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The human remains from the Lumentxa cave (Lekeitio, Biscay, Northern Iberian Peninsula): Paleobiology, Taphonomy and Chronology

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Abstract:

Lumentxa is a classic site in Basque Prehistory, excavated in three different phases during the 20th century, which has yielded evidence of both Pleistocene and Holocene occupations. In this article, we present a detailed study of the human remains from this site including paleobiological, taphonomic, biomechanical and chronological perspectives. The human assemblage comprises of a minimum number of seven individuals: three subadult and four adults, with both sexes represented, although part of the human collection is currently lost. We have obtained C14 dates from 4 of these 7 individuals indicating a prolonged funerary use of the cave from the Early Neolithic until the Bronze Age. We observed some biases in the skeletal representation which could be due to differences in the excavation methods between field seasons and/or the action of carnivores, the latter being evident in at least three of the individuals. The taphonomic modifications are typical of those found in the post-abandonment phases in cave funerary contexts. The relatively low number of individuals compared with other sites in the region and extended timespan over which the remains were deposited suggest that the cave was used only sporadically for funerary purposes. We report the first biomechanical data for a Neolithic individual from the Iberian Peninsula, which show greatest overall similarity to the Neolithic sample from France and Italy. Finally, the broad time period covered by the direct dates and the more complex taphonomic history than was previously assumed for such sites indicate that caution is warranted when assigning sepulchral caves to cultural periods in the Western Pyrenees when no direct ¹⁴C dates have been obtained.

Key words: Recent Prehistory; Biomechanics; Long bones; Radiocarbon dates; Funerary practices.

1. Introduction

During the Holocene, the last hunter-gatherers and the first farming societies in the Iberian Peninsula show variation in their mortuary practices with chronological and regional differences in their ways of treating their dead (Arias, 2012a; López-Onaindia and Subirà, 2017). Most of the variation in mortuary practices refer to differences in funerary treatment, and the types of funerary locations used, which include caves, rockshelters, megalithic structures and open-air sites (Armendáriz, 1992; Armendáriz and Etxeberria, 1995; Ontañón and Armendáriz, 2005; Fernández-Crespo, 2010, 2015, 2016). Additionally, there is scant evidence of cannibalism in the Bronze age (Cáceres et al., 2007). However, there is a dearth of systematic taphonomic studies of the human remains recovered from cave deposits, which could give greater insight into the treatment of the human remains both at the time of deposition and in subsequent manipulation or disturbance by both human and other factors (González Rabanal et al., 2017; Saladié and Rodríguez-Hidalgo, 2017).

The Western Pyrenees (WP) is an area of special interest due to its geography and ecological particularities (Arrizabalaga and Rios-Garaizar, 2012). First, it serves as a passage between the Iberian Peninsula and the rest of Europe and has been an important cultural and biological corridor (Arias Cabal, 2012a; Gómez-Olivencia et al., 2014). Second, this area encompasses coastal and mountainous areas, as well as the peripheral areas of the Iberian plateau, resulting in a diversity of landscapes and ecological conditions in a relatively small area.

Primary individual burials were predominant during the Palaeolithic, Mesolithic and Early Neolithic (Armendáriz, 1999; Pettit, 2011), until the end of the 5th millennium BCE (before Common Era), when collective burials increased in frequency. In the individual burials, each skeleton is found isolated (and/or in a specific pit), while in the second one all skeletons are found in the same place. The latter could be due to the accumulation of single individuals buried diachronically, and/or due to simultaneous burial in form of mass grave, for example due to disease outbreak or interpersonal violence (Armendáriz and Etxeberria, 1983; Armendáriz, 1992, 1999).

During the Mesolithic, both open-air sites and caves were used for funerary purposes (Arias and Cubas, 2018), where the skeletons were buried laterally flexed in individual graves (Armendáriz, 1999; Cubas et al., 2016). Examples in WP include J3 (8,300 ± 50 BP; 7,492-7,184 cal BCE -before Common Era-) and Linatzeta (7,315 ± 35 BP; 6,236-6,077 cal BCE). In J3, a male adult was found who may have been tied or wrapped (Álvarez-Fernández et al., 2010; Iriarte et al., 2010), while in Linatzeta the skeleton belonged to a 6-month-old infant (Tapia et al., 2008). In other sites in the Cantabrian and Asturian region such as El Truchiro (6th millennium BCE) or Tito Bustillo (8,470 ± 50 BP; 7,593-7,472 cal BCE) (Arias Cabal, 2012b), the skeletons were also found in the same laterally flexed position. The burials from Los Canes (7th-6th millennium BCE) are notable: five individuals were found in what was thought to be a collective burial, but it has been subsequently demonstrated that the skeletons were buried individually and the graves were reused (Cubas et al., 2016; Arias and Cubas, 2018).

The neolithization process in northern Iberian Peninsula began with a different chronology and with a different dynamic compared with the rest of Iberia and was more similar to the Atlantic coast of Europe (Cubas et al., 2016). The discovery of barley and coated wheat in caves such as El Mirón (Cantabria), Lumentxa, Kobaederra and Pico Ramos (Basque Country) and cereal pollen in Herriko Barra (Basque Country) locate the beginning of agriculture around the late 6th-early 5th millennium BCE (Zapata, 2002; Peña-Chocarro et al., 2005; Zapata et al., 2005). This would coincide with the persistence of Mesolithic populations in the region (Fano et al., 2015; Cubas et al., 2016). The megalithic phenomenon started in the mid-5th millennium BCE in the north of the Peninsula (Ontañón and Armendáriz, 2005; López-Onaindia and Subirà, 2017; Arias and Cubas, 2018), with a major presence around 4,000-3,900 BCE (4th millennium), suggesting that their construction was limited to a relatively short period of time (Arias Cabal, 2012a; Cubas et al., 2016; Arias and Cubas, 2018).

During the Neolithic, collective burials more frequently took place in megaliths than in caves/rockshelters (Armendáriz, 1992, 1999; Fernández-Crespo, 2010; Arias Cabal, 2012a). During the second half of the 4th millennium (Late Neolithic), the use of the megaliths, although still predominant (Arias Cabal, 2012; López-Onaindia and Subirà, 2017), started to decline, and the use of caves and rockshelters increased. There are some examples of entirely sepulchral caves dated to this millennium, like Pico Ramos (Muskiz, Biscay; *n* = 104) or Urtao II (Oñati, Gipuzkoa; *n* = 51).

Signs of interpersonal violence have been identified in some of the Neolithic collective burials (Etxeberria and Herrasti, 2007; Fernández-Crespo and De la Rúa, 2015), probably resulting from warfare (Armendáriz, 1999; Fernández-Crespo, 2007). The site of San Juan Ante Portam Latinam, which yielded 338 individuals, is well known for the discovery of several individuals who died during warfare and were buried simultaneously (Etxeberria and Vegas, 1988; Etxeberria and Herrasti, 2007; Fernández-Crespo, 2007). Additionally, there is evidence for the rearrangement of some individuals, mostly cranial remains, into a corner in order to leave more space for new inhumations (Fernández-Crespo et al., 2018). Another interesting characteristic of this site is that it is geographically surrounded by several megalith structures (Vegas et al., 1999, 2012; Fernández-Crespo and De la Rúa, 2015).

In the Chalcolithic period, the use of the sepulchral caves coincides with the decreased use of megaliths, and a preference for reusing existing structures rather than constructing new ones (Armendáriz, 1990; Fernández-Crespo, 2007; Cubas et al., 2016; Fernández-Crespo and De la Rúa, 2016; López-Onaindia and Subirà, 2017; Arias and Cubas, 2018). The intensity of megalith use continued to decrease in the 3rd millennium BCE, especially in the Late Chalcolithic and Early Bronze Age (Arias Cabal, 2012a; Fernández-Crespo and De la Rúa, 2015; Fernández-Crespo, 2015, 2016; Cubas et al., 2016; Arias and Cubas, 2018).

Caves were commonly used until the Bronze Age (Ontañón and Armendáriz, 2005), but they were used for occupation as well as funerary purposes (Armendáriz, 1992). In this period, collective burials were also predominant, and continued for most of the Bronze Age (Armendáriz, 1992; Arias Cabal et al., 2005).

There are geographical differences in the use of megaliths vs. caves/rockshelters as funerary sites: megaliths tend to be found at high altitudes, while caves are normally used at lower altitudes (Ontañón and Armendáriz, 2005; Arias Cabal et al., 2005; Arias Cabal, 2012a). This difference could derive from the need to control the landscape and be close to streams (Ontañón and Armendáriz, 2005; Fernández-Crespo and De la Rúa, 2016).

Both in megaliths and caves, all age groups and both sexes are represented (Armendáriz and Etxeberria, 1983; Ontañón and Armendáriz, 2005; Arias Cabal, 2012a; Cubas et al., 2016), but higher numbers of adult males in megaliths and of adult females in caves has been observed (Fernández-Crespo and De la Rúa, 2015, 2016).

The study of recent prehistoric populations has been very variable in the WP. There are detailed reports for some sites (e.g., Santimamiñe, Pico Ramos or San Juan Ante Portam Latinam; De la Rúa, 1990; Zapata, 1995; Baraybar and De la Rúa, 1995; Etxeberria and Herrasti, 2007; Herrasti and Etxeberria, 2011; López Quintana et al., 2015; Fernández-Crespo et al., 2018). Others, despite having been the focus of ancient DNA analysis, have not been studied in detail until very recently (e.g., Atxuri; García-Sagastibelza, 2017; García-Sagastibelza et al., in this volume). We also lack a general understanding of the Holocene dwellers of WP, with little basic information such as average stature, lifestyle and mortuary behaviour, both due to preservation bias but also because many studies have centred on the cranium. The application of taphonomic and forensic techniques have provided important new insights into the mortuary practices of extinct species (Sala et al., 2015a, 2015b; Rougier et al., 2016; Gómez-Olivencia et al., 2018a), but these techniques have only been partially applied recent prehistoric sites in the WP, specifically to certain sites with evidence of violence (Etxeberria and Herrasti, 2007; Fernández-Crespo, 2007, 2015; Fernández-Crespo et al., 2018). Finally, advances in imaging techniques offer new ways to study long bones which can provide important information regarding the paleobiology of past human populations, including important aspects such as sexual dimorphism, mobility or subsistence strategy (Rodríguez et al., 2018; Ruff, 2018a, Sparacello et al., 2018), but such methods have not been widely applied in the Iberian Peninsula (but see Ruff and Garvin 2018).

