**Calculus**		**AMTL**		**Extensive dental wear**	
	N	**%**	***N***	**%**	***N***	**%**	***N***	**%**	***N***	**%**
EBA	0/328	0	0/472	0	227/328	69.2	28/472	5.9	39/328	11.9
MBA	2/833	0.2	11/1210	0.9	433/833	52	84/1210	6.9	161/833	19.3
LBA	3/401	0.7	8/639	1.3	129/401	32.2	48/639	–	43/401	10.7
Total	5/1554	0.3	19/2321	0.8	789/1562	50.5	160/2321	6.1	243/1562	15.6
EIA	1/714	0.1	7/1211	0.6	449/714	62.9	55/1157	4.8	63/714	8.8
MIA	4/448	0.9	20/865	2.3	357/448	79.7	63/865	7.3	76/448	17
LIA	3/555	0.5	23/973	2.4	420/555	75.7	81/973	8.3	125/555	22.5
N/D IA	1/465	0.2	7/612	1.1	311/465	66.9	21/612	3.4	31/465	6.7
Total	9/2182	0.4	57/3661	1.6	1537/2182	70.4	220/3661	6	295/2182	13.5
Total	**14/3736**	**0.4**	**76/5982**	**1.3**	**2326/3744**	**62.1**	**380/5982**	**6.4**	**538/3744**	**14.4**

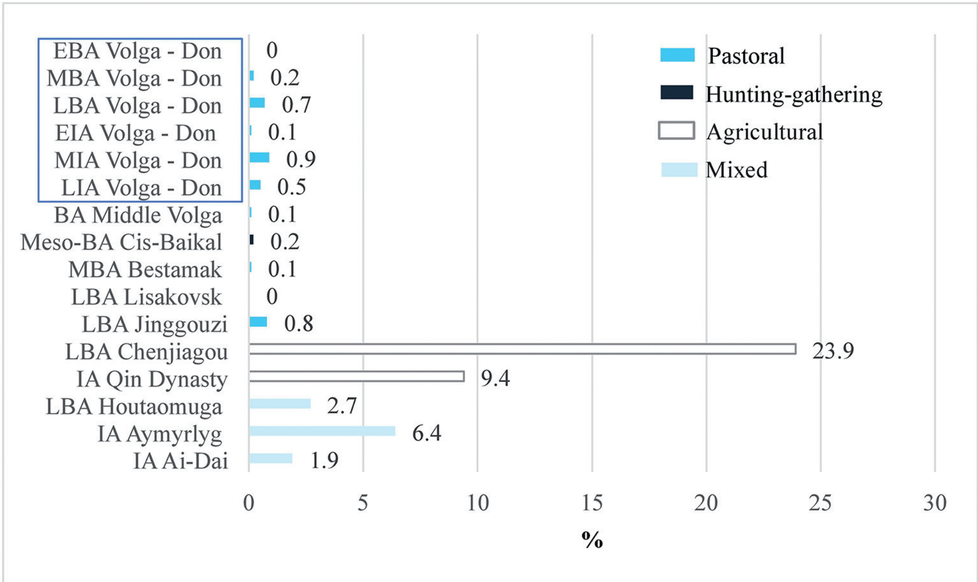

Fig. 2 Prevalence of caries among the teeth of the Volga–Don populations (rectangle) in comparison with the Bronze Age populations of the Middle Volga [29], the mid-Holocene hunter-gatherers from Cis-Baikal, Siberia [42], the MBA and LBA steppe pastoralists from Lisakovsk and Bestamak, Kazakhstan [43], the LBA Chenjiagou, Houtaomuga, and Jinggouzi populations, China [44], the Iron Age males buried in the Mausoleum of Emperor Qinshihuang, China [45], and the Iron Age Aymyrlyg and Ai-Dai populations from South Siberia [27] / *Prévalence des caries dentaires au sein des populations de l'âge du Bronze et du Fer de la Volga et du Don (rectangle) en comparaison avec les populations de l'âge du Bronze de la Volga Moyenne* [29], *les chasseurs-cueilleurs de l'Holocène Moyen du Cis-Baikal, Sibérie* [42], *les pasteurs de l'âge du Bronze Moyen et Récent de Lisakovsk et Bestamak, Kazakhstan* [43], *les populations de l'âge du Bronze Récent Chenjiagou, Houtaomuga et Jinggouzi, Chine* [44], *les hommes de l'âge du Fer inhumés dans le Mausolée de l'empereur Qinshihuang, Chine* [45], *et les populations de l'âge du Fer d'Aymyrlyg et Ai-Dai, Sibérie du Sud* [27]

The osteoarchaeological data supports the results of recent palaeoenvironmental and zooarchaeological analyses, which emphasise the likely absence of cultivated cereals and the importance of domesticated animals (sheep, cattle and horses) in the daily life and presumably the diet of all the Bronze and Iron Age societies from the Volga–Don region. In addition, wild animals (e.g. wild birds, kulan, fox), river fish and wild gramineous steppe plants appear to have been important components of the diet of some groups [13,48]. Subsistence adaptations of Eurasian steppe groups were probably extremely diverse depending on the localities and the socio-cultural orientations, and we are only starting to comprehend spatial and chronological diversity of the prehistoric pastoralist populations of the region.

Everyday life and violence in the steppe

Osteoarthritis and non-violence related injuries of the appendicular skeleton

The general trends show that all the groups seem to have been similarly affected by osteoarthritis and prevalence rates ranged from 60% of the individuals affected for the Late Bronze Age group to 74.4% for the Late Iron Age group, and no statistical difference between the groups was evident (Fig. 3). The shoulder and the elbow were amongst the most affected joints. The elbow joint is considered to be less influenced by genetics and may better represent activity patterns than the shoulder [49]. All groups displayed similar levels of osteoarthritis of the elbow that ranged from 48.7% to 57.4%. Osteoarthritis of the elbow reflects repetitive stress involved during supination, flexion, pronation and extension, especially while carrying heavy loads. A pastoral economy would have involved repetitive activities involving the upper limbs, such as the daily collection and transport of water and fuel, building and packaging of temporary dwellings, milking animals, and shearing wool and tanning skin [3].

Overall, the Bronze and Iron Age groups appear to have been equally susceptible to injuries of the appendicular skeleton but differences occur when looking at prevalence data for each group. It is possible that the emergence of a new mobile way of life based on pastoralism during the Early Bronze Age was physically quite strenuous and involved a higher susceptibility to injuries of the appendicular skeleton (28.1%, 9/32) compared to the Middle (12.8%, 10/78) and Late (16.2%, 6/37) Bronze Age groups (Fig. 3). Early Bronze Age people were also more prone to osteochondritis

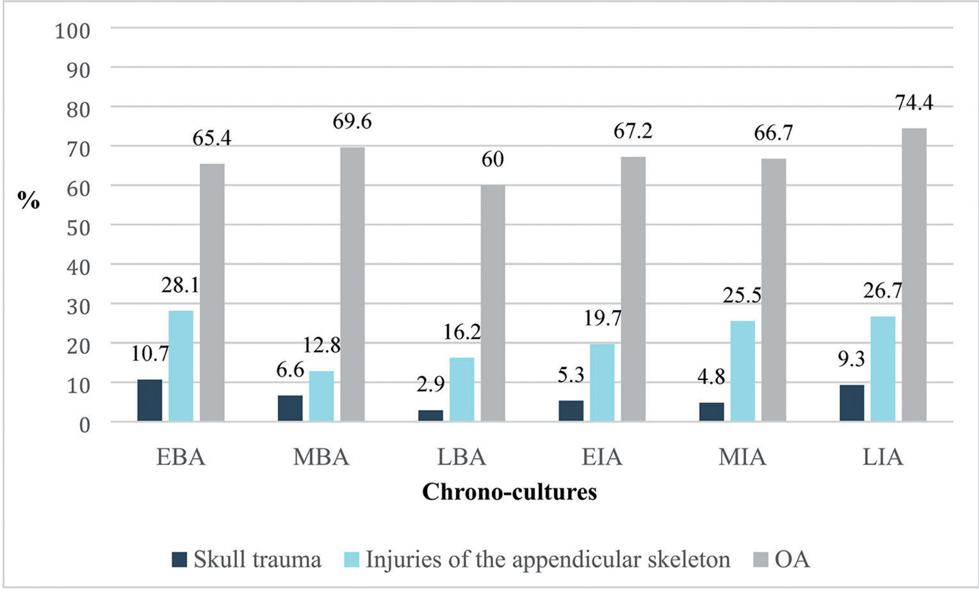

Fig. 3 Summary of prevalence of skull trauma, injuries of the appendicular skeleton, and osteoarthritis (OA) in the different Bronze and Iron Age adult populations (*n*: individuals affected / *N*: individuals) / *Résumé des prévalences des traumatismes crâniens et du squelette appendiculaire, ainsi que de l'arthrose (OA) dans les différentes populations adultes des âges du Bronze et du Fer (*n *: individus affectés /* N *: individus)*

dissecans (9.4%, 3/32) than the Middle Bronze Age group (1.3%, 1/78). Previous studies have also reported high rates of injuries of the appendicular skeleton and strong muscular insertions in the Early Bronze Age individuals of the Volga region [29,50].

The Iron Age group displayed more diverse injuries compared to the Bronze Age, as myositis ossificans traumatica and cortical desmoids became more frequent alongside fractures and ossified haematomas. In addition, when looking at the prevalence by bone, the Iron Age populations (3.2%, 38/1187) displayed statistically (χ^2 = 8.1431, P = 0.004) more injuries of the lower limbs in comparison with the Bronze Age (1.5%, 20/1360). The fibula (7.5%, 11/147) and tibia (5.2%, 12/232) followed by the femur (3.8%, 10/260) were the bones that are most frequently injured. More mobile than the Bronze Age groups, the semi-nomadic Iron Age people were masters of the horse and riding was regularly practiced facilitating travel for long distances during seasonal migrations and martial operations, as well as to exchange products and search for new grazing lands. It is therefore probable that intense horse riding throughout an individual's lifetime may have been associated with one or more injuries [51,52].