Biomechanical studies of the long bones can provide relevant information about the lifestyle of past populations (Ruff, 2008), as the upper and lower limb bones are involved in various activities like manipulation or locomotion respectively. Bone adapts functionally to the mechanical loading it experiences during life through by the addition of bone tissue in areas experiencing greatest loads, and the resorption of bone in regions under lower mechanical stress (Ruff and Hayes, 1983; Pearson and Lieberman 2004; Ruff et al. 2006; Ruff 2008). By examining the cross-sectional geometric properties (CSGP) of long bone shafts, we can infer past behavioural patterns such as the degree of bilateral asymmetry in upper limb use, gendered differences in mobility and labour patterns, or the impact of changes in subsistence strategy on lifestyle (e.g., Macintosh et al., 2013; Stock and Macintosh, 2016; Rodríguez et al., 2018; Ruff, 2018a). A common observation is that the transition to food production and more sedentary lifestyles is associated with decreased habitual mobility (Ruff and Hayes, 1983; Holt et al., 2018a), especially among males, that is reflected in decreased lower limb bone robusticity (biomechanical properties adjusted to mechanically relevant measures of body size). For certain European regions, long-term studies of the evolution of biomechanical variables

have been possible (e.g., Holt et al., 2018b). However, for the Iberian Peninsula, biomechanical data from Holocene populations is restricted to a few Mesolithic individuals from Moita de Sebastiao (5 males), Muge Arruda (1 male), Los Canes and the Argar populations of Terrera del Reloj (2 males) and Castellon Alto (15 males), and there is so far no data from the Neolithic (Ruff and Garvin, 2018).

In this context, Lumentxa is a classic site for which the presence of human remains was reported more than 90 years ago (Aranzadi, 1929). Preliminary studies have demonstrated the diachronic use of this cave for funerary purposes (Arribas Pastor, 1993; Arias Cabal, 2012a; García-Sagastibelza et al., 2018, 2019), yet we lack a detailed study of the whole human bone assemblage. The principal aim of this article is to present a complete anthropological study of the human remains from the site, including a taphonomic study to provide insights into funerary behaviour, new direct C14 dates of some of the individuals to refine the chronology of site use, and the first biomechanical information from an individual from the Neolithic ($5,105 \pm 80$ BP; 4,147-3,700 cal BCE) of this region. We finally discuss the new results in the context of the new information gathered from the excavation of this site and with the known general context for the Western Pyrenees.

2. The Lumentxa cave site

Lumentxa cave (Lekeitio, Biscay, Northern Iberian Peninsula) is located on the hillside of Calvario, a mountain in Kakueta (Arribas Pastor, 1997; Garate Maidagan et al., 2013), at 70 meters above sea level, near the mouth of the Lea river, in the bay of Lekeitio (Figure 1 a-c).

[INSERT FIGURE 1]

The entrance (2.5 x 3.5 m) of the cave is oriented to the south-west (Garate Maidagan, 2012) and connects with a large four-sided hall (18 x 9 m, area of c. 200 m²) where the archaeological excavations took place. To the left of the main hall, there is a small gallery. At the end of the main hall is a small curved gallery which connects with a corridor leading to a gallery of 50 m of length that represents the end of the cave (Figure 1d).

The archaeological site in the cave was discovered on August 12th 1921 by José Miguel de Barandiarán, Nicolás de Arroita and Eustasio de Arritola (Aranzadi and Barandiarán, 1935). Three archaeological excavations took place at different times during the 20th century, recovering a rich archaeo-paleontological record that spans the Upper Palaeolithic through to the historic (Roman) period (Aranzadi and Barandiarán, 1935; Barandiarán Maestu, 1967; Garate Maidagan, 2012; Arribas Pastor and Berganza Gochi, 2018). The first excavation was directed by Telesforo de Aranzadi and José Miguel de Barandiarán between 1926 and 1929. Barandiarán alone directed further excavations between 1963 and 1964, and more recently (1984-1993), the cave was excavated under the direction of one of us (JLA). The first excavations were organised in trenches, but during the second phase of excavations, a complete plan was made using grid squares, on which the locations of the previous excavations were also recorded (Figure 1d). In parallel, the entire collection of finds from the 1920's was reorganised into the grid system (Arribas Pastor and Berganza Gochi, 2018). The cave's proximity to the village of Lekeitio, as well as the easy access to its entrance, have

facilitated the visits of many people since the second half of the 19th century, which has damaged the site.

The Upper Paleolithic levels yielded a rich assemblage, comprising lithic industry (mainly burins and scrapers), worked bones (spear-heads, harpoons, burins and some perforated faunal teeth; Garate Maidagan, 2012), remains of wild fauna, including reindeer (Castaños, 1986; Gómez-Olivencia et al., 2014), and an abundance of molluscs (Barandiarán, 1966; González Sainz, 1989). More recently, evidence of cave art was discovered: Garate Maidagan and collaborators (2013) found three zoomorphic (two bison and a horse) and 25 ideomorphic representations (lines, points and patches) in several galleries. Additionally, other unusual finds have been made, including a wall structure, one flint inserted on the wall or one patch of ochre processed on a hanging platform. These characteristics are directly associated with artistic activities during the Recent Magdalenian at the Cantabrian-Pyrenean area (Garate Maidagan et al., 2013).

The more recent excavations directed by Arribas in a different sector of the cave unearthed a sedimentary sequence in which only Holocene levels were excavated. Three levels were discovered, but this excavation mostly concentrated on the first two levels (level I and II). The sequence comprises Roman and recent prehistoric occupations (Arribas Pastor and Berganza Gochi, 2018). Level I is the result of a mix of modern and prehistoric material. Level IIA is a mix of Roman (mainly “Terra sigillata” and “Common local” pottery, assigned to the 4th century BCE) and modern materials (Arribas Pastor and Berganza Gochi, 2018). Layers IIB and IIC have yielded Bronze Age, Chalcolithic and Late Neolithic remains, mainly pottery, with a few flint lithics and some worked bone (Arribas Pastor and Berganza Gochi, 2018).

The faunal assemblage is dominated by domestic animals (ovicaprines, bovine and porcine), with occasional wild animals (wild boar, red and roe deer, and fox), fish, and molluscs (Arribas Pastor and Berganza Gochi, 2018). Finally, a small quantity of microfaunal remains have been reported from Levels IIB, IIC and III, dominated by *Apodemus sylvaticus-flavicollis* and *Anguis fragilis* (Suárez-Bilbao et al., 2018).

2.1 The human remain collection from Lumentxa

During the first excavation period, a total of 25 human remains were recovered. Eight of these remains were recorded in the excavation diary (Aranzadi and Barandiarán, 1935), so that information about their recovery is available. However, there is uncertainty about the locations of and possible connections between the other remains.

The first anthropological studies described a subadult cranium and mandible recovered in 1928, along with five other human remains (Aranzadi, 1929; Aranzadi and Barandiarán, 1935), which are not currently housed in the Arkeologi Museoa (Bilbao, Biscay). Arias Cabal (2012b) directly radiocarbon dated one fibula from this excavation phase to $6,122 \pm 38$ BP (4,724–4,523 cal BCE.), i.e. Mesolithic or Early Neolithic period. Isotopic analyses suggested a high level of consumption of marine foods or animal protein (Arias Cabal, 2012b; Arias and Cubas, 2018).

The second period of excavation (1963–1964) only yielded six human remains. Four of them were recovered from Level II, which was characterised by the presence of pottery and assigned to the Neolithic and the Bronze Age due to the similarity with

material from Santimamiñe (Barandiarán, 1966). The exact provenance of other two of these human remains is unknown.

One hundred and seventy-five human remains were recovered during the third excavation phase directed by one of us (J.L.A.; 1984-1993): 108 of these came from the Late Neolithic layer (IIC layer), 55 from the Chalcolithic-Bronze Age layer (Level IIB) and six from the mixed Late Roman and modern materials (Level IIA). Six remains have no stratigraphic context.

3. Materials

We have studied all the human remains from Lumentxa cave curated at the Arkeologi Museoa (Bilbao, Biscay). The collection consists of 213 human remains (222 before refits). There is no evidence that six of the remains mentioned in Aranzadi (1929) were stored at the Arkeologi Museoa, so these were unavailable for study.

Comparative data on stature and body mass from Mesolithic and Bronze Age samples from the Iberian Peninsula were selected (Ruff and Garvin, 2018), along with Neolithic data from Caño Bajo (Valera Pérez, 2013), Cerro Ortega (Feucht et al., 1999), San Juan Ante Portam Latinam (Vegas et al., 2007; this study) and Segudet (Yáñez et al., 2002).

For the biomechanical study, data from various European comparative samples were used, given the lack of comparative data from the study region. Because in Europe, modern humans have shown a general decline in skeletal robusticity since the Palaeolithic to the present interpreted as reflecting a long term trend for decreased habitual activity and mobility (Ruff et al. 2015; Ruff 2018a, 2018b; Cox et al., 2019), European comparative samples from a wide range of time periods were employed to help to put our results into context and offer preliminary interpretations of activity patterns (while recognising the limitations of our sample size).

For the humerus, comparative samples from Mesolithic and Bronze Age from the Iberian Peninsula came from Ruff and Garvin (2018). Comparative data from Neolithic sites in France and Italy were included in the study (Holt et al., 2018b).

For the femur, Mesolithic and Bronze Age samples from the Iberian Peninsula were selected from Ruff and Garvin (2018), while Mesolithic, Neolithic and Bronze Age samples from France and Italy were obtained from Holt et al. (2018b). A femur from Atxuri I ($3,570 \pm 30$ BP) has also used for comparisons (García-Sagastibelza et al., in this volume). When data were available from both femora of an individual, the mean of right and left was used in analyses (Trinkaus and Ruff, 2012).

A sample dating to the 7th-8th century from the Jau-Dignac-et-Loirac commune, near the Gironde estuary (Nouvelle Aquitaine, France: Cartron and Castex, 2006, 2010, Deguilloux et al., 2014; d’Incau et al., 2015) was also included in this study. CT-scans of 18 of the 65 individuals from this site were available for analyses (9 males and 9 females).

4. Methods

4.1. Age-at-death and dental discrete traits

In non-adult individuals, we studied the degree of calcification and eruption of the dentition (Crétot, 1978; Buikstra and Ubelaker, 1994; AlQahtani et al., 2010) as well as the general size and degree of fusion of the secondary centres of ossification (Scheuer and Black, 2000; White and Folkens, 2005). CT-scans of two subadult mandibles were made, to try to offer a more accurate age estimate. In adults we estimated the age-at-death from dental wear (Brothwell, 1981; Lovejoy, 1985; Buikstra and Ubelaker, 1994).