Violence and society

Skull trauma was recorded with a similar frequency in the Bronze (6.5%, 9/139) and Iron (5.4%, 9/166) Age groups. Yet, the Early (10.7%, 3/28) and Middle (6.6%, 5/76) Bronze Age groups appeared to have been more susceptible compared to the Late Bronze Age group (2.9%, 1/35) (Fig. 3). The Early and Middle Bronze Age trauma comprised a diversity of injury types that affected males only. However, the numbers of female individuals was low for the Middle Bronze Age (7 females, 27 males, 22 indeterminate), and Early Bronze Age females were absent from the corpus of skeletons, which may be related to males being selected for kurgan burials at this period [53]. One third of skull injuries during the Early Bronze Age and half of them during the Middle Bronze Age were penetrating injuries located in the occipital and, as such, had likely been caused by weapons, perhaps from attacks from behind (Fig. 4). It is considered that Early Bronze Age societies were quite hierarchical as kurgans burials were not representative of the full population [53]. In addition, adult males were occasionally accompanied by metalworking tools and weapons, which were not abundant at that time [11,12]. Since the Early Bronze Age group is not considered to have been very mobile, it therefore seems possible that interpersonal violence within communities occurred. A different scenario may have occurred during the Middle Bronze Age when improved wheeled vehicles enabled access to new territories. This period is also marked by a sharp aridisation of the climate [54], and it would have been necessary to repetitively abandon territories and seek for new grazing lands and water points to ensure the survival of humans and their herds. Changing climate can have critical effects on pastoral systems [55] and, therefore, it is possible that increasing competition for pastures led to conflicts between communities.

The Early (5.3%, 3/57) and Middle (4.8%, 2/42) Iron Age showed similar frequencies of skull trauma, whereas an increase, although not statistically significant, was evident during the Late Iron Age (9.3%, 4/43). All Middle Iron Age trauma comprised facial injuries, whereas this type of injury was not recorded in the Early and Late Iron Age populations. It is possible that a change in battle technique may have occurred or that face-to-face fighting was more common at that time. The rise in skull injuries at the end of the Iron Age may reflect the increasing role of martial activities. The large number of artificially deformed skulls of people buried within kurgans dated to the Late Iron Age suggests that conflicts may have been associated with a rise in social hierarchy [56].

Physiological stress and the environment

The integration of multiple skeletal indicators of stress together with contextual data enables the overall health status of a population to be interpreted [57]. Overall, it seems the general health of the Volga–Don steppe populations worsened during the Iron Age compared to the Bronze Age but, the change was perhaps not substantial and may be attributable to the presence of a greater diversity of diseases (Fig. 5). The Iron Age populations displayed more non-specific stress indicators including CO (25.5%, 38/149) and PO (20.6%, 34/165) than the Bronze Age populations (CO: 14.4%, 19/123; PO: 15.2%, 20/132) although the difference was only statistically significant for CO ($\chi^2 = 4.114$, $P = 0.043$). The rates of DEH and periosteal new bone formation by individuals were similar in both the Bronze and the Iron Age (Fig. 5). When looking at the prevalence of periosteal new bone formation by bones however, the Iron Age (4.5%, 106/2352) adults were statistically ($\chi^2 = 11.825$, $P = 0.0001$) more affected than those of the Bronze Age (2.4%, 36/1515) and all anatomical regions were affected, whereas only the bones of the lower limbs presented lesions in the Bronze Age. Therefore, it is possible the Iron Age individuals suffered from more systemic infections than the Bronze Age people, or survived longer with infectious diseases [58]. The appearance of conditions that were almost absent during the Bronze Age, such as rickets, residual rickets and osteomalacia, may reflect a diversification of physiological stressors during the Iron Age, a period when mobility and exchanges with other groups increased and martial activities became an important aspect of nomadic life.

DEH, PO and CO are indicators of periods of immunological and/or nutritional stress during childhood [59,60]. Their high levels in both periods indicate that a pastoral lifestyle in the steppe involved the exposure of children to various stressors. Children of the Volga – Don steppe area may have spent a lot of time exploring and playing in the steppe in close contact with animals, and helping their parents with daily tasks, and may have been exposed to various pathogens which sometimes would have caused illness [61,62]. A mobile lifestyle also means that children would have faced additional stressors such as changing environments, exposure to new diseases, as well as perhaps physical involvement in the migration process.

Fig. 4 Examples of skull traumas possibly caused by weapons: (1) Penetrating injury in the occipital bone of a Middle Bronze Age adult, (2) Peri-mortem sharp force trauma next to the bregma in the skull of an Early Iron Age middle-aged male / *Exemples de possibles traumatismes crâniens par arme : (1) Traumatisme pénétrant dans l'os occipital d'un adulte de l'âge du Bronze Moyen, (2) Traumatisme peri-mortem par arme tranchante à proximité du bregma du crâne d'un homme adulte de l'âge du Fer Ancien*

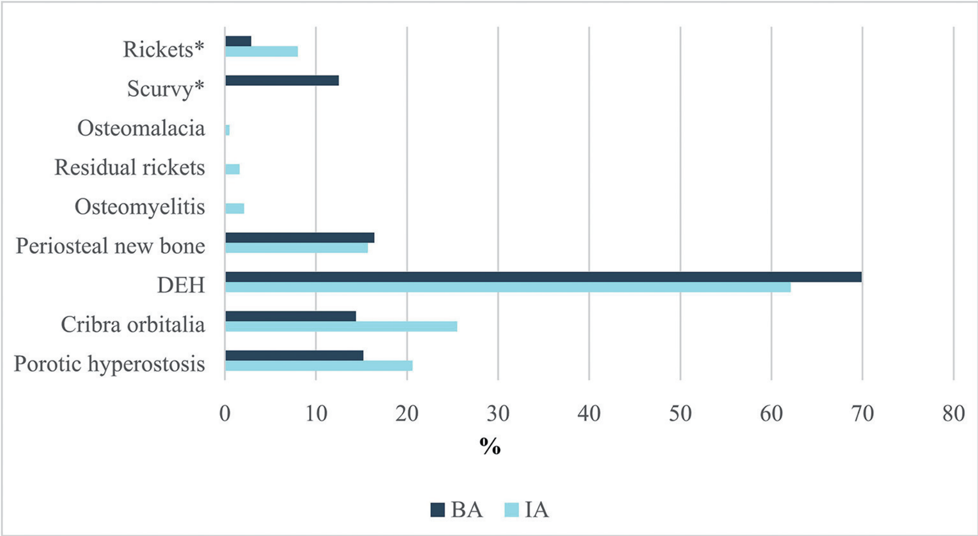

Fig. 5 Summary of non-specific physiological stress, non-specific infections, and metabolic diseases in the Bronze Age and Iron Age populations (*n*: individuals affected / *N*: individuals). *Frequencies of rickets and scurvy are calculated within the juvenile populations / *Résumé des marqueurs de stress non-spécifiques, des infections non-spécifiques, et des maladies métaboliques au sein des populations des âges du Bronze et du Fer (*n *: individus affectés /* N *: individus). *Les fréquences de rachitisme et scorbut sont calculées au sein des populations immatures*.

Metabolic disorders reflect deficiencies during both childhood and adulthood [63]. The sole case of rickets and three of the four cases of scurvy identified were found in Middle Bronze Age juveniles. In addition, levels of periosteal new bone formation and CO considerably increased for both adults and juveniles during the Middle Bronze Age. This increase in disease may be linked to the climate change of the second half of the 3rd millennium BC, which caused the density of vegetation cover to reduce and water sources to decline [54]. Studies of modern mobile pastoralists from Mongolia emphasise the dramatic impacts of climate change, anomalous harsh winter conditions (*dzud*), dust and snowstorms, and droughts, on the mortality and morbidity of both animals and humans [64].

In addition, the occurrence of chronic maxillary sinusitis and ear diseases indicates that both children and adults experience chronic respiratory tract infections. Immunodeficiency and infection, as well as environmental and climatic factors, are the most common causes for these diseases [65]. The climatic continentality of the steppe means that seasonal transitions are short. Winters are marked by cold temperatures, dry winds and heavy snowfall, whereas summers have high temperatures, low precipitation and hot winds. In spring, the snow melts and rivers unfreeze, which often results in flooding [66]. Prehistoric steppe pastoralists would have probably spent most of their time outside during seasonal migrations and when carrying out essential daily activities, and exposure to such climatic conditions could have triggered respiratory infections.

Surgery, disability and care

Care for people with limited mobility and reduced efficiency in physical activities, or who suffered from severe injuries that resulted from diseases, accidents or deliberate violence, has been identified in these Bronze and Iron Age populations. For example, an Early Iron Age adult of undetermined sex displayed advanced diffuse idiopathic skeletal hyperostosis (DISH) with spinal ankylosis extending from the fourth thoracic to the first sacral vertebra that would have impaired spinal mobility. This individual may have had difficulty with the physically challenging activities of a nomadic lifestyle. Interpersonal violence and accidents can result in serious injuries that can be either temporary or permanently disabling [67]. For example, a Middle Bronze Age middle-aged male exhibited a healed comminuted mandibular fracture, which caused the loss of most teeth and undoubtedly serious soft tissue damage (e.g. sublingual haematoma, muscular and nerve damage) (Fig. 6). The man would have experienced pain and swelling, anaesthesia of the lip, limited movement of the mouth, and loss of tongue control. It would have been very difficult for him to eat in the days following the trauma and, as such, he would have required assistance from others. Much in the same way, four Early and Middle Bronze Age adults displayed penetrating fractures of the occipital probably caused by weapons (Fig. 4). In all cases, the fractures displayed evidence of healing and hence survival perhaps associated with care by others.

Fig. 6 Healed fracture of the mandible with teeth lost ante-mortem in a Middle Bronze Age male (1 – superior view, 2 – inferior view). Arrows point at fracture lines and bone remodelling / *Fracture consolidée de la mandibule avec perte des dents ante-mortem chez un homme de l'âge du Bronze Moyen. Les flèches montrent plusieurs lignes de fracture et une consolidation osseuse avancée*

In addition, evidence of trepanation and limb amputation indicate that medical procedures and an advanced level of follow up care were undertaken in the Volga–Don region. A single individual, an Early Bronze Age adult male, displayed a healed trepanation in the form of a substantial opening at the intersection of the two parietals above the lambda (42 mm × 44 mm). Surgical opening of the cranium has already been recorded for the Bronze Age of the Lower Volga—North Caucasus steppe region [68]. In addition, a Middle Iron Age adult male displayed a left trans-tibial amputation that showed an advanced level of healing at the time of death. The individual also suffered from additional injuries to the appendicular skeleton, which were healed before the death. Therefore, this adult man may have been involved into multiple violent events, which appear to have generally increased during the Iron Age.

Conclusions

This research represents the first attempt to adopt a holistic approach to explore the evolution of health status, diet and lifestyles of the Bronze and Iron Age pastoralist populations of the Volga–Don steppe region. This research shows that despite changes in lifestyles (settled versus mobile), all pastoralist groups had a non-cariogenic diet probably based on the consumption of resources rich in protein, such as meat, dairy products and fish. A diversification of injuries and the appearance of conditions almost absent during the Bronze Age (e.g. rickets, residual rickets and osteomalacia) may indicate that the general health of Iron Age populations had worsened. However, a pastoral lifestyle in the steppe seems to have exposed the children from both the Bronze and Iron Ages to various stressors. Increasing violence and martial activities during the Iron Age are well documented by the numerous weapons in burials. However, evidence of interpersonal violence was observed in both the Bronze Age and the Iron Age groups. In particular, weapon-related injuries in the skulls of both the Early and Middle Bronze Age populations indicate that violent conflicts occurred at that time. Various levels of health-related care for people with physical impairments, as well as evidence of skilled medical procedures, contradict the "barbaric" historical descriptions of prehistoric Eurasian steppe societies [69].

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References

1. Humphrey C, Sneath D (1999) The end of Nomadism? Society, state, and the environment in Inner Asia. Duke University Press, Durham, 368 p
2. Galvin KA (2009) Transitions: pastoralists living with change. Ann Rev Anthropol 38:185–98
3. Stépanoff C, Ferret C, Lacaze G, et al (2013) Nomadismes d'Asie centrale et septentrionale. Armand Colin, Paris, 287 p
4. Mu H, Battsetseg B, Ito TY, et al (2010) Effects of Asian dust storm on health-related quality of life: A survey immediately after an Asian dust storm event in Mongolia. Int J Health Res 3:87–92
5. Herrero M, Addison J, Bedelian C, et al (2016) Climate change and pastoralism: impacts, consequences and adaptation. Rev Sci Tech 35:417–33
6. Portier CJ, Thigpen TK, Carter SR, et al (2010) Ahuman health perspective on climate change: areport outlining the research needs on the human health effects of climate change. Environmental Health Perspectives/National Institute of Environmental Health Sciences, Research Triangle Park, 70 p
7. Pinhasi R, Stock JT (eds) (2011) Human bioarchaeology of the transition to agriculture. John Wiley & Sons, London, 500 p
8. Loyer J (2019) Life, health and death in the steppe: a bioarchaeological study of Bronze Age and Iron Age populations of the Volga-Don region, Russia. PhD thesis, Queen's University, Belfast
9. Hanks B (2010) Archaeology of the Eurasian steppes and Mongolia. Annu Rev Anthropol 39:469–86
10. Kelekna P (2009) The horse in human history. Cambridge University Press, Cambridge, 476 p
11. Anthony DW (2007) The horse, the wheel and language. How bronze-age riders from the steppes shaped the modern world. Princeton University Press, Princeton, 568 p
12. Koryakova L, Epimakhov AV (2007) The Urals and western Siberia in the bronze and Iron Ages. Cambridge University Press, Cambridge, 408 p
13. Anthony DW, Brown, DR, Mochalov OD (2016) A bronze age landscape in the Russian steppes: The Samara valley project. Cotsen Institute of Archaeology Press, Los Angeles, 560 p
14. Popova LM (2009) Blurring the boundaries: Foragers and pastoralists in the Volga-Urals region. In: Hanks BK, Linduff KM (eds) Social complexity in prehistoric Eurasia: Monuments, metals, and mobility. Cambridge University Press, Cambridge, pp 296–320
15. Popova LM (2016) Paleoecological evidence for vegetation, climate, and land-use change in the lower Samara river valley. In: Anthony DW, Brown DR, Mochalov OD, et al (eds) A bronze age landscape in the Russian steppes: The Samara valley project. Cotsen Institute of Archaeology Press, Los Angeles, pp 91–102
16. Chernykh E (2008) The "Steppe belt" of stockbreeding cultures in Eurasia during the early metal age. Trabajos De Prehistoria 65:73–93
17. Demkin VA, Borisov AV, Demkina TS, et al (2010) Evolution of soils and dynamics of the climate of steppes in the southeast of the Russian plain during the late eneolithic and bronze ages (fourth to second millennia BC). Eurasian Soil Sci 43:1515–26
18. Kremenetski CV, Chichagova OA, Shishlina NI (1999) Palaeoecological evidence for holocene vegetation, climate and land-use change in the low Don basin and Kalmuk area, southern Russia. Veg HistArchaeobot 8:233–46
19. Wanner H, Beer J, Bütikofer J, et al (2008) Mid- to late Holocene climate change: An overview. Quat Sci Rev 27:1791–828
20. Blench RM (2001) Pastoralism in the new millennium. Animal production and health paper n° 150, UN Food and Agriculture Organization, Rome, 99 p
21. Crawford MH, Leonard WR (2002) The biological diversity of herding populations: an introduction. Cambridge Studies in Biological and Evolutionary Anthropology, Cambridge, 328 p
22. Johnsen KI, Niamir-Fuller M, Bensada A, et al (2019) A case of benign neglect: Knowledge gaps about sustainability in pastoralism and rangelands. United Nations Environment, Nairobi/Arendal, 78 p
23. Daire MY, Koryakova L (2002) Habitats et nécropoles de l'âge du Fer au carrefour de l'Eurasie. Les fouilles de 1993 à 1997. De Boccard, Paris, 292 p
24. Gerling C (2015) Prehistoric mobility and diet in the west Eurasian steppes 3500 to 300 BC: An isotopic approach. Walter de Gruyter GmbH & Co KG, Berlin/Boston, 414 p
25. Loyer J, Murphy E, Ruppe M, et al (2019) Co-morbidity with hypertrophic osteoarthropathy: a possible Iron Age Sarmatian case from the Volga steppe of Russia. Int J Paleopathol 24:66–78
26. Murphy EM (2003) Iron Age archaeology and trauma from Aymyrlyg. South Siberia, BAR Ltd, Oxford, 231 p
27. Murphy EM, Schulting R, Beer N, et al (2013) Iron Age pastoral nomadism and agriculture in the eastern Eurasian steppe: Implications from dental palaeopathology and stable carbon and nitrogen isotopes. J Archaeol Sci 40:2547–60
28. Pererva EV (2013) Palaeopathology of the Sarmatians from the Lower Volga–Don region. PhD thesis, Volgograd State University
29. Murphy EM, Khokhlov AA (2016) A bioarchaeological study of prehistoric populations from the Volga region. In: Anthony DW, Brown DR, Mochalov OD (eds) A Bronze Age Landscape in the Russian Steppes: The Samara Valley Project. Cotsen Institute of Archaeology Press, Los Angeles, pp 149–215
30. Murail P, Bruzek J, Houët F, et al (2005) DSP: a tool for probabilistic sex diagnosis using worldwide variability in hip-bone measurements. BMSAP 17:167–76
31. Brůžek J, Santos F, Dutailly B, et al (2017) Validation and reliability of the sex estimation of the human os coxae using freely available DSP2 software for bioarchaeology and forensic anthropology. Am J Phys Anthropol 164:440–49
32. Brůžek J (2002) A method for visual determination of sex, using the human hip bone. Am J Phys Anthropol 117:157–68
33. Murail P, Bruzek J, Braga J (1999) A new approach to sexual diagnosis in past populations. Practical adjustments from Van Vark's procedure. Int J Osteoarchaeol 9:39–53
34. Webb PAO, Suchey JM (1985) Epiphyseal union of the anterior iliac crest and medial clavicle in a modern multiracial sample of American males and females. Am J Phys Anthropol 68:457–66
35. Schmitt A (2005) Une nouvelle méthode pour estimer l'âge au décès des adultes à partir de la surface sacropelvienne iliaque. BMSAP 17:89–101
36. Brothwell DR (1981) Digging up bones: The excavation, treatment, and study of human skeletal remains. Cornell University Press, Ithaca, 208 p
37. Moorrees CF, Fanning EA, Hunt EE (1963) Age variation of formation stages for ten permanent teeth. J Dent Res 42:1490–502
38. Moorrees CF, Fanning EA, Hunt EE (1963) Formation and resorption of three deciduous teeth in children. Am J Phys Anthropol 21:205–13
39. Ubelaker DH (1989) The estimation of age at death from immature human bone. In: İşcan M (ed) Age markers in the human skeleton. Charles C Thomas, Springfield, pp 55–70
40. Maresh MM (1970) Measurements from roentgenograms, heart size, long bone lengths, bone, muscles and fat widths, skeletal maturation. In: McCammon RW (ed) Human growth and development. Charles C Thomas, Springfield, pp 155–200
41. Coqueugniot H, Weaver TD (2007) Brief communication: Infracranial maturation in the skeletal collection from Coimbra, Portugal: New aging standards for epiphyseal union. Am J Phys Anthropol 134:424–37