4.2 Sex

Due to the absence of pelvises and complete cranial bones, qualitative characters of the mandibles were assessed (Bass, 2005), mainly the mental eminence (Buikstra and Ubelaker, 1994). Moreover, some measurements in complete humeri and femora were also used for sex determination (Buikstra and Ubelaker, 1994).

4.3 Stature and Body mass estimation

Stature was estimated for adults using maximum femur length, following the formula of Ruff et al. (2012).

Body mass (BM) was estimated in adult individuals from femoral head diameter (FHD). For FHDs smaller than 38 mm, the formula of McHenry (1992) was used, while an average of three formulae (Ruff et al. 1991; McHenry, 1992; Grine et al., 1995) was used for FHDs between 38 and 47 mm. For FHDs larger than 48 mm, an average of the formulae of Ruff et al. (1991) and Grine et al. (1995) was used (Auerbach and Ruff, 2004, 2006; Trinkaus and Ruff, 2012; Sparacello et al., 2018).

4.4 CT-scans

CT-scans of the complete long bones (for biomechanical analyses) and two mandibles (in order to assess the age-at-death) from Lumentxa were performed at the IMQ Zorrotzaurre Hospital using the Siemens Definition As 20, with a source energy setting of 120 kv/180 mAs, slice thickness was collimated to 0.6 mm, and a slice increment of 0.6 mm. The images obtained were exported as DICOM files. These CT scans are available with the identifier <https://doi.org/10.6084/m9.figshare.12254942>. The Jau-Dignac-et-Loirac femora, were scanned in Tivoli Medical Center in Bordeaux.

4.5 Biomechanical analysis

The study of the biomechanical properties is restricted to individual 5 (one humerus and one femur) due to skeletal preservation and completeness. The 3D models of the bones derived from the CT-scans were aligned and the cross-sectional geometric properties (CSGP) of the bones were quantified in ImageJ (rsbweb.nih.gov/ij/), using the plugins BoneJ (Doube et al., 2010) and MomentMacroJ (Ruff, 2006; www.hopkinsmedicine.org/fae/mmacro.html).

The CSGP chosen for this study are percent cortical area (%CA) and polar section modulus (Z_p), although other biomechanical properties are also reported in the supplementary tables as a matter of record (see supplementary Table S1 for details).

Percent cortical area (%CA) is a measure of relative cortical area relative to the total area of the cross section that reflects axial loading (body mass and activity levels), as well as other lifestyle factors like nutrition (e.g. Garn et al. 1967; Ruff, 2008; Mays et al 2009; Robbins Schug 2011; Rodríguez et al., 2018; Ruff, 2018b). The polar section modulus (Z_p) represents the torsional and average bending strength and is used as an indicator of the overall mechanical loading on bone (Ruff, 2002, 2008; Trinkaus and Ruff, 2012; Pomeroy et al., 2018; Rodríguez et al., 2018; Ruff, 2018b).

The most relevant CSGP section in the femur for the analysis of activity patterns is the midshaft (50% section of the biomechanical length measured from the distal end), while in the humerus the cross section at 35% from the distal end is typically analysed, to avoid the undue influence of the deltoid tuberosity (Ruff, 2018a). However, data from other cross-sectional locations are reported in the appendices to make them available for future studies.

As the robusticity of the long bones is influenced by body mass and limb lengths in addition to physical activity (Ruff et al., 1991; Marchi et al., 2006; Ruff, 2008), CSGP data must be standardised to remove the effects of these parameters (Ruff et al., 1991; Ruff, 2000; Davies et al., 2014). The polar section modulus (Z_p) was standardized by dividing by the product of body mass and bone length (Ruff, 2000, 2002, 2018b; Sparacello et al., 2018). %CA is by its nature self-standardising.

4.6 Paleopathological lesions and dental non-metric traits

All the bones were examined macroscopically for anomalies, that could constitute pathological lesions. All the lesions of the vertebrae were recorded using a numerical code in order to indicate the presence as well as the degree of development of these anomalies on the surface and edges of the articular facets and vertebral bodies (Dawson and Trinkaus, 1997, based on Trinkaus, 1985).

To evaluate whether individuals may have had scoliosis, the height of the vertebral body and articular pillars of the vertebrae were measured to document any asymmetries.

Dental pathologies were also evaluated and studied, focusing on the presence and location of caries, dental calculus and alveolar reabsorption (< 3mm, 3-6 mm, > 6mm) as an indicator of periodontal pathology, as well as the presence of enamel hypoplasia.

In addition, we studied the non-metric traits from the permanent dentition following the ASUDAS method (Turner et al., 1991).

4.7 Direct radiocarbon dating of human remains

Two previous direct dates on human remains, corresponding to two different individuals, were available (Arias Cabal, 2012b; Arribas Pastor and Berganza Gochi, 2018; García-Sagastibelza et al., 2018). Five additional human remains, belonging to at least another three individuals were submitted for direct dating: two samples were sent to the Beta Analytics Inc (Florida, USA) and three samples to Centro Nacional de Aceleradores (Sevilla, Spain). One of the latter samples (one premolar; label: L.14Z.455.2) could not be dated, due to the lack of collagen. These new radiocarbon

dates of the human bone samples were obtained with AMS methodology, which is more suitable for this material, since it needs a smaller sample, ca. one gram, than traditional radiometric methods.

While the collagen of samples analysed in Beta Analytics (Florida, USA) was obtained using the standard collagen extraction including alkali pretreatments, collagen from the samples prepared at the Centro Nacional de Aceleradores (CNA; Seville; Spain), was obtained following a modified version of the so called “Longin collagen method” (Longin, 1971) with the addition of the ultrafiltration step (Higham et al., 2006).

The new and previously published dates were calibrated using Oxcal v.4.3 software (Bronk Ramsey, 1998; 2009) and Intcal13 calibration curve (Reimer et al. 2013).

4.8 Taphonomic analysis

For the taphonomic analysis, 180 remains were examined, of which 77 (42% NISP) are complete, including several long bones (2 humeri, 2 radii, 1 ulna, 1 femur and 2 fibulae) and various flat bones (cranial remains, 1 scapula and articular remains). Dental remains were excluded. The taphonomic analysis was performed using standardised methods and techniques (Henderson 1987; White 1992; Lyman, 1994; Pokines and Symes, 2013). Both taphonomic modifications on the surface of the bones and the fracture analysis were studied, looking for fossildiagenetic (Behrensmeyer, 1975; Fernández-Jalvo and Andrews, 2016) and biostratinomic modifications, specially modification by carnivores (Binford, 2014).

Trampling was identified following Domínguez-Rodrigo et al. (2009). To assess the degree of fragmentation and the condition of the bones at the time of breakage, the methodology of Bunn (1983) modified by Villa and Mahieu (1991) was followed.

In the case of the crania, ribs, scapulae, coxal bones and vertebrae, the type of fracture was described, although in some cases it was not possible to determine reliably the cause of fragmentation.

Damage attributable to cremation was described by colour, using the six-degree scale proposed by Stiner et al. (1995). Other modifications associated with postdepositional processes were also identified, such as modification by plant roots, chemical erosion, biochemical marks, manganese and iron oxide staining, cementation and trampling (Fiorillo, 1989; Lyman, 1994; Domínguez-Rodrigo and Barba, 2006; Pokines and Symes, 2013).

5. Results

A minimum of 7 individuals are represented in the Lumentxa human osteological collection: 170 remains (182 before refitting) were assigned to these individuals, one of which being the individual studied by Aranzadi (1929). Forty-three remains (46 before refitting) were not assigned to any individual. The number of anatomical elements assigned to each individual is detailed in Table 1, while the anatomical representation of the identified individuals is summarised in Table 2. The

age-at-death estimates are summarised in Table 3 and the C14 dates for the Lumentxa specimens and their chronology can be seen in Table 4.

The new four samples sent for radiocarbon dating preserved good collagen quality, as they show acceptable extraction yield, and all the samples' C:N ratio is between 2.9 and 3.3 with good concentrations for both C and N (van Klinken, 1999). In addition, all the new dates display small standard deviations (Table 4).

The six available direct dates from human remains for Lumentxa have helped in reconstructing the chronology of the inhumations at this site. In this sense, the combination of the six dates provide four different chronologies (Figure 2), which comprises a range of 3,000 years spanning from the Early Neolithic (Arias and Cubas, 2018) until the Bronze Age. These four timeframes correspond to four of the individuals recovered from the cave and allowed us to determine the number of adult individuals (individuals 3 to 6). Two of the new dates – CAN 5113.1.1 and Beta-493405 – belong to the Chalcolithic period and likely correspond to the same individual considering the high overlap of the date span, Individual 4. None of the new dates coincides with the chronology of Ua-12665, which belongs to a burial from the Neolithic. Finally, one of the new dates – CNA 5114.1.1 – is very close to and overlaps with the date obtained by Arias Cabal (2012b), indicating that both likely belong to the same individual and reinforcing the validity of these dates.

[INSERT FIGURE 2 & TABLES 1-4 HERE]

Selected taphonomic traits observed in the different individuals, as well as the modifications associated with carnivore activities are shown in Figure 3. All the different taphonomic modifications are documented in Table 5. These results are considered below for each individual, in order to reconstruct their distinct taphonomic histories.

[INSERT FIGURE 3 & TABLE 5 HERE]

5.1 *Individuals*

5.1.1 Subadult individuals 1 and 2

Individual 1 is represented by 11 remains including the neurocranium (see supplementary Figure S1), part of the maxilla and part of the mandible (Table 2 and 3; Figure 4a-c2; supplementary Table S2) and four teeth. All bones show a good preservation of the cortical surfaces. Overall, these bones are either disarticulated (e.g. temporal bone L.16H.160.1A) or fragmented, with break edges compatible with diagenetic fragmentation (e.g. the maxilla L.14H.1 with a small fracture to the zygomatic bone, or cranium L.16H.160.1 with several fractures). The cranium also presents evidence of trampling in the form of concentrated grooves in the outer face of the neurocranium, as well as erosion, colour changes (brown) probably of biochemical origin and dissolution domes scattered on both sides compatible with chemical erosion of biological origin (Figure 3a, 3a1). There is a large groove (31 mm long) in the right orbital, which may be compatible with superficial trampling, showing microstriation in the bottom of a shallow mark and accompanied with several smaller and more superficial striae (Figure 3a, 3a2). On the right temporal bone, there is a short and deep groove of 12 mm length, compatible with modern scraping made by a metallic tool, as indicated by its width and colour change (Figure 3a, 3a1). The mandible (label:

L.28K.1198.rev) presents scattered arborescent black staining caused by the precipitation of manganese oxide (Table 5).