42. Lieverse AR, LinkDW, Bazaliiskiy VI, et al (2007) Dental health indicators of hunter–gatherer adaptation and cultural change in Siberia's Cis-Baikal. Am J Phys Anthropol 134:323–39
43. Ventresca Miller A, Usmanova E, Logvin V, et al (2014) Dental health, diet, and social transformations in the Bronze Age: Comparative analysis of pastoral populations in northern Kazakhstan. Quat Int 348:130–46
44. Zhang H, Merrett DC, Xiao X, et al (2016) A comparative study of oral health in three late Bronze Age populations with different subsistence practices in north China. Quat Int 405:44–57
45. Meng Y, Shao J, Jiang N, et al (2014) The frequency and distribution of caries among the Iron Age population (about 2200 years BP) buried in the mausoleum of emperor Qinshihuang. Arch Oral Biol 59:207–16
46. Lieverse AR (1999) Diet and the aetiology of dental calculus. Int J Osteoarchaeol 9:219–32
47. Keyes PH, Rams TE (2016) Dental calculus arrest of dental caries. J Oral Biol 3:4
48. Shishlina NI (2008) Reconstruction of the bronze age of the Caspian steppes: Life styles and life ways of pastoral nomads. BAR Ltd, Oxford, 313 p
49. Weiss E, Jurmain R (2007) Osteoarthritis revisited: A contemporary review of aetiology. Int J Osteoarchaeol 17:437–50
50. Boroutskaya SB (2012) Osteological characteristics of male burials from the Yamnaya culture of the Bronze Age Samara Volga region. Proceedings of the Irkutsk State University. Series: Geoarchaeology, Ethnology, Anthropology 1 :234-45
51. Moss PS, Wan A, Whitlock MR (2002) A changing pattern of injuries to horse riders. Emerg Med J 19:412–14
52. Ki HC, Shin E, Woo EJ, et al (2018) Horse-riding accidents and injuries in historical records of Joseon dynasty, Korea. Int J Paleopathol 20:20–25
53. Khokhlov AA (2016) Demographic and cranial characteristics of the Volga-Ural population in the Enolithic and Bronze Age. In: Anthony DW, Brown DR, Mochalov OD (eds) A Bronze Age Landscape in the Russian Steppes: the Samara Valley Project. Cotsen Institute of Archaeology Press, Los Angeles, pp 105–25
54. Demkina TS, Borisov AV, Demkin VA, et al (2017) Paleoecological crisis in the steppes of the lower Volga region in the middle of the bronze age. Eurasian Soil Sci 50:791–804
55. Thornton PK, van de Steeg J, Notenbaert A, et al (2009) The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. Agric Syst 101:113–27
56. Pererva EV, Balabanova MA, Zubareva EG (2013) Collection of artificially deformed skulls from the Science–Education Cabinet Museum of Anthropology of the Volgograd State University (Palaeoanthropology). Volgograd branch of RANEPA, Volgograd, 116 p
57. Goodman AH (1993) On the interpretation of health from skeletal remains. Curr Anthropol 34:281–88
58. Wood JW, Milner GR, Harpending HC, et al (1992) The osteological paradox: Problems of inferring prehistoric health from skeletal samples. Curr Anthropol 33:343–70
59. Walker PL, Bathurst RR, Richman R, et al (2009) The causes of porotic hyperostosis and cribraorbitalia: A reappraisal of the iron-deficiency-anemia hypothesis. Am J Phys Anthropol 139:109–25
60. Goodman AH, Rose JC (1991) Dental enamel hypoplasias as indicators of nutritional status. In: Kelley M, Larsen C (eds) Advances in dental anthropology. Wiley-Liss, New York, pp 225–40
61. Murphy EM (2008) Abiocultural study of children from Iron Age south Siberia. In: Bacvarov K (ed) Babies reborn: Infant/child burials in pre-and proto-history. BAR International Series 1832, Oxford, pp 175–87
62. Michelet A (2016) What makes children work? The participative trajectory in domestic and pastoral chores of children in southern Mongolia. Ethos 44:223–47
63. Brickley I, Ives R (2008) Bioarchaeology of metabolic bone disease. Academic Press, Oxford, 350 p
64. Du C, Shinoda M, Tachiiri K, et al (2018) Mongolian herders' vulnerability to dzud: a study of record livestock mortality levels during the severe 2009/2010 winter. Natural Hazards 92:3–17
65. Bluestone CD, Klein JO (2007) Otitis media in infants and children. PMPH-USA, Hamilton, 400 p
66. Rodionov S (1994) Global and regional climate interaction: The Caspian Sea experience. Springer Science & Business Media, Norwell, 250 p
67. Tilley L, Schrenk AA (2017) New developments in the bioarchaeology of care. Springer, Cham, 408 p
68. Gresky J, Batieva E, Kitova A, et al (2016) New cases of trepanations from the 5th to 3rd millennia BC in southern Russia in the context of previous research: Possible evidence for a ritually motivated tradition of cranial surgery? Am J Phys Anthropol 160:665–82
69. Bell-Fialkoff A (2000) The Role of Migration in the History of the Eurasian Steppe: Sedentary Civilization vs. "Barbarian" and Nomad. St. Martin's Press, New York, 355 p

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COMPTE RENDU D'OUVRAGE / *BOOK REVIEW*

Cemeteries and Sedentism in the Later Stone Age of NW Africa: Excavations at Grotte des Pigeons, Taforalt, Morocco (2019)

Barton R.N.E., Bouzouggar A., Collcut S.N., Humphrey L.T. (Editors).
Monographien des Römisch Germanisches Zentralmuseum, Band 147.
Mainz: Römisch Germanisches Zentralmuseum, 628 pp., ISBN 978-3-88467-312-6

V.S. Sparacello

Reçu le 4 mars 2020 ; accepté le 12 mars 2020

This remarkable volume is a welcome addition to the growing body of research on the prehistory of north-western Africa in the late Pleistocene and early Holocene (e.g. [1–3]). This region is, regrettably, often overlooked by archaeological and anthropological studies on Upper Palaeolithic Euro/Mediterranean material culture, subsistence and funerary behaviour. Yet, similarly to other better known sites, Taforalt has a long history of explorations and an impressive archaeological and funerary record. In recent studies, including this volume, researchers have made new discoveries not only through modern excavations, but also through the collection and critical re-analysis — in the light of direct observations at the site — of excavation diaries and ichnographic and photographic evidence from older excavations. I believe that this approach is always fruitful (see also, [4–6]), and the research team should be commended.

The introductory Chapter 1 (Editors) does a good job of setting the scene, providing an initial overview of the history of the research and detailing the geography of the area, with the added benefit of numerous large illustrations, both historical and contemporary, that help to familiarize the reader with the site. Particularly useful is the section detailing the aims and research questions addressed by the two successive projects ("Environmental factors in human evolution and dispersal in the Upper Pleistocene of the Western Mediterranean", funded by NERC, UK, and "Cemeteries and sedentism in the Epipalaeolithic of North Africa", funded by the Leverhulme Trust) that led to this monograph. The volume mainly explores issues of environmental and subsistence reconstruction, continuity and cultural variability of occupation, funerary behaviour, and the nature of the two main sequences, the "Yellow" and "Grey" series. While the over arching theoretical backgrounds relate economic intensification, ecological deterioration, increased sedentism and broad-spectrum subsistence patterns, the authors wisely avoid the constraints of rigidly-framed hypothesis-testing, which would be limiting given the fragmentary nature and resolution of the evidence.

Chapter 2 (Collcut) and its Appendix 2 is a *tour de force* detailing the lithostratigraphy and sediments at the site, both for the earlier excavations (Ruhlmann, 1944–7; Roche, 1951–5/1969–76; Raynal, 1977–82; Courty, 1980s) through a painstaking analysis of old documentation, and for the new explorations by the current research team. This is one of the most detailed and well-documented chapters in the whole volume, and it is not always an easy read. However, the value of the raw data and analyses put forward, nicely complemented by the micromorphological analysis in Chapter 3 (Macphail), cannot be overstated. An exploration of one of the main questions raised in the volume, the nature of the Yellow *vs*. Grey series, concludes that the more recent Grey series was formed by faster sedimentation of an anthropogenic nature, in contrast to the mostly colluvial nature of the Yellow series. The numerous illustrations and maps are mostly of high quality and definitely useful for the reader.

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The difference in sedimentation rates between the Yellow series (c. 27–15 kya cal. BP) and the Grey series (c. 15–12.5 kya cal. BP) is confirmed by the chronostratigraphic evaluation of the site, mostly conducted through AMS dates, in Chapter 4 (Staff, Ditchfield, Rhodes, Schwenninger, Clark-Balzan, Lee, and Barton). All AMS and the few OSL dates are usefully reported by sector in detailed tables.

Chapter 5 (Marco) on anthracological analysis, Chapter 6 (Morales) on macroscopic plant remains, and Chapter 7 (Jones, Ward, Parker) on phytolites, all provide useful data and discussions on palaeoenvironmental reconstructions and human palaeoecology and diet. The charcoal diagram in Fig. 5.3 is particularly illuminating, including for non-specialists, and is nicely complemented by a well-written discussion. Of great interest is the charcoal analysis of the funerary sector of the cave, which concludes that there is no evidence of *in situ* burning, that the charcoal was not altered by other activities and that no particular kind of wood was used in connection with mortuary behaviour. In the context of these studies, a shortcoming of the palaeo environmental study is the absence of a detailed study on the pollen profile of the sequence.

In the next chapters, the focus shifts from plant to animal resources. Chapter 8 (Taylor and Bell) focuses on malacofauna, Chapter 9 (Turner) on large mammals, and Chapter 10 (Cooper) on avifauna. The study of malacofauna is fundamental considering the importance of land snail middens in North African Epipalaeolithic sites. This chapter does an excellent job in introducing the research questions raised by the middens and discussing the evidence at Taforalt. From palaeoecological and subsistence considerations to experimental cooking and notes on the modern significance of this resource, this chapter is a thoroughly enjoyable and informative read for experts and non-specialists alike. The conclusion that the malacofauna in the Grey series due to human activity seems to be overwhelmingly supported by the evidence, although the authors warn that land snails should not be considered as a staple food. It is nevertheless an important element that points to a broad-spectrum subsistence regime for these Epipalaeolithic foragers.

Chapter 9, on large mammalian fauna, provides a large amount of data on the range of animals identified in the deposit, on butchering techniques, hunting preferences and seasonality (through an interesting albeit preliminary study of dental cementum, led by Wall-Scheffler). It highlights the importance of Barbary sheep and the transportation of their crania to the cave, which was most likely for reasons other than dietary use.

Chapter 10 on avian assemblages is based on fewer data, but it is well written and extremely interesting, especially for its implications about the use of avifauna in funerary contexts. Given the almost unique nature of this study for north African prehistory and its relevance to Late Palaeolithic research in general, I would have welcomed more comparative discussions on other funerary contexts with evidence evoking uses of avifauna for ritual purposes (if any exist, for example at Arene Candide see [7–8]). However, I assume that the topic will be further developed in the future publications.

In Chapter 11, the Editors essentially report that the study of microfauna is still in progress, and that only preliminary results on herpetofauna are available, from which it is difficult to discern an environmental signal (Chapter 11.2 by Gleed-Owen and Barton).

Chapter 12 (Hogue and Bouzouggar) describes the lithic assemblage of the LSA series, discussed in section 12.1 on raw materials (Hogue and Barton). This section provides abundant detail, with a large number of tables and illustrations, as does the wider regional comparison with other Iberomaurusian assemblages. A drawing next to each specimen would have allowed a better appreciation of both the raw material and the technological information.

Organic artefacts are the focus of Chapter 13, particularly bone tools (Desmond) and shell ornaments (Freyne). The chapter also provides insights into the possible use of bone tools: the inferences on basket weaving are particularly interesting. The section devoted to the relatively low number of shell ornaments found during the new excavations suggests a possible association with funerary behaviour, and highlights the connection with the coastal area via travel or trade.

Chapter 14 reviews the evidence on inorganic matter, such as irregular clay fragments that appear to have been baked (14.1 Barton and Collcutt), grindstones and pestles (Barton, Collcutt, Humphrey, Freyne) and ochre and minerals (Collcutt). A connection is considered between the small grindstones/pestles and the sector of the cave used for funerary purposes, although no definitive answer is proposed at this stage.

Chapter 15, on human burial evidence (Humphrey, Freyne, Berridge PJ, Berridge P), is one of the most important in the volume, as highlighted in the title. A number of burials were unearthed in previous excavations by Roche in the 1950s. These were first studied by Ferembach [9] and subsequently by Mariotti et al. [4,10], who re-assessed and reduced the minimum number of individuals. Nevertheless, this large skeletal series remains central to our understanding of funerary behaviour and the biological makeup of Iberomaurusian Later Stone Age people. The new excavations, conducted in the back western end of the cave, have yielded fourteen additional individuals, who appear to be slightly older than the ones found in previous investigations. This is suggested by the chronostratigraphy and by the lack of evidence of funerary behaviour involving secondary manipulation of human remains, as detailed by Mariotti and colleagues on Roche's skeletal series, and which appear to have developed in the later Capsian [5]. The description of each of the new burials is clear and detailed, with both drawings and photographs. Charts representing recovered skeletal elements are given for each individual, and the inferences on taphonomic processes and possible/probable grave goods are comprehensive. The section describing the sequence of mortuary behaviours is not easy to follow but intriguing for people who are interested in these aspects. The authors are cautious in their interpretations of possible intentional *vs*. unintentional manipulation of earlier remains during the placement of new depositions. The thorough discussion compares the evidence at Taforalt with contemporary assemblages in the wider region, and elaborates on the diachronic changes in funerary behaviour at the site. As in other sections in this volume, the authors refrain from wider comparisons with other Late Palaeolithic and Mesolithic funerary sites in the Euro-Mediterranean macro-region. One assumes that these wider implications will be explored in future research.

In contrast, Chapter 16 (De Groote and Humphrey), on the physical anthropology of the new remains, is quite brief. Stature, lower limb proxies of mechanical adaptations and some aspects of dental anthropology (like attrition, dental avulsion and oral pathologies) are outlined. The comparative data on stature from European Middle and Late Upper Palaeolithic individuals (16.2) could have been better summarized and displayed in tables and figures, and the implications of variation in mean stature are implied rather than explained for non-specialist readers. An additional point is that the Grimaldi Caves are in the province of Ventimiglia in Italy, not in Monaco as indicated in the chapter.

The section on mobility (16.3) as inferred from diaphyseal structural properties uses diameters (Dprod) rather than periosteal contours or full cross-sections (which include the reconstruction of the medullary cavity). While regressions of Dprod *vs*. J (polar moment of area) show strong correlations, there is virtually no comparative data using this method, and indeed the comparison in this section is limited to male *vs*. females among Taforalt individuals. Regarding the section on shape indices, which are assumed to correlate with mobility levels, diameters are not equivalent to bending moments, and these data are not the best comparison with indices derived from second moments of area, as done in this section when comparing Taforalt with "Late Upper Palaeolithic individuals from Europe", a "Neolithic sample from Italy" and an "Iron Age series" (to help track the source of the data, Chapter 6 should be referenced [11], instead of the whole book [12]). Furthermore, if we assume that diameters approximate mechanical shape indices, that $n = 7$ (individuals from Fig. 15.5 showing a mid-diaphyseal portion of femur), a sample with mean $I_x/I_y = 1.1$ and s.d. = 0.11 would be significantly lower in a *t*-test than the one shown by the Late Upper Palaeolithic hunters and Neolithic pastoralists mentioned in the text, and not significantly different when compared to the more sedentary Iron Age people. Although a non-parametric test would probably be more appropriate, this statistical datum would have strengthened the section's conclusion that data are "suggestive of moderate levels of terrestrial mobility" (although a statement earlier in the text suggests otherwise: "The mean shape index of the individuals from Taforalt is indicative of high mobility levels"). In a volume where the issue of possible sedentism in the Epipalaeolithic is explored, this could have been further discussed.

The section on dental anthropology (16.4) provides insights into age estimation via dental attrition, and highlights the practice of dental evulsion in the Iberomaurusian; I would have appreciated pictures of the three individuals who were subjected to this practice. The section on caries and other dental pathologies is quite interesting, and supports an increased reliance on carbohydrates among Epipalaeolithic foragers at Taforalt.

Chapter 17 (Lee-Thorp, Vaughan, Ditchfield, and Humphrey) discusses calcium and nitrogen isotopic analysis in both humans and fauna at Taforalt. The raw data are usefully reported in a table, and displayed in the bivariate plot. The diet at Taforalt included a significant amount of protein, despite evidence of greater reliance on carbohydrates (see above), and no evidence of marine foods. Regarding mobility issues, future research may implement other isotopes such as strontium and sulphur.

The final Chapter 18 brings all the previous evidences together in a discussion taking in the different theoretical backgrounds (intensification and resource depletion, broad spectrum subsistence, optimal foraging theory), and touches on issues of continuity of human occupation, seasonality, mobility and division of labour. Overall, there is an evidence of a broadening foraging spectrum, but this does not appear to be driven by environmental constraints. The final chapter offers an apt conclusion to a well-researched book, and brings out the wealth of interpretable data that the multi-disciplinary research team was able to gather. This book would be an important addition to the library of any researcher interested in Late Upper Palaeolithic archaeology and bio-cultural adaptations, regardless of their regional focus.

References

1. Mulazzani S (ed) (2013) Le Capsien de Hergla (Tunisie). Culture, environnement et économie. Reports in African archaeology, 4. Africa Magna Verlag, Frankfurt, 439 p
2. Douka K, Jacobs Z, Lane C, et al (2014) The chronostratigraphy of the Haua Fteah cave (Cyrenaica, northeast Libya). J Hum Evol 66:39–63

3. Lubell D (ed) (2016) Holocene prehistory in the Télidjène Basin, eastern Algeria: Capsian occupations at Kef Zoura D and Aïn Misteheyia. Archaeopress, Oxford, 232 p
4. Mariotti V, Bonfiglioli B, Facchini F, et al (2009) Funerary practices of the Iberomaurusian population of Taforalt (Tafoughalt; Morocco, 11–12,000 BP): new hypotheses based on a grave by grave skeletal inventory and evidence of deliberate human modification of the remains. J Hum Evol 56:340–54
5. Jackes M, Lubell D (2014) Capsian mortuary practices at site 12 (Aïn Berriche), Aïn Beïda region, eastern Algeria. Quat Int 320: 92–108
6. Sparacello VS, Rossi S, Pettitt P, et al (2018) New insights on Final Epigravettian funerary behavior at Arene Candide Cave (Western Liguria, Italy). J Anthropol Sci 96:61–184.
7. Cassoli PF (1980) L'avifauna del Pleistocene superiore delle Arene Candide (Liguria). Mem Ist It Paleontol Um 3:155–234
8. Alhaique F, Molari C (2006) Nuove considerazioni sulle sepolture delle Arene Candide alla luce della revisione dei materiali conservati presso l'Istituto Italiano di Paleontologia Umana di Roma. In: Martini F (ed) La cultura del morire, origines, progetti, III. Istituto Italiano di Preistoria e Protostoria, Firenze, pp 211–38
9. Ferembach D (avec la collaboration de Dastugue J, Poitrat-Targowla MJ) (1962) La nécropole épipaléolithique de Taforalt (Maroc oriental) : étude des squelettes humains. Edita Casablanca, Rabat, Paris, 175 p
10. Mariotti V, Condemi S, Belcastro MG (2014) Iberomaurusian funerary customs: new evidence from unpublished records of the 1950s excavations of the Taforalt necropolis (Morocco). J Archaeol Sci 49:488–99
11. Sparacello VS, Marchi D, Shaw CN (2014) The importance of considering fibular robusticity when inferring the mobility patterns of past populations. In: Carlson K, Marchi D (eds) Reconstructing mobility: environmental, behavioral, and morphological determinants. Springer, New York, pp 91–111
12. Carlson K, Marchi D (eds) (2014) Reconstructing mobility: environmental, behavioral, and morphological determinants. Springer, New York, 295 p

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COMPTE-RENDU / *REPORT*

Parker Pearson M, Sheridan A, Jay M, et al (eds) (2019) The Beaker People: Isotopes, Mobility and Diet in Prehistoric Britain, Oxbow Books, Oxford (Prehistoric Society Research Papers), ISBN: 9781789250640, 616 pages, £49,99

K. Gerdau

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Au moment où l'origine des Européens préhistoriques fait l'actualité de la recherche, et pas uniquement dans le monde académique, cette publication de Mike Parker Pearson et collaborateurs tente d'éclairer les origines et le mode de vie des Campaniformes britanniques. Les auteurs se posent la question de l'existence et de l'origine d'un peuple campaniforme en Europe et sur les îles Britanniques. Les deux projets de recherche[1] qui ont abouti à cette publication ont démarré trop tôt pour intégrer les nouvelles données génétiques parues depuis 2015. Les interprétations se fondent donc principalement sur les analyses isotopiques mais intègrent aussi d'autres types des données — dentaires, craniométriques et céramiques, entre autres.

Les directeurs de l'ouvrage sont des chercheurs et chercheuses britanniques reconnus dans leurs disciplines respectives : Mike Parker Pearson et Alison Sheridan pour la Préhistoire des îles Britanniques ; Andrew Chamberlain pour l'anthropologie biologique ; Michael P. Richards, Mandy Jay et Jane Evans pour les analyses isotopiques et leur utilisation en bioarchéologie. D'autres chercheurs ont participé à la rédaction de plusieurs chapitres.