Based on the pattern of dental eruption, age-at-death is estimated to be between 3 and 5 years old (Table 3; Crétot, 1978; AlQahtani et al., 2010). The maxilla and the mandible are partially preserved (see supplementary Figure S1 and Table S2).

[INSERT FIGURE 4 HERE]

The cranium of this individual was recovered in a small strip of intact sediment located between the areas excavated during the first and last excavation seasons (Figure 4a-c2 and supplementary Figure S1). A trench of 5 x 1 m² was excavated between squares 14H and 22H, where modern materials and sediment collapsed from the section wall were found, that filled the void left by the archaeological intervention. One fragment of this cranium has been directly dated in $3,550 \pm 30$ BP (2,009-1,773 cal BCE) (Table 4), which is chronologically and culturally located in the context of the upper part of the IIB Level, corresponding to the Bronze Age (Figure 2).

In 1928, an immature individual was recovered, comprising the cranium and the mandible with an estimated age-at-death similar to Individual 1 (Figure 4d) (Aranzadi, 1929). We refer to this individual as Individual 2. This individual is not stored in the Arkeologi Museoa and its whereabouts are currently unknown.

Additionally, there are five immature human remains (Figure 4e-g; Tables 1 and 2) that could be compatible with both Individuals 1 and 2, which include cranial and fragmented postcranial remains. They do not have diagnostic characters that allow us to deduce the type of fragmentation, but the cranial fragments composed of six small fragments (label: L.16H.160.D) present fractures of diagenetic type (right and mixed angles and irregular edges). A complete humerus (label: L.12Q.7; on both sides) and a pubis (label: L.12Q.135; on the outer face) present biochemical erosion in form of (eroded) domes and colour changing. The humerus also shows arborescent staining from the precipitation of manganese oxide (Figure 3e, 3e1). As these two bones were recovered in a wall cavity rather than from sediment, we cannot rule out the possibility that these taphonomic alterations are very recent (Table 5). The remaining three bones are slightly eroded, with some tissue loss in areas with low mineral density (spongy and/or epiphyseal bone). The lack of precise stratigraphic context for these remains precludes further association. Apart from the cranium and mandible from Individual 2, Aranzadi (1929) described the recovery of five additional human remains, all of which are currently lost, including a minimum of two belonging to subadult individuals. The lack of precise description and stratigraphic context for these remains precludes further association.

5.1.2 Individual 3

Six human remains have been assigned to Individual 3 (Table 1 and 2): a mandible, four isolated teeth and a radius.

The radius (label: L.10D.75.1) shows a colour change toward the distal epiphysis of indeterminate origin, where the bone darkens while the rest of the bone looks normal. The dark colour could have been caused by changes related to biochemical modifications (Table 5). It also has some small and very superficial root

etching with colour changes to reddish-brown. Some biochemical changes were observed (blue staining) with cortical peeling on the other side of the distal epiphysis.

The mandible only preserves its right half (Figure 5), conserving the first to third molars (M_1 - M_3). As the root of the third molar is formed, despite the tooth not being in occlusion, the age-at-death has been estimated between 18 and 21 years old (Table 3) (Crétot, 1978; AlQahtani et al., 2010). The dentition does not present any caries and there is no evidence of alveolar resorption. The wear on the dentition is slight and only the M_1 has wear, exposing the dentine in a small percentage of its surface (state B1; Lovejoy, 1985). The discrete dental traits of this individual are summarised in supplementary information Table S2.

[INSERT FIGURE 5 HERE]

The radius shows a distal metaphyseal line which could be consistent with the age-at-death estimated from the mandible. Moreover, the stratigraphic provenance of some of the isolated teeth (based on the information of the label) is similar to the radius.

The human remains attributed to this individual have different stratigraphic contexts. Two of the teeth were recovered on the surface of the floor (Level A of the first period of excavation and inferior part of Level IIA from the third period of excavation), which has modern intrusions and evidence of a Late Roman occupation. The other two teeth come from the superior part of Level IIB from the recent period of excavation. The mandible was found in the same trench as the Individual 1 cranium. Lastly, the radius was recovered during the 1920's excavation at a depth corresponding to the lower part of Level II (Neolithic).

5.1.3 Individual 4

The fourth individual comprises 24 remains (Table 1 and 2). This individual preserves the right half of the mandible (Figure 5), a scapula, two ribs, 12 vertebrae, a humerus, an ulna, a femur, two fibulae, a metatarsal and two foot phalanges.

The vertebrae present minor tissue loss (erosions) compatible with diagenetic destruction, primarily located in the vertebral body in four of them. Two vertebrae display isolated biochemical erosion, while another has black manganese oxide staining. The L.15V.485 vertebra shows three non-circular depressions of unknown origin on the vertebral body (two on one side and one on the other). This vertebra is complete and does not present any fracture or modification, and thus it is unlikely that these depressions were caused by carnivores (Table 5). The L.11F.125.2 vertebra presents a small groove of unknown origin in the right lamina of the lateral apophysis, which is not compatible with cut marks, trampling or bite marks. The L.32G.215,5.18.L7 vertebra shows small carbonate concretions filling fissures and holes. The ulna (label: L.30K.221,5.76.L7) is missing the distal epiphysis and part of the proximal epiphysis as a consequence of diagenesis.

The femur (label: L.26E.221,5.20.L8) lacks the distal epiphysis and has some damage to the femoral head and the greater trochanter, due to the action of carnivores (Figure 3b). There are some bite marks in the spongy tissue of the proximal epiphysis (width > 3 mm), compatible with large size carnivores. There is also evidence of trampling in the form of scattered marks (Figure 3d). A fragment of the diaphysis of the fibula (label: L.28F.44.L7) presents a double colour cremation (rubefacted and partially

carbonised). This is probably accidental, due to the location of the bone close to a hearth (Arribas Pastor and Berganza Gochi, 2018). It also has an evidence of trampling in form of isolated grooves and root etching.

Based on the wear of the preserved teeth, the age-at-death has been estimated between 25 and 40 years old (Table 3). This individual is probably a female, due to the gracility of the mandible, the fibula and the vertebrae.

Evidence of caries can be found on the distal cervical region of the M₁ and in the vestibular half of the occlusal side of M₂, which affects the enamel and the dentine. M₁ also has a loss of cementum and dentine on the distal side of the root. The three molars have small deposits of dental calculus and alveolar recession of between 3 and 6 mm relative to the cemento-enamel line around M₁ and M₂ and of less than 3 mm around M₃ (see supplementary Table S2). Some of the vertebrae show osteophytes, to a lesser degree compared to individuals 5 and 6 (see supplementary Table S3), indicating the possible presence of osteoarthritis (White and Folkens, 2005).

A proportion of the remains of this individual were recovered during all three different excavation seasons, but the greatest amount was recovered in the most recent excavation. Three remains were recovered during the first period of excavation and another three remains during the second period. The latter have coherence with the spatial distribution and the depth of the bones recovered in the 80s and 90s ($n = 18$; Level IIB; Chalcolithic, Early Bronze Age). It is noteworthy that the vertebrae recovered in these two periods of excavation are consistent in size and age-at-death (as far as can be assessed from these elements) and perfectly articulate with each other.

Two samples from this individual were directly dated (Table 4), a fibula fragment to $4,780 \pm 30$ BP (3,641-3,519 cal BCE), and a vertebral fragment to $4,810 \pm 35$ BP (3,656-3,521 cal BCE). Both dates are highly consistent with one another and correspond to the Chalcolithic (Figure 2).

5.1.4 Individual 5

The fifth individual is the best preserved and most complete from this collection, preserving 110 anatomical elements from all major anatomical regions (Table 1 and 2). The long bones assigned to this individual (one humerus and one femur), were biomechanically analysed.

The remains do not show any remarkable taphonomic modifications. Fourteen remains present biochemical erosion to different degrees and extent, ranging from small scattered domes to areas that are completely altered. Additionally, another 14 bones have manganese deposits, in an arborescent form, scattered on the surface. Another three remains have areas with carbonate encrustation and other two present root etching. Some bones have been refitted and it seems, based on the fracture shape (transversal, mixed and jagged) that the breaks are all post-depositional. A rib fragment (label: L.28F.253.34.L9) presents copper oxidation in the form of green staining on the lateral side (Table 5). The most common modifications are the erosions and slight loss of bone tissue from the articular surfaces of the long bones and vertebral bodies. All the fractures of the long bones have the characteristics of dry breakage, i.e. are post-mortem.

Based on the dental wear of both the maxilla and the mandible (Figure 5), age-at-death was estimated at between 35 and over 55 years old, depending on the methodology used (Table 3). The projection of the mental eminence (Buikstra and Ubelaker, 1994) and the square shape of the chin (Bass, 2005) suggest that this was a male individual, with an estimated stature of 156.8 cm and an estimated body mass of 61.7 kg.

The high level of wear has allowed only the limited study of dental traits (Supplementary Table S2). There is no sign of any caries, but there are large deposits of dental calculus, mostly in the posterior inferior dentition. There is also severe alveolar reabsorption, which indicates the presence of periodontal disease. The radius shows evidence of a healed fracture of the radial head (Figure 6). Most vertebrae (except C1 and C2; see supplementary Table S4) present substantial osteophytic growth (Figure 7) which suggests the presence of osteoarthritis (White and Folkens, 2005). The absence of marked asymmetries in the vertebrae suggests that this individual would not have scoliosis.

[INSERT FIGURES 6 & 7 HERE]

The human remains, not anatomically connected but in close proximity and with some superposition, were found between the squares 24 and 32 E, F and G in an area not exceeding 5m², where the deposit had a thickness around 25 cm (Figure 8). Most of the remains were found in level IIC, except for a few of them, which were found in the base of the level IIB.

[INSERT FIGURE 8 HERE]

This individual has been directly dated using a rib fragment to $5,105 \pm 80$ BP (4,147-3,700 cal BCE) (Table 4), corresponding to the Neolithic (Figure 2).