Une série de ratios isotopiques de différents éléments obtenus à partir du collagène de l'os et de la dentine (carbone ($\delta^{13}C$), azote ($\delta^{15}N$) et soufre ($\delta^{34}S$)) et à partir de l'émail (oxygène ($\delta^{18}O$) et strontium ($^{87}Sr/^{86}Sr$)) est présentée, provenant de 370 individus, dont 183 fournissent des résultats sur l'ensemble des éléments. À travers ces analyses, les auteurs cherchent :

- à identifier les migrants campaniformes en provenance du continent ;
- à caractériser le degré de mobilité des Campaniformes britanniques et leur(s) régime(s) alimentaire(s).

Il ne s'agit pas uniquement de caractériser le « peuple campaniforme » britannique en identifiant les similitudes et les différences entre individus au sein de ce groupe identifié par le biais des objets associés, mais aussi de les comparer :

- à des individus contemporains non identifiés comme campaniformes ;
- à des échantillons des périodes plus anciennes ou récentes sur les îles Britanniques ;
- à des échantillons dits campaniformes sur le continent européen.

L'ouvrage comprend 12 chapitres et 6 annexes. Les trois premiers chapitres récapitulent les études sur le Campaniforme britannique, présentent de nouvelles dates radiocarbone à côté de nouvelles modélisations et font le point sur le niveau des connaissances actuelles au sujet des pratiques culturelles des Campaniformes, principalement sur les îles Britanniques. Le chapitre 4 présente les individus inclus dans le projet Beaker People ainsi que le mobilier qui leur est associé. Le chapitre 5 est un résumé du projet écossais Beakers and Bodies. Le chapitre 6 présente les données ostéologiques, y compris une section sur l'étude craniométrique de 41 individus du Peak District s'étalant du Néolithique à l'âge du Bronze ancien (4000–1500 avant notre ère) en Grande-Bretagne. Cette étude met en avant des cas et des styles de déformation crânienne au Néolithique et pendant le Campaniforme. Le chapitre 7 présente l'étude de microabrasion dentaire. Les chapitres 8 à 11 présentent les analyses

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[1] Beaker People Project (« Projet sur le peuple campaniforme »), financé par le Arts and Humanities Research Council UK (Commission des recherches sur les arts et les sciences humaines au Royaume-Uni) ; Beakers and Bodies Project (« Projet sur les vases campaniformes et les corps »), financé par le Leverhulme Trust, Royaume-Uni.

isotopiques — carbone et azote (8), soufre (9), strontium (10) et oxygène (11). Le dernier chapitre (12) synthétise les résultats et propose des conclusions et des nouvelles avenues de recherche.

Les auteurs présentent leur ouvrage de plus de 600 pages comme étant « *de loin, la plus vaste étude isotopique d'un peuple préhistorique en Europe* » (p. xvi)[2]. Bien que des études avec des échantillons plus larges soient déjà parues (par exemple, Goude et Fontugne [1] sur le Néolithique en France et Ligurie ; Bickle et Whittle [2] sur le Rubané d'Europe centrale), il faut saluer l'effort considérable mis en œuvre par les auteurs pour rassembler les données et pour les interpréter comme un ensemble cohérent. Cette étude souligne l'importance de lire les résultats isotopiques des individus à la lumière de toutes les données disponibles — intra- et interindividuelles, environnementales et matérielles *inter alia* (mobilier, parure, architecture, pratiques funéraires, etc.). Ainsi, les seules données isotopiques (individuelles et environnementales) ne permettent pas de trancher si les « Boscombe Bowmen » (les archers de Boscombe), par exemple, ont grandi sur les îles Britanniques ou sur le continent. Le style d'inhumation, collectif, et celui du mobilier poussent les auteurs à proposer une origine continentale pour ces individus, dans le Nord de la France, région qui a une géologie comparable à celle de certaines parties des îles Britanniques.

Toutefois, il est regrettable que dans un volume de cette envergure les données brutes ne soient pas facilement accessibles et repérables. Certes, les données pour les isotopes sont publiées dans des annexes en ligne[3], les résultats et estimations des analyses au radiocarbone apparaissent dans le chapitre 2 (tableau 2.4, pp 68–74), le chapitre 4 contient des tableaux, divisés selon des régions géographiques, qui présentent l'âge, le sexe, les résultats des datations radiocarbone et les objets associés à chaque individu, et l'annexe 6 présente des données pour les individus du projet Beakers and Bodies (Écosse). Cependant, le lecteur ne peut pas se rendre sur la base de données (*BPP Database*) censée être disponible en ligne. L'adresse donnée à plusieurs reprises dans le texte mène à une page inexistante. Impossible de vérifier quelles informations sont mises en ligne. L'intégralité des données brutes métriques et ostéologiques reste donc inaccessible.

Pour conclure, ce volume est utile non seulement aux chercheurs qui s'intéressent aux Campaniformes ou aux études isotopiques, mais il est aussi un excellent exemple d'une étude multidisciplinaire employant tout un éventail de données et de méthodes à la pointe de la technologie au moment de l'étude. Il faut espérer que les auteurs régleront le problème d'accès à la base de données en ligne.

Références

1. Goude G, Fontugne M (2016) Carbon and nitrogen isotopic variability in bone collagen during the Neolithic Period: influence of environmental factors and diet. J Archaeol Sci 70:117–31
2. Bickle P, Whittle A (eds) (2013) The first farmers of Central Europe: diversity in LBK lifeways. Oxbow Books. Cardiff Studies in Archaeology, Oxford, 608 p

[2] Traduction de l'auteure. « *[...] by far the largest isotopic study on any prehistoric population in Europe* ».
[3] https://books.casematepublishing.com/The_Beaker_People_isotopes_mobility_and_diet_in_prehistoric_Britain.pdf

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NECROLOGY / *NÉCROLOGIE*

Jochen Holger Schutkowski
Biological Anthropologist Specializing in Scientific Studies to Reconstruct Diet, Disease, and Mobility in Ancient Populations

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As a teacher of osteology for archaeology and anthropology students, Holger Schutkowski often had to be inventive. On one occasion he faced a long wait from suppliers for models of human teeth in order to demonstrate natural variation and sampling strategies so had casts made of his own masticators. Fully up to the job the casts are still in use, showing not only his appetite for home-spun solutions but also a preference for circumventing officialdom and bureaucracy when it suited him (Fig. 1).

Human remains fascinated Holger, and his enthusiasm was infectious. Colleagues recall his patience when excavating complicated prehistoric burials, and his precision when laying out ancient skeletons in the laboratory for analysis. Ethical considerations were always at the forefront of his thinking and led to his involvement in the Working Group on the Revision of Burial Legislation led by the Ministry of Justice in 2011. He was soon afterwards appointed as Chairman of the influential Advisory Panel on the Archaeology of Burials in England (APABE), a tricky time as deep-seated concerns about the storage and treatment of human remains found voice through protest groups and the popular press, challenging museums and researchers to rethink working practices and tighten up established systems. As colleague Simon Mays recalls, 'his unfailing good humour and people-skills allowed many potentially difficult situations to be successfully resolved through compromise and consensus'.

Research into the life and death of individuals and whole communities lay at the heart of his academic work. Starting with studies into the determination of the age and sex of individuals as a way of building up profiles of small population groups he quickly moved into the field of human ecology with studies of diet, disease, and adaptation, publishing in quick succession a monograph entitled *Human ecology: Biocultural adaptations in human communities* in 2006 [1] and an edited volume entitled *Between biology and culture* in 2008 [2]. Both were well received and pushed the field of bioarchaeology forwards, arguing for synthesis and greater nuance to be applied in the analyses of interactions between biological systems and human cultures.

Never one to shy away from a challenge, Holger took on the knotty problem of making sense of cremated bone, becoming an expert on burned remains at a time when few others had got to grips with this widely represented material. In class he sometimes played a video in which he demonstrated how to excavate an urn full of cremated bone in the field, a film no doubt as memorable to students as a "how-to-do-it" piece as it was amusing to see their tutor with long hair and flared trousers. Another pioneering line of research was determining the sex of infant skeletons, a problem previously regarded as intractable. But his big break came with the development of isotope analysis as a way of documenting mobility patterns amongst human communities by looking at chemical signatures in tooth enamel that could be related back to drinking water in the places people lived. Quickly seeing the potential, he applied the technique to look at populations from prehistoric and early historic times across the Middle East to help sort out some of the most puzzling melting pots of human culture anywhere in the world. He was one of the first in Britain to take an explicitly biocultural approach to isotopic studies of human remains, demonstrating that isotopic and histological analysis should only, and can only, exist within the context of wider bioarchaeological studies, and are meaningless without the biocultural background.

Outside of archaeology, music was his great passion. Almost any music was of interest, but chamber music was his favourite and while competent on many instruments from the piano to guitar it was the viola at which he excelled. As a

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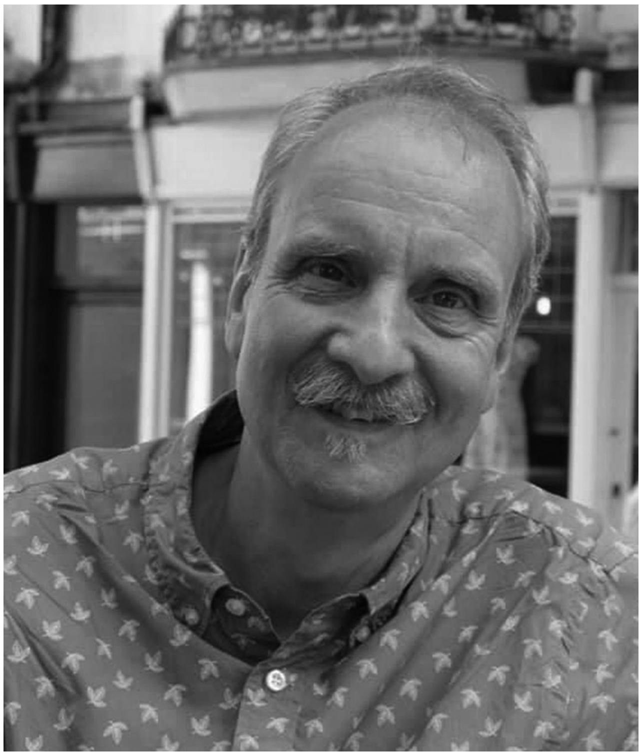

Fig. 1 Jochen Holger Schutkowski in 2015 in Kent

young man he mastered the demanding viola parts in Smetana's string quartet number 1 in E minor 'AusmeinemLeben' (For my Life). And from school-days onwards he played in orchestras and ensembles both for personal pleasure and for the delight of those listening. Most recently, he played with the Winchester Symphony Orchestra where friends and fellow musicians described him as the 'best viola player we ever had', delivering solos in pieces such Elgar's Enigma Variations with unparalleled expression and poignancy.