5.1.5 Individual 6

Nine human remains (eight vertebrae and a fibula; Tables 1 and 2) were assigned to Individual 6. The vertebral remains present small erosions and slight tissue loss in the vertebral bodies: some cases are more pronounced than others, but all cases have a diagenetic origin. Two vertebrae (labels: L.10B.80bis and L.20G.227.18.L11) show partial and important carbonate precipitations respectively. One lumbar vertebra (label: L.14H.2.L6 + L.14H.3.L6) has a slight loss of tissue in the vertebral body, compatible with diagenetic erosion (Table 5). The fibula (label: L.10B.80) is missing the distal epiphysis and presents erosion with tissue loss in the proximal epiphysis, all due to diagenesis (Figure 7).

As most of the vertebrae are broken, it has not been possible to record in detail the presence of lesions, and therefore, the paleopathological study of this individual is more limited. The presence of osteophytes can be observed in some of the vertebrae (Figure 11, see supplementary Table S5). As it was only possible to measure one vertebra, the presence of scoliosis could not be assessed.

During the first period of excavations, two human remains ascribed to this individual were recovered, including the fibula dated by Arias Cabal (2012b). The rest of the bones come from the third period of excavation, including the vertebra dated in this study. Based on the depth of the two remains recovered in Aranzadi and

Barandiarán's excavation, they could be ascribed to the lower part of Level B (Azilian; Aranzadi and Barandiarán, 1935). The remaining bones were recovered in squares not too far from where the other bones were found. Three of these bones come from the material gathering in the border of collapse from the first period of excavation, so that they do not have any original context. The other four remains were recovered at the base of the level IIC, where several dates were performed yielding similar results, which establish a short chronological interval for the Neolithic occupations with ceramic technology and domestic cabins (Arribas Pastor and Berganza Gochi, 2018).

Two almost identical direct C14 dates were obtained from two different bones from two different excavation periods attributed to this individual (Table 4). One fragment of the fibula was previously dated by Arias Cabal (2012b), which yielded a date of $6,122 \pm 38$ years BP (5,209-4,959 cal BCE). The vertebra dated in this study supports the chronology previously obtained, as it has a chronology of $6,110 \pm 35$ BP (5,208-4,943 cal BCE). The dates are consistent with the Early Neolithic of the Cantabrian region (Arias Cabal, 2012b; Arias and Cubas, 2018).

5.1.6 Individual 7

This individual is represented by only three remains: two fragmentary humeri and the distal femoral epiphysis. The two humeral fragments are distal shaft fragments and present diagenetic fractures. The distal fracture of the L.30H.26.L5 humerus shows bite marks and tissue loss due to carnivore consumption (Figure 3c). Between the two observed depressions, the one on the metaphysis has a width of 2.3 mm and a high degree of furrowing (Table 5). These two depressions are opposite, where one of them conserves the cortical tissue collapsed. There are some small depressions on the diaphysis, which are not measurable. The epiphysis has been lost probably due to a combination of furrowing and tissue loss because of diagenesis. No associated pitting or scoring can be observed. Both humeri present staining by manganese oxide, scattered and in an arborescent form on all the surface. The L.30J.9.L5 humerus shows some precipitation of a thin carbonate film and the loss of the distal epiphysis due to diagenesis.

It has an age-at-death between 8 and 16 years old, so that the individual would be a child or an adolescent. The three human bones were recovered close to one another in Level IIB. This is the same level as that in which Individual 4 was found, so these two individuals may be of the same cultural and temporal period.

5.1.7 Non-associated remains

There are 43 additional human remains that cannot currently be associated to any of the individuals.

The non-associated remains present few modifications. The most common is biochemical erosion, which affects 52% of the non-dental remains. The erosion varies in its degree and intensity, from slight dissolution domes associated to with localised or scattered tissue loss on the surface of the remains, to large generalized attack with major modifications to the entire surface of the bones. Six remains present black manganese oxide staining, while one shows cementation. A rib fragment (label: L.14F.126.L6) has

an area of gnawing caused by rodents. Another rib fragment (label: L.20G.212.1.L10) presents carnivore bite marks on the surface (Table 5).

Three specimens stand out for their anatomy or their spatial origin, and could correspond to additional individuals: an axis, a molar and a deciduous molar.

The complete axis (label: L.25C.300) corresponds to a subadult individual, with an age-at-death between 13 and 16 years old, as the epiphyseal ring is not fused. This bone has not been assigned to any individual; it was recovered in the stratigraphical context of the small gallery near the main hall with a Neolithic assignation (Barandiarán, 1966).

The isolated M₃ (label: L.22G.27.L8; supplementary Figure S2), cannot be attributed to any of the individuals preserving the dentition. This tooth was found in Level IIB, and it could be ascribed to the Chalcolithic-Bronze Age, although its morphology and large measurements make it look archaic and more similar to older groups.

In Level IIB, a deciduous second molar (label: L.28G.139.L7) has been recovered, indicating the possibility of the presence of a living population with at least one child using the cave.

5.2 Biomechanics

The humerus and femur of Individual 5 from Lumentxa were studied, and the results for each element are presented separately.

5.2.1 Humerus (Individual 5)

The standardised and non-standardised %CA and Zp results for the biomechanical parameters of the humerus of Individual 5 are summarised in Table 6. The cross-sections at 35% and 50 % of length are illustrated in Figure 9. The results of the remaining standardised and non-standardised biomechanical parameters are summarised in supplementary Table S6 and S7. The database of comparative Mesolithic, Neolithic and Bronze Age right male humeri is summarised in supplementary Table S10.

[INSERT TABLE 6 & FIGURE 9 HERE]

Relative cortical area (%CA)

The cortical thickness (%CA) of the humerus is low compared with Upper Palaeolithic samples from France and Italy and the Mesolithic sample from Iberian Peninsula.

Individual 5 shows a similar value to the median of the Neolithic samples from France and Italy, but lower than the Bronze age samples from France, Italy, and the Iberian Peninsula. Finally, this individual falls above the median value of the Iron Age/Roman samples from France and Italy, but below that of the higher values of the early Medieval sample from the Iberian Peninsula.

[INSERT FIGURE 10]

Polar section modulus (Z_p)

The pattern of similarity between Individual 5 and the comparative dataset is similar to that for %CA: Individual 5 falls below the Upper Paleolithic and Mesolithic samples and is similar to the median of the Neolithic sample from France and Italy. Our Neolithic individual has a Z_p value that is lower than median for the Bronze Age sample from Iberian Peninsula, but higher than median for France and Italy. Furthermore, this individual falls between the medians of the Iron Age/Roman period sample from France and Italy and that of the Early Medieval sample from the Iberian Peninsula.

5.2.4 Femur (Individual 5)

The %CA and Z_p parameters for the Individual 5 femur are summarised in Table 6. Various cross-sections are illustrated in Figure 9. Further biomechanical parameters of the Individual 5 femur are summarised in supplementary Table S8 and S9. The data for the Mesolithic, Neolithic and Bronze Age male comparative sample from the Iberian Peninsula and France and Italy are summarised in supplementary Table S11.

Relative cortical area (%CA)

The Individual 5 femur shows a lower value than both Upper Palaeolithic and Mesolithic sample median from France and Italy, but more similar to the Mesolithic sample from Iberian Peninsula and close to the median of the Neolithic sample from France and Italy. Moreover, Individual 5 has a lower %CA value than the median of both Bronze Age samples from France and Italy, and the Iberian Peninsula, as well as the individual of Atxuri I (García-Sagastibelza et al., in this volume). Individual 5 is close to the median of the Iron Age/Roman Age sample from France and Italy and the medieval sample from Jau-Dignac-et-Loirac.

Polar section modulus (Z_p)

The results for the polar section modulus of the femur of Individual 5 parallel those for humerus in general terms: Individual 5 has a lower value than the medians of the Upper Palaeolithic and Mesolithic samples from France and Italy but a higher value than the values for the Mesolithic sample from the Iberian Peninsula.

Compared with the Neolithic sample from France and Italy, our individual shows a value slightly above the median. In the case of the Bronze Age period, our individual shows a value between the medians of the samples from the Iberian Peninsula and from France and Italy, and a bit higher than the individual of Atxuri I (García-Sagastibelza et al., in this volume). Individual 5 is within the (large) variation of the Iron Age/Roman Age sample from France and Italy, though above its median and below the medians of Jau-Dignac-et-Loirac and our other early Medieval sample from the Iberian Peninsula.

In summary, from all the available comparative data, the biomechanical properties of the humerus and femur of Individual 5 from Lumentxa show greatest overall similarity to the Neolithic sample from France and Italy. We have also detected differences between the Iberian Peninsula and France and Italy in the Mesolithic and the Bronze age samples that require further research.

6. Discussion

6.1. *Skeletal bias, taphonomy and funerary practices*

The present study has determined the presence of a minimum of seven individuals in the Lumentxa human collection, one more than reported in previous studies (García-Sagastibelza et al., 2018, 2019). One of the individuals is not present in the collection (Aranzadi, 1929), and only six individuals have been studied. These individuals were recovered in different excavations with different methodologies and there is marked variation in their completeness. Part of the bias in the skeletal representation could be due to the fact that some of the material was not excavated to modern standards, and there is evidence of recovery bias in other excavations performed by J.M. Barandiarán (Gómez-Olivencia et al., 2018b).

Another limitation is that the human remains come from different layers with different chronologies. As all of them were deposited in cave, slight differences in funerary behaviour could have conditioned the subsequent taphonomic modifications.

In any case, when taken together, the preservation of remains with low mineral density (e.g. vertebrae, epiphyses of the long bones and subadult remains) does not indicate that differential susceptibility to taphonomic destruction caused that bias. Calculating the survival rate (Brain, 1981), it can be seen that the loss of remains is more pronounced in carpals, metacarpals, tarsals, metatarsals and phalanges (see supplementary Figure S3), possibly caused by a combination of several factors.

The action of carnivores, clearly observed in individuals 4, 7 and in non-assigned bones, could be another possible cause of the bias. The access of these animals to the buried or deposited remains is not unusual and could also produce the scattering of bones across larger areas (Kerluke et al., 1972; Brain, 1981; Horwitz and Smith, 1987).

The taphonomic modifications are the typical ones found in the post-abandonment phases in sepulchral contexts in caves. There is no evidence of perimortem cut-marks or fractures: all fractures were on dry bone and there is evidence that remains were modified by trampling, postdepositional processes and the process of excavation and storing of the remains. Most of the modifications, such as biochemical erosion and the bite marks (from carnivores and rodents) are processes that produce attrition and loss of remains (Horwitz and Smith, 1987; Larsson, 2003). These modifications are relatively homogeneous across the various individuals. This points out a relatively stability of the depositional environment where there is humidity and presence of decomposing organic matter, indicated by a high percentage of manganese staining (Marín-Arroyo et al., 2008) and biochemical attack (Domínguez-Rodrigo and Barba, 2006).