Jochen Holger Schutkowski, always known as Holger, was born on September 3, 1956, in Berlin, but spent most of his childhood in the town of Wilhelmshaven in Lower Saxony on Germany's North Sea coast, with his parents and older sister Bettina. The north-lands suited him, and in later life he defined himself as a 'Northerner', accepting the inherent propensity for directness, modesty and the delights of a strong cup of tea accompanied by sweets. Holger studied anthropology at Göttingen University, mentored by Professor Bernd Herrmann, the renowned German anthropologist. He completed a dissertation on the diagnostic value of the petrous portion of the temporal bone for sex determination in 1983 [3], a PhD on the sex determination of juvenile remains in 1990 [4], published as [5–6], and his Habilitation in 1998.

He was appointed to a lectureship in the Department of Archaeology in the University of Göttingen in 1989, pursuing his interests in bioarchaeology with a Deutsche Forschungsgemeinschaft (DFG) postdoctoral fellowship in 1994-1995 and a research fellowship in the University of Copenhagen in 1995. Returning to Göttingen, he became acting head of department in 1995-1996, by this time married to the prehistorian, Helen Hofbauer.

In 2000, he moved to Britain to take up a Readership in Biological Anthropology in the School of Archaeology, Geography and Environmental Sciences at the University of Bradford, later becoming Associate Dean for Research and Knowledge Transfer, and Head of Division from 2006 to 2010. During this time, he became closely involved in the excavations at Sidon in Lebanon with Claude Serhal, but never neglected his administrative duties back home. Faculty in Bradford recall that he was at the helm during a difficult period for the Department with staff cuts looming and talk of closure. He was pivotal in turning that around, well-liked and trusted despite the hard decisions concerning staffing issues that had to be made. Indeed, colleagues fondly remember that he always seemed to be on their side rather than the voice of management; a real testament to his skills was that the department retained a close sense of identity and friendship that endured through those years.

After a decade in Bradford, new opportunities beckoned, and in 2011 he moved south to Bournemouth University to become Professor of Bioarchaeology and Deputy Dean in the School of Applied Sciences. He led the Bioarchaeology Group through several organizational reshuffles that galvanized their future within what is now called the Department of Archaeology and Anthropology. His research bridged science and the humanities, investigating the biological outcomes of socio-cultural strategies in human/environment interaction and looking also at forensic applications of physical anthropology. He combined morphological and instrument-analytical approaches to the study of human skeletal remains, and employed ecological and social theory as interpretive frameworks. Key projects included studies of dietary variability amongst human populations of the Near East from the Neolithic to the modern period funded by the Polish Ministry of Science and Higher Education, the interrelationship of diet and status in early medieval Alemannic societies funded by the British Academy, and the Hyksos Enigma funded by the European Research Council. More than forty papers in peer-reviewed journals and conference proceedings resulted from this work, as well as monographs and edited volumes. He served as an associate editor for the *American Journal of Physical Anthropology*, *Environmental Archaeology*, and *Bulletins et mémoires de la Société d'anthropologie de Paris*, and was a regular participant and speaker at international conferences and meetings on both sides of the Atlantic. But despite all these successes at the cutting edge of the discipline, he never lost sight of the importance of teaching. Again, this was an area where

Holger excelled, in which his eloquence and love of precision combined perfectly with his boundless enthusiasm and joy of knowledge sharing with others. In this sense perhaps Holger's most significant legacy is the many great students who were privileged to benefit from his wisdom and insights, and who now carry that forward.

Holger was widely recognized and honoured for his contributions to physical anthropology and bioarchaeology, being elected a Fellow of the Royal Anthropological Institute in 2012, and a longstanding member of the British Association for Biological Anthropology and Osteology (BABAO). He was Chair/President of BABAO from 2004 to 2009, and at the 2018 Annual Meeting in Cranfield was appointed their first Honorary Lifetime Member. He was also a member of the Accreditation Panel for Forensic Practitioners of Royal Anthropological Institute and the British Association for Forensic Anthropology, recognizing the need to integrate academic training with professional practice.

Always happy at heart and unpretentious, he had a wicked sense of humour. It is said that he once laughed so much that he half fell out of his chair at a graduation ceremony in Bradford when the Chancellor, the cricketer Imran Khan, peddled the age-old joke in which a well-known commentator absent-mindedly tells listeners that 'the bowler's Holding, the batsman's Willey'. Preferring small gatherings to large crowds, he espoused down-to-earth wisdom, was calm under pressure, and an unfailing source of sane and sensible advice.

Despite enduring Motor Neurone Disease (MND) for more than five years, Holger was teaching and researching right up until his death, latterly leaving his palliative care unit in order to spend a day at the university giving lectures, attending seminars, and talking to his students and research team. He showed remarkable courage and a positive outlook throughout, asserting that while it could take his physical abilities it could never dull his determination to live life to the fullest. Reflecting on the time living with MND Nivien-Speith remembers how he constantly accepted change and adjusted accordingly: favourite walks became rides in his wheelchair; voice-banked words became bright new lectures, and listening to concerts replaced playing in the orchestra. The whirr of his motorized wheelchair became a familiar sound around the Bournemouth campus, and no-one will forget his impish smile as he swung into view. Stoic to the end, he perhaps sometimes secretly savoured the idea that casts of his teeth would be preserved for ever in the Department's teaching collection.

Jochen Holger Schutkowski, biological anthropologist, was born on September 3, 1956. He died of Motor Neurone Disease (Amyotrophic Lateral Sclerosis) at the age of 63, on March 30, 2020.

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References

1. Schutkowski H (2006) Human ecology. Biocultural adaptations in human communities. Springer, Berlin, p 303
2. Schutkowski H (2008) Between biology and culture. Cambridge University Press, Cambridge 328 p.
3. Schutkowski H (1983) Diagnostic value of the petrous portion of the temporal bone for sex determination. Z Morph Anthrop 74:129–44
4. Schutkowski H (1990) ZurGeschlechtdiagnose von Kinderskelleten. Morphognostische, metrische, und diskriminanzanalytischeUntersuchungen. University of Göttingen
5. Schutkowski H (1989) Age and sex diagnosis of the skeleton of immature individuals. Anthrop Anz 47:1–9
6. Schutkowski H (1993) Sex determination of infant and juvenile skeletons: I. Morphognostic features. Am J Phys Anthropol 90:199–20

Bulletins et Mémoires de la Société d'Anthropologie de Paris (BMSAP)

Recommandations aux auteurs

La Société d'Anthropologie de Paris publie dans ses* Bulletins et Mémoires *des articles originaux, des revues de synthèse ou des notes concernant le champ disciplinaire de l'anthropologie biologique, depuis la paléoanthropologie jusqu'à l'écologie humaine, en passant par la génétique des populations et l'histoire de la discipline. Tous les manuscrits soumis à la revue font l'objet d'un processus d'évaluation (*reviewing*). Pour être publié, chaque article doit :

- ***recueillir les avis favorables des membres du Comité de lecture auquel ils sont soumis***
- ***obéir aux normes de présentation exposées ci-dessous***

1 - Soumission électronique du manuscrit

Le **manuscrit** doit être soumis en un seul fichier au format DOC comprenant successivement texte, légendes des tableaux et des figures, tableaux, illustrations (300 DPI), par e-mail à l'adresse suivante : **redacchef@sapweb.fr**

La **version acceptée du manuscrit** devra être envoyée en plusieurs fichiers distincts : un unique fichier Word (DOC) correspondant au texte, aux tableaux et aux légendes d'une part, et les figures sous la forme de fichiers JPEG, EPS ou TIFF séparés d'autre part.

Il est explicitement convenu que tout manuscrit soumis aux ***Bulletins et Mémoires de la Société d'Anthropologie de Paris*** est un travail original qui n'a pas été publié et qui n'est pas en cours d'évaluation par une autre revue.

2 - Préparation du manuscrit

Le manuscrit sera rédigé en français ou en anglais. Il devra comporter successivement : un **titre** en anglais **et** en français, les **nom, prénom et adresse des auteurs,** l'adresse **e-mail** du contact, des **mots clés** (6 maximum) en français **et** en anglais, un **résumé** en anglais **et** en français (1500 caractères maximum espaces compris), une **version abrégée** facultative (4000 caractères maximum espaces compris) en anglais **ou** en français (dans la langue non utilisée pour l'article), le texte du manuscrit, la liste des références bibliographiques, la liste des tableaux, la liste des figures, les tableaux et les figures. Les pages et les lignes du manuscrit seront numérotées de façon continue dès la page de titre.

Le **texte** du manuscrit (texte, titres et intertitres, notes infrapaginales, abréviations ou sigles, références bibliographiques, légendes des tableaux et figures) n'excédera pas 50 000 caractères (espaces compris) pour un article et 20 000 caractères (espace compris) pour une note. Il sera de préférence rédigé avec la police Times New Roman, 12 pt, en double interligne, et mis en page au format A4 avec des marges de 25 mm.

Titres et intertitres. Le titre principal de l'article n'excédera pas 200 caractères (espaces compris). En outre, le corps du texte de chaque article comportera au maximum 2 niveaux de titres que l'auteur veillera à bien rendre distincts sur son manuscrit. Ceux-ci ne seront pas numérotés.

Les **notes infrapaginales** sont appelées dans le texte par un numéro en chiffres arabes et en exposant, sans crochets ni parenthèses. Elles seront rejetées en bas de page et devront être limitées en nombre et en longueur.

Les **abréviations ou sigles** doivent être explicités lorsqu'ils apparaissent pour la première fois. Les termes scientifiques et techniques, ainsi que les unités de mesures et les symboles statistiques, doivent être conformes aux normes internationales.