Bias can also be produced by the emptying of the collective burials (which would not be this case; Chambon, 2003; Larsson, 2003; Scarre, 2007), the possible alteration derived from the use of the cave for occupation (Arribas Pastor, 1993; Arribas Pastor and Berganza Gochi, 2018), and prehistoric, historic or contemporary plundering (Chambon, 2003).

The bone remains of the individuals recovered during the last excavation phase were found scattered without any clear anatomical connection. Additionally, some of the individuals show the presence of carnivore chewing. This would be consistent with some of the individuals (e.g., 4 and 5) having been deposited directly on the surface within the cave, without any (or just a slight) covering as has been proposed for other individuals (Arias Cabal, 2012a; Cubas et al., 2016). For other individuals, the incompleteness of the remains and lack of precise contextual information precludes any further discussion.

The presence of palaeontological and archaeological materials (animal bones, pottery, worked bone, etc.) indicates that the site was also used for occupation from the Palaeolithic until the Bronze Age (Arribas Pastor, 1993; Arribas Pastor and Berganza Gochi, 2018). Therefore, this could indicate that the cave's main use was habitational and that occasionally it was used for burial purposes (Arribas Pastor and Berganza Gochi, 2018). Moreover, the users of the cave may have removed and/or displaced sediment from the cave which may have also caused disturbance of the stratigraphy.

6.2. Chronological context

The direct dating of six human remains has helped in reconstructing the chronology of the inhumations at the site. Four different periods of funerary use were identified, spanning 3,000 years from the Early Neolithic (Arias and Cubas, 2018) until the Bronze Age. This indicates a prolonged use of the cave for funerary purposes. One of our dates overlaps with the date reported by Arias Cabal (2012b), reinforcing the validity of both dates which were likely performed on the remains of a single individual.

In the region, we have evidence of diachronic and synchronic burial practices in caves during the recent prehistory (Garcia-Sagastibeltza et al., in this volume; and references therein). Lumentxa is one of the better-dated sites, as four of the seven individuals identified have a chronology ascribed (Table 4). Some other sites in the Basque Country also have a more secure chronology. The best-dated funerary context in the region is that from Santimamiñe, where all the identified human individuals ($n = 9$) have a direct date. Similarly, at other sites like Arlanpe, Covachón III, Kobaederra, Punta Lucero II or J3; small numbers of individuals have been recovered and all of them have been dated. In contrast, there are some sites such as Pico Ramos, Lacilla II, Urratxa III, Iruaxpe I or Abauntz, where there are a small number of direct dates for the high number of recovered individuals (Garcia-Sagastibeltza et al., submitted; and references therein).

Additionally, the direct dating of some individuals from Lumentxa also allows us to establish some chronological parallels. Lumentxa is one of the few sites that show a long and repetitive funerary use in the region, showing similarities in its use with sites such as Santimamiñe, Marizulo or Aizpea. Individual 6 from Lumentxa is, together with one of the individuals recovered from Santimamiñe (Herrasti and Etxeberria, 2011; López-Quintana and Guenaga, 2011; López Quintana et al., 2015) the only burial from

the 6th millenium cal BCE in Biscay. Individual 5 is Neolithic in date, but there is no other site with dated human remains from this period in Biscay. Even so, several sites in nearby regions like Marizulo (Gipuzkoa) (Altuna, 1995; Cava, 1978; Laborde et al., 1967) and Aizpea (Navarre) (Barandiarán and Cava, 2001) have individuals dated to the same period, although their dates are slightly earlier. Individual 4 from our sample, ascribed to the Chalcolithic period, is broadly contemporary with diverse sites such as Covachón III (Gómez-Olivencia et al., 2015), Lacilla II (Gil Abad and Llamosas Rubio, 2016-2017), Pico Ramos (Zapata, 1995), Txotxinkoba (Garcia-Sagastibeltza, submitted) and Punta Lucero II (Gómez-Olivencia et al., 2015) in Biscay province. Furthermore, there are additional sites like Aintzulo (Altuna and Mariezkurrena, 2013), Iruaxpe I (Armendariz, 1987), Marizulo (Altuna, 1995; Cava, 1978; Laborde et al., 1967) and Urtao II (Armendariz, 1989; Etxeberria, 1989) in the province of Gipuzkoa and Abauntz (Utrilla et al., 2015) and Aizpea (Barandiarán and Cava, 2001) in Navarre that have individuals of a comparable date. Finally, Individual 1 is so far the only individual from the site dating to the Bronze Age. In the province of Biscay there are several sites with individuals of the same period, including Atxuri I (Garcia-Sagastibeltza, submitted), Arlanpe (Gómez-Olivencia, 2013; Rios-Garaizar et al., 2013), Santimamiñe (Herrasti and Etxeberria, 2011; López-Quintana and Guenaga, 2011; López Quintana et al., 2015) and Urratxa III (Muñoz Salvatierra and Berganza, 1997; de la Rúa et al., 1997). Urtiaga (Altuna and de la Rúa, 1989), Nardakoste IV (Armendariz et al., 1998) or Langatxo (Zumalabe, 1993) in the province of Gipuzkoa and Padre Areso (Begiristain, 1997) in the province of Navarra have also yielded Bronze age human remains. Nonetheless, none of these other sites show a chronology spanning the Early Neolithic to the Bronze Age like Lumentxa, making it an exception on the region, both for the quantity of dates and the chronological span they represent.

6.3. *Paleobiology of the Lumentxa dwellers*

The paleobiological information on the humans from Lumentxa is quite limited, as the number of individuals is quite small, and there is variation in skeletal representation and chronology, which demands all the individuals are treated separately. Individuals of different ages at death and, both sexes are represented in the collection (Ontañón and Armendariz, 2005; Arias Cabal, 2012a). This pattern is consistent with the profiles reported previously for different caves with extended periods of funerary use, where a moderate number of individuals from all ages and both sexes were usually deposited (e.g. Armendariz and Etxeberria, 1983; Herrasti and Etxeberria, 2011; Garcia-Sagastibeltza et al., in this volume).

Changes in stature has been regarded as a proxy for health/stress differences between population (Ruff and Garvin, 2018). The Neolithic Individual 5 (156.8 cm) is shorter than the mean obtained from the site of San Juan Ante Portam Latinam (SJAPL), from the same period (163.7 ± 6.21 cm; this study). The comparison with individuals from various sites around the Iberian Peninsula of the same approximate chronology are consistent with this observation, as Individual 5 is shorter than the individual of unknown sex from Caño Bajo (Córdoba; Valera Perez, 2013) or the male from Cerro Ortega (Ciudad Real; Gil Pitarch et al., 1999) (see supplementary Table S12). Ruff and Garvin (2018) found an increase of stature from the Mesolithic to the Bronze Age in the Iberian Peninsula. In fact, the SJAPL population would indicate that the increase of stature occurred earlier, and the Lumentxa Individual 5 would represent

a short individual within the range of Neolithic variation of the North of the Iberian Peninsula.

In the Iberian Peninsula, body mass (BM) increases from the Mesolithic to the Bronze Age in parallel with stature (Ruff and Garvin, 2018). The BM of the Individual 5 from Lumentxa (61.7 kg) is similar to estimates for the Bronze Age male samples from the Iberian Peninsula (Ruff and Garvin, 2018; supplementary Table S12).

Unfortunately, there is still a dearth of data for both stature and BM in Holocene prehistoric populations, and more data is needed in order to observe to a finer detail chronological and geographical trends within the Iberian Peninsula.

The comparison and interpretation of the biomechanical data from Individual 5 should be treated with caution, given that we have results from a single individual. Nonetheless, for the humerus, %CA is more similar to the Bronze Age male median than to that of Mesolithic males from the Iberian Peninsula (Ruff and Garvin, 2018), which could be consistent with a different pattern of the arm use between the last hunter-gatherers and the first productive societies. The greater similarity of Individual 5 to the Neolithic male samples from France and Italy than to the Bronze Age male sample could also be consistent with changes in behaviour between these periods. While the polar section modulus (Z_p) is lower than both Mesolithic and Bronze Age male means from the Iberian Peninsula, it is within the range of values for comparative samples and little interpretation can be offered based on this single individual. Relative to the comparative data from France and Italy, the Lumentxa result suggests that this individual could have been stronger than the average Neolithic and Bronze Age males in our samples, but not as strong as the average Mesolithic male from our sample, potentially consistent with a difference in strength between last hunter-gatherers and first food producing societies. As there is only one humerus, it is not possible to study the sexual dimorphism or the bilateral asymmetry for this population.

The femur of the Neolithic Individual 5 show a more similar pattern of cross-sectional geometry to the Atxuri I individual (García-Sagastibelza et al., in this volume), which dates to the Bronze Age. Whether this similarity between these two individuals, which are 2,000 years apart in date is influenced by the orography of the Basque Atlantic area is a question for future investigation. Comparison with additional contemporaneous samples from adjacent flatter areas such as the Ebro valley or the Northern Iberian plateau will help to clarify this issue, since the nature of terrain influences lower limb skeletal robusticity (Marchi et al. 2006).

The medieval sample from Jau-Dignac-et-Loirac possibly belonged to the aristocracy (Cartron and Castex, 2006; Holt et al., 2018b), and therefore these individuals may have had a particularly sedentary lifestyle and better diet compared to the average medieval population. Moreover, it has been seen that the value of the individual of Lumentxa is slightly lower than Mesolithic and Bronze Age male sample means (Ruff and Garvin, 2018), perhaps indicating that Basque samples are less mobile than in the rest of the Iberian Peninsula, although this interpretation is speculative without further data. In contrast, compared with samples from France and Italy Lumentxa is more similar to the Neolithic sample mean, but below the Mesolithic and Bronze Age sample means. This might suggest similarities in mobility between Neolithic samples from nearby areas, but also that Neolithic people were, on average, less mobile than previous and later populations.

As Lumentxa falls between Mesolithic and Bronze Age male means from the Iberian Peninsula for the section modulus (Z_p), this could be consistent with a trend towards increasing femoral robusticity during this time. Even if the Atxuri I femur is dated to Bronze Age, its value (1092.98 mm^3) is lower than of Lumentxa, perhaps suggesting the former individual could belong to a female, though any such interpretation is necessarily speculative (García-Sagastibelza et al., in this volume). The higher value of Lumentxa compared to Neolithic and Bronze Age male means from France and Italy show that this individual is stronger than the average individual from food-producing societies from nearby countries.

7. Conclusions

The classic site of Lumentxa, with evidence of occupations during the Late Pleistocene (Upper Paleolithic) and Holocene (Early Neolithic-Roman age) has yielded human remains belonging to a minimum of 7 individuals of different ages at death, both sexes, and a chronological span from the early Neolithic to the Bronze Age. One of these individuals, described at the beginning of the 20th century is not currently in the Museum collection, and it is lost. Although all anatomical regions are represented, there is a bias in the skeletal representation of the bones, especially in the lack of carpal and tarsal bones, metacarpals, metatarsals and phalanges. This bias is likely the result of both older excavation methods and carnivore action, among other factors. The general pattern of taphonomic modifications is that typical of such sepulchral contexts. These are relatively homogeneous among the different individuals, implying that similar taphonomic or cultural factors could have caused the scattering and disappearance of the remains.

The direct dates obtained in this study confirm the long-term funerary use of the cave, spanning the Early Neolithic until the Bronze Age. The presence of archaeological materials also indicates the occupational use of the cave between the Palaeolithic and Bronze Age. The main use of the cave appears to have been habitational, with occasional sepulchral use, in contrast to other caves in the region (e.g., Lacilla II or Pico Ramos) that show the presence of a large number of individuals and that can be defined as exclusively sepulchral caves.

The femur of Individual 5 from Lumentxa shows affinities and probably a similar mobility pattern compared with the Neolithic samples from France and Italy. The humerus, on the other hand, shows lower robusticity, implying that the manual activities performed by this individual were not as demanding as those of the average UP male and comparative samples from the Iberian Peninsula, though it falls within their range of variation. Furthermore, compared with samples from nearby area, humeral robusticity for Lumentxa would be as great as the average man in a Neolithic population and stronger than the average member of early food-producing societies. This is the first time that a biomechanical study has been done in the Iberian Peninsula for a Neolithic individual. More biomechanical studies are necessary in order to understand mobility and activity patterns during recent prehistory and their potential change through time, but the data from Lumentxa Individual 5 represent an important start in beginning to study such trends. Biomechanical evidence could complement other data, such as those obtained from isotopic and genetic analyses, in order to further understand the paleobiology of recent prehistoric populations from the Western Pyrenees.

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Figure legends

Figure 1. a-b) Location of Lumentxa (L) in the northern Iberian Peninsula, relative to the cities of Bilbao (B) and Vitoria-Gasteiz (V-G). c) Location of the Lumentxa (L) site relative to the village of Lekeitio. d) Partial plan of the cave with the different excavation phases (modified from Garate, 2012). Note that the grid for the Barandiarán excavations (1926-29 and 1963-64) was established in 1963, during the second excavation phase.

Figure 2. Radiocarbon dates of the human remains of Lumentxa.

Figure 3. Taphonomic modifications observed on the human remains from Lumentxa: a) cranium with postdepositional fracture (black dashed line), a1) biochemical erosion (white arrows) and modern damage from metal tools (black arrow), a2) trampling; b) gnawing of the proximal epiphysis of the femur, furrowing (*) and bite marks (scores and pits, black arrows); c) humerus with a total loss of the epiphyses by furrowing finally generating scooping out (#), (pits, black arrows); d) loss of the epiphysis (#) and associated bite marks (scores) (arrows); e) subadult humerus with tissue loss (^), e1) enlargement of the slight biochemical erosion with colour changes (white arrows), cementation (black dotted arrow) and black staining by precipitation of manganese oxide (black arrow).

Figure 4. Lateral (a1), superior (a2) and inferior (a3) views of the neurocranium (found in 1984 and directly dated- see Table 5), inferior (b1) and lateral (b2) views of the maxilla, and superior (c1) and lateral (c2) views of the mandible assigned to Individual 1. Lateral (d) view of the cranial remains of the Individual 2 (cranial drawing from Aranzadi, 1929), which show a similar age-at-death to Individual 1. The immature postcranial remains, a left humerus (e) and two pubis fragments (f,g) cannot be clearly attributed to any of these individuals.

Figure 5. Mandibles of Individuals 3, 4 and 5 from Lumentxa in occlusal and lateral views. The mandible of Individual 3 (label: L.14H.5) gives an estimated age-at-death of between 15 and 21 years old, based on the complete root development of the three molars and the degree of dental wear (see text). Left: photographs. Right: 3D surface model (above) and radiograph (below) showing root development. The mandible of Individual 4 (label: L.14Z.455.2) belonged to an adult aged between 25 and 40 years old, based on dental wear (see text). Note the carious lesions in the cervical region of the M₁ and on the occlusal surface of the M₂. The mandible of Individual 5 (label: L.14Z.480.1) belonged an older adult with an estimated age-at-death of between 40 and 55 years old, based on dental wear.

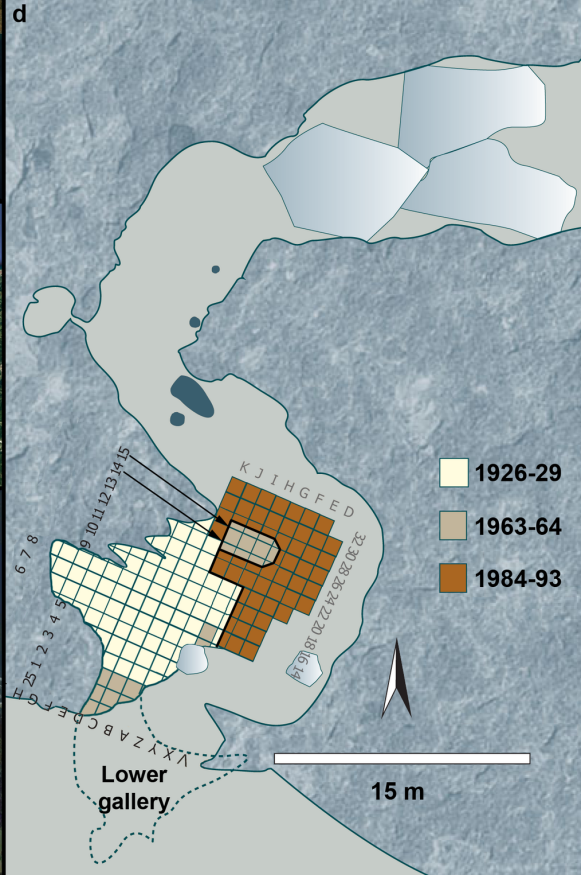
Figure 6. Anterior, posterior and superior views of the radius (L.30F.257.44.L10) assigned to Individual 5, showing a healed fracture of the proximal epiphysis. The grey images are 3D surface models derived from CT scans, while colour images are photographs.

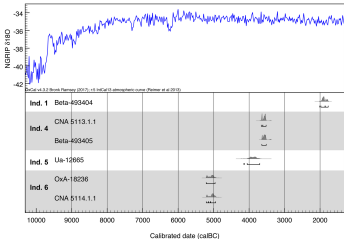
Figure 7. Selected spinal anomalies from Individuals 5 and 6. Individual 5: selected cervical (top row), thoracic (middle row), lumbar vertebrae and sacrum (bottom row). * indicates osteophytes, while # indicates porosity. Individual 6: Cranial and lateral views of two pathological lumbar vertebrae whose vertebral bodies have collapsed, which probably resulted in postural problems in this individual. Note the presence of calcium carbonate crust adhering to the caudal-most vertebra.

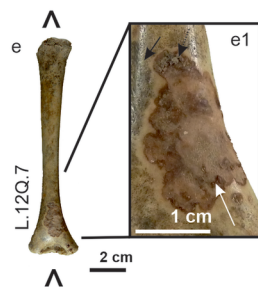
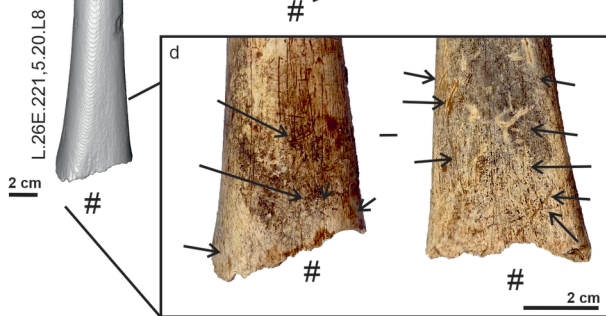
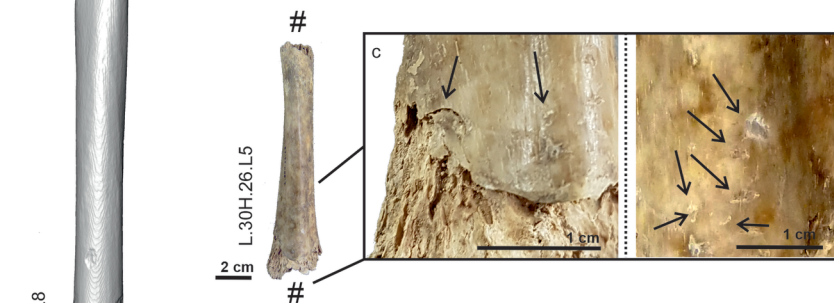
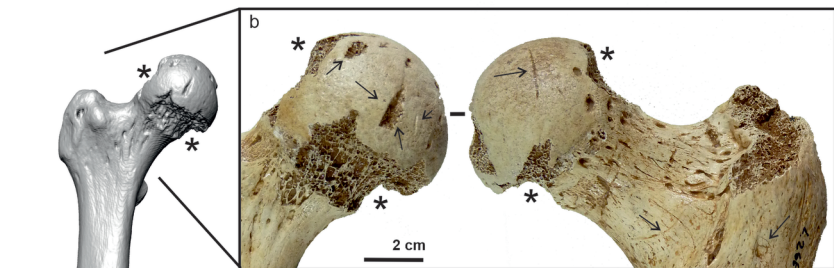
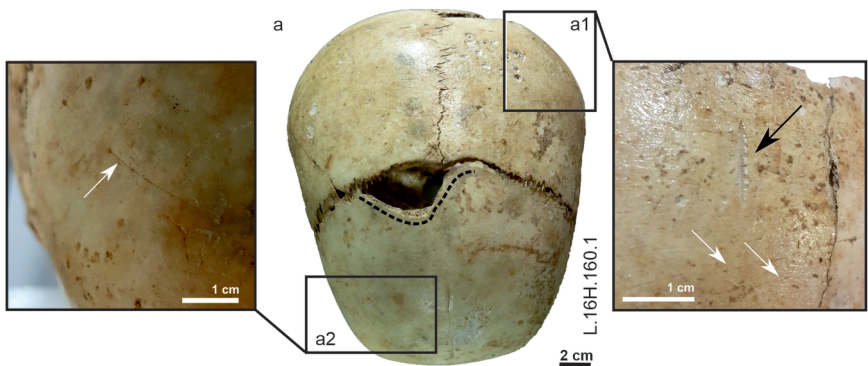
Figure 8. Two views of the human remains (Individual 5) scattered mainly in squares 28F and 28G (spit 9) during the 1990 field season. The black lines indicate the humerus (label: L.28F.240.5.1.L9) found in the square 28F (Figure 12), the femur (label: L.28G.253,5.9.L9) found in square 28G (Figure 14) and their location on the cave. The red lines indicate the separation between the 1963-1964 excavation of Barandiarán and that directed by one of us (JLA).