Les **références bibliographiques** sont signalées entre [crochets] et numérotées par ordre d'apparition.

- Dans le corps du texte, seul le premier auteur est mentionné suivi de « et al. » lorsqu'il y a plusieurs auteurs (par exemple : « Fisher a montré que… [1] ; Cette hypothèse due à Jablonski et al… [2] ; Deux articles de paléoanthropologie… [3] et [4] »). Dans la mesure du possible, les numéros des références seront placés en fin de phrase.
- Dans la liste des références, celles-ci seront agencées par ordre d'apparition dans le texte. S'il y a quatre auteurs ou plus, seuls les trois premiers seront mentionnés, suivis d'une virgule et de la mention « et al ». Seules les références appelées dans le texte doivent figurer dans la liste de références en fin d'article. Les titres des périodiques sont écrits en respectant les abréviations standard (List of Serial Title Word Abbreviations).

Le **modèle de présentation** est illustré par les exemples suivants :

- Pour un article dans un périodique : Hershkovitz I, Smith P, Sarig R, et al (2011) Middle pleistocene dental remains from Qesem Cave (Israel). Am J Phys Anthropol 144(4):575-92
- Pour un ouvrage : Scheuer JL, Black S (2000) Developmental Juvenile Osteology, Academic Press, San Diego, California, 587 p
- Pour un article dans un ouvrage collectif :

Gomila J (1980) L'Afrique subsaharienne. In: Hiernaux J (ed) La diversité biologique humaine. Masson, Paris, pp 107-196

Les **légendes des tableaux et figures** seront portées en fin de manuscrit, sur une feuille séparée du texte avec leur traduction en anglais ou en français. Chaque légende doit être suffisamment explicite par elle-même, sans qu'il soit nécessaire de se référer au texte. Les auteurs veilleront toutefois à limiter leur longueur. La numérotation des tableaux (en chiffres arabes) et des figures (en chiffres arabes) se fait selon leur ordre d'apparition dans le texte.

Les **tableaux** seront fournis au format word, présentés sur des pages séparées et placés à la fin du document texte.

Les **illustrations** seront fournies aux formats JPEG, AI ou EPS, avec une résolution minimale de 600 dpi et doivent être composées avec une largeur correspondant à une colonne (8,5 cm), une colonne et demi (12 cm) ou deux colonnes (17,5 cm) de l'article imprimé ; les textes des illustrations sont écrits en police Times New Roman, 10 pt (taille d'impression) et 11 pt pour les titres.

Les images seront reproduites par défaut en couleur dans la version électronique et en noir et blanc dans la version imprimée. Les images couleur devront être fournies dans une qualité permettant le transfert en niveaux de gris.

Rappel des points à vérifier avant de soumettre votre article :

- Titres, résumés et mots clés en français et en anglais
- Affiliation et coordonnées complètes de chacun des auteurs, auteur correspondant et co-auteurs
- Références citées dans le texte, numérotées par ordre d'apparition dans le texte et mises en forme selon les règles
- Appels dans le texte entre crochets du numéro des références citées
- Titres des tableaux et appels des tableaux dans le texte
- Légendes des figures et appels des figures dans le texte
- Attention spéciale à la qualité de la langue utilisée, français et/ou anglais

Bulletins et Mémoires de la Société d'Anthropologie de Paris (BMSAP)

Guidelines to authors

The Société d'Anthropologie de Paris publishes in its* Bulletins et Mémoires *original articles, reviews of works or notes in the field of biological anthropology, from the palaeoanthropology to the human ecology and population genetics, and the history of the discipline. All submitted manuscripts are evaluated during a reviewing process. Publication of articles is subject to the following conditions:

- ***approval by members of the Review Committee to which it is submitted;***
- ***adherence to the standards of presentation set out below.***

1 - Electronic submission of Manuscript

The **manuscript** including text, tables, illustrations (300 DPI) and their captions must be submitted as a single DOC file by e-mail to **redacchef@sapweb.fr**

The **accepted version of the manuscript** will be sent as separate files: a single Word text file (DOC) including the text, tables and captions on the one hand, and the illustrations as separate JPEG, EPS or TIFF files on the other hand.

The author guarantees that his/her contribution is original. It is assumed that all manuscripts sent to the ***Bulletins et Mémoires de la Société d'Anthropologie de Paris*** is an original paper which has not been published before and which is not evaluated in another Journal.

2 - Preparation of manuscript

The manuscript must be written in either English or French. It must include successively: the **title** in both English **and** French, the **name**, **surnames** and **address of the authors,** the **email** address of the corresponding author, keywords (maximum of 6) in both English **and** French, an **abstract** in both English **and** French (1,500 characters including spaces), a facultative **abridged version** (4,000 characters including spaces) in either English **or** French (depending on the language of the manuscript), the text of the manuscript, the list of bibliographic references, the list of tables, the list of figures, the tables and the figures. Each page and line of the manuscript must be sequentially numerated from the title page.

The **text** of the manuscript (text, titles and headings, footnotes, abbreviations, bibliogaphical references, captions for tables and figures) should not exceed 50,000 characters (including spaces) for an article and 20,000 characters (including spaces) for a note. It will be preferentially written using the font Times New Roman 12 pt, double spaced, A4 page size with margin of 25 mm.

Titles and headings. The main title of the article will not exceed 200 characters (including spaces). In addition, the text of each article will contain a maximum of 2 clearly distinct title levels. They will not be numbered.

Footnotes are noted in the text by Arabic numerals and in superscript, without brackets or parenthesis. They are to be placed at the bottom of the page and should be limited in number and in length.

Abbreviations or **initials** must be explained when they appear for the first time. Scientific and technical terms, as well as units of measurement and statistical symbols, must conform to international norms.

Bibliographical references are indicated using [brackets] and numbered in their order of appearance in the text.

- In the text, only the first author is listed. It is followed by a comma and the words "et al." When there are many authors (example: "Fisher showed that… [1] ; This hypothese formulated by Jablonski et al… [2] ; Two articles in paleoanthropology… [3] and [4]"). Wherever possible, the numbers of references are to be placed at the end of the sentence.
- The reference list is organised in alphabetical order of the authors cited and in chronological order of the publications for each author. All authors are listed if there are three or less. If there are more than three, only three are listed first, followed by a comma and the words "et al". The titles of journals should be abbreviated according to standard abbreviations (List of Serial Title Word Abbreviations).

The **presentation model** is illustrated by the following examples:

- For an article in a journal: Hershkovitz I, Smith P, Sarig R, et al (2011) Middle pleistocene dental remains from Qesem Cave (Israel). Am J Phys Anthropol 144(4):575-592
- For a book: Scheuer JL, Black S (2000) Developmental Juvenile Osteology, Academic Press, San Diego, California, 587 p
- For an article in a collective work: Gomila J (1980) L'Afrique subsaharienne. In: Hiernaux J (ed) La diversité biologique humaine. Masson, Paris, pp 107-196

The **captions for tables and figures** will be presented on a separate page at the end of the manuscript, with a French or English translation. Each caption must be explicit enough in itself, so that reference to the text is not necessary. The numbering of the tables (in Arabic numerals) and figures (in Arabic numerals) must follow the order in which they appear.

The **tables** must be presented in Word format, on separated pages, and provided at the end of the text document.

The **illustrations** must be provided in JPEG, AI or EPS format, with a minimum resolution of 600 DPI. Illustrations must be composed with a width of one column (8,5cm), one column and half (12cm) or two columns (17,5cm) of the printed paper. The text of illustrations must be written in police Times New Roman, 10 pt (printed size) and 11pt for titles.

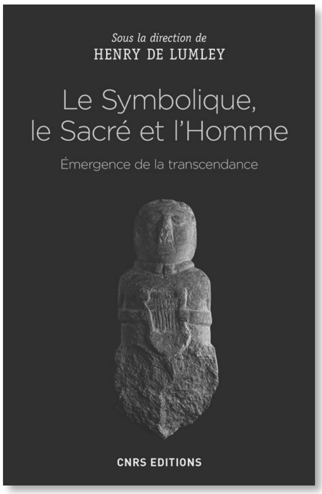
Color art is free of charge for online publication. If black and white will be shown in the print version, make sure that the main information will still be visible. Many colors are not distinguishable from one another when converted to black and white. A simple way to check this is to make a xerographic copy to see if the necessary distinctions between the different colors are still apparent. If the figures will be printed in black and white, do not refer to color in the captions. Color illustrations should be submitted as RGB (8 bits per channel).

Items to verify before manuscript submission:

- Title, keywords and abstract in both French and English
- Full contact details of each author, corresponding author and co-authors
- References numbered alphabetically and formatted following the guidelines
- Quotations in the text of the reference number in square brackets
- Title of tables and call for tables in the text
- Caption of figures and call for figures in the text
- Special attention to the quality of the language used, French and/or English.

Le Symbolique, le Sacré et l'Homme

Sous la direction de Henry de Lumley



L'Homme, cet être vivant doué de raison, fabricant d'objets élaborés, doté d'un langage articulé, chez lequel a émergé la pensée conceptuelle et symbolique, se caractérise par une aptitude à l'émerveillement, et une capacité d'espérance accompagnée d'un refus de l'absurde. Avec l'invention de l'outil manufacturé et les premiers témoignages d'une pensée symbolique, comment la fabuleuse aventure culturelle et spirituelle de l'Homme a-t-elle débuté ? Pourquoi à travers les temps, même les plus anciens, et dans toutes les cultures, l'émergence du sens de la transcendance n'a-t-il cessé de se manifester et de s'inscrire au cœur de notre humanité ? Comment est-il devenu une caractéristique de l'Homme, une de ses aspirations profondes ? Comment définir le sens du sacré ?

C'est de cette dimension intrinsèquement humaine, et des traces qu'elle a laissées, qu'il est ici question. Après L'Univers, la Vie et l'Homme : émergence du sens de la Conscience et Le Beau, l'Art et l'Homme : émergence du sens de l'Esthétique, voici le troisième et dernier opus dirigé par Henry de Lumley, issu d'un cycle de conférences au Collège des Bernardins. L'ambition de ces rencontres ? Faire dialoguer physiciens, astrophysiciens, géologues, biologistes, paléoanthropologues, préhistoriens, historiens de l'art, philosophes et théologiens autour de questions qui ont trait à l'essence de l'humanité.

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