Figure 9. Anterior view of the 3D surface model of the humerus (label: L.28F.240.5.1.L9) and the femur (label: L.28F.240.5.1.L9) of the Individual 5 from Lumentxa showing the 35% and 50% sections of the humerus and the 20%, 35%, 50%, 65% and 80% sections of the femur.

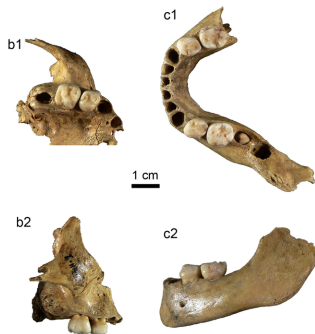
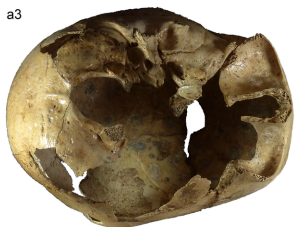
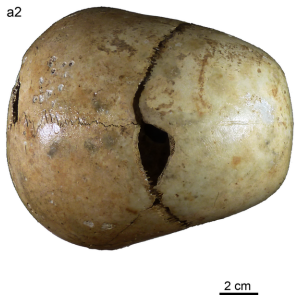
Figure 10. Percentage cortical area and relative strength of the Individual 5 humerus (35% section) and femur (mid-shaft) compared to a temporal series from Western Europe. Open boxes: Iberian Peninsula (Ruff and Garvin, 2018); grey boxes: France and Italy (Holt et al., 2018b). IP (single data point from the Iberian Peninsula; Ruff and Garvin, 2018). J = 7th-8th century Early Medieval sample from the Jau-Dignac-et-Loirac (this study). The early Medieval sample from the Iberian Peninsula is from Santa María de Hito (Ruff and Garvin, 2018).



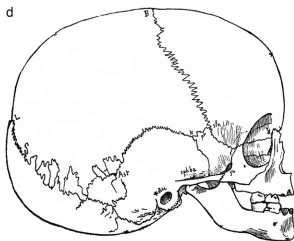




Ind. 1



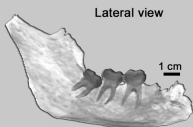
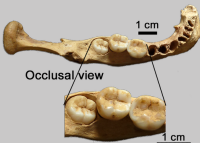
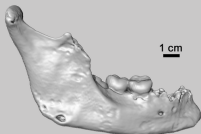
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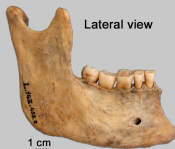
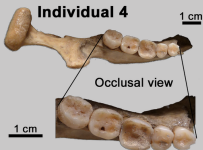
Ind. 1-2



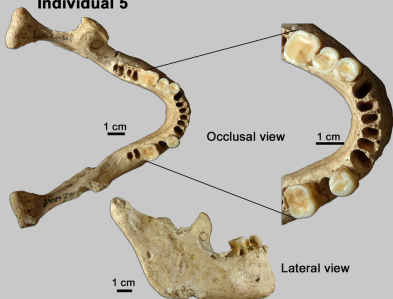
Individual 3



Individual 4



Individual 5



Anterior view



Posterior view



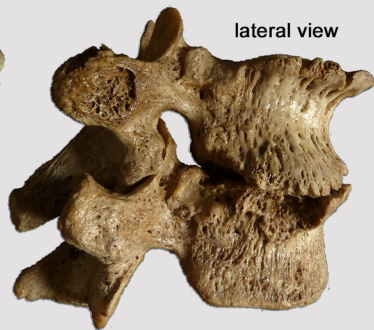
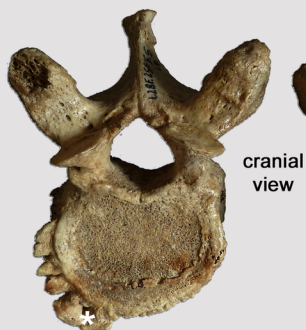
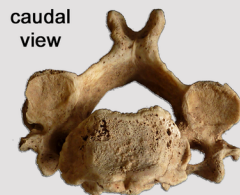
Superior view



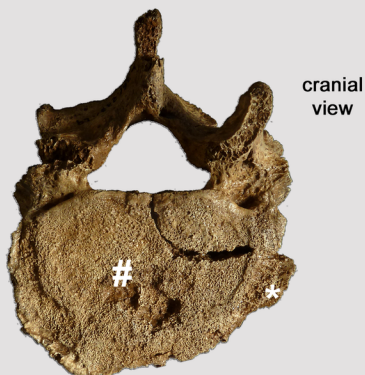
1 cm



Ind. 5



1 cm



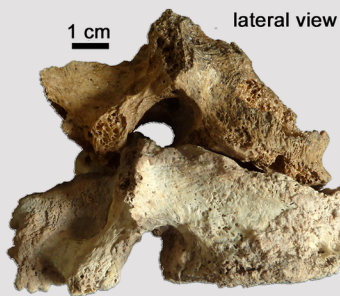
Ind. 6



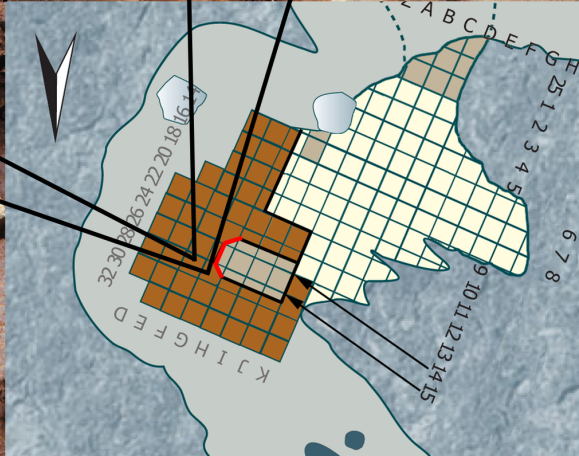
cranial
view

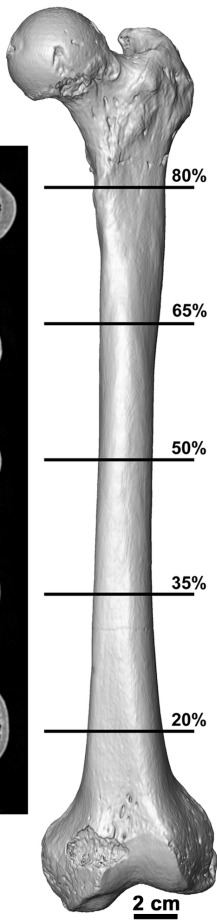
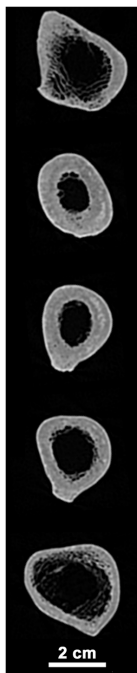
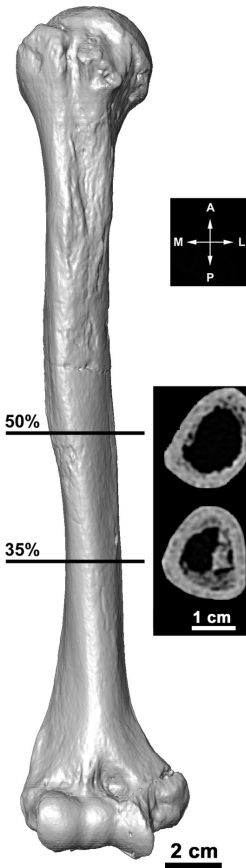


1 cm



1 cm





High
Moderate



Force



Table 1. Individuals from Lumentxa and their assigned minimum number of elements (MNE).

Individual ^a	NME	Estimated age-at-death ^b	Determined sex
Individual 1	11	3-5	-
Individual 2 ^{*a}	2*	3-5	-
Individual 1-2	5	-	-
Individual 3 ^a	6	18-21	-
Individual 4 ^a	24	25-40	F
Individual 5 ^a	110	40-55, >55	M
Individual 6	9	-	-
Individual 7	3	8-16	-
Indeterminate	38 + 5*	-	-
Total	213		

*Specimens
the Arkeologi Museoa (Bilbao, Bizkaia) but listed in Aranzadi (1929).

not stored at

^aThe number of these individuals have changed from previous studies (García-Sagastibelza et al., 2018, 2019).

^bSee Table 3.

Table 2. Anatomical representation of the individuals identified in the site of Lumentxa.

Anatomical region	Individual 1	Individual 2	Individual 1-2	Individual 3	Individual 4	Individual 5	Individual 6	Individual 7	Indeterminate	Total
Neurocranium	4	1*	1 (6 small fragments)						14	20
Maxillae	2					1				3
Mandibles	1	1*		1	1	1				5
Isolated teeth	4			4		12			6 + 1*	27
Hyoid bone						1			1	2
Cervical vertebrae					2	6	1		1	10
Thoracic vertebrae					7	9	4			20
Lumbar vertebrae					3	5	3			11
Sacrum						1				1
Coccyx						1				1
Indeterminate vertebrae									1 + 1*	2
Ribs			1		2	17			7	27
Scapulae					1	2			2	5
Clavicles						2			1 + 1*	4
Humerii			1		1	1		2	2	7
Radii				1		1				2
Ulnae					1	1				2
Carpal bones						7				7
Metacarpals						6				6
Hand phalanges (proximal/intermediate/distal)						9/3/7			0/2/0 + 1*	22
Pubis			2							2
Femora					1	1		1	1*	4
Fibulae					2	2	1			5
Tarsal bones						8				8
Metatarsals					1	3			1	5
Foot phalanges (proximal/intermediate/distal)					1/1	2/1/0				5
Total	11	2*	5	6	24	110	9	3	43	213

*Human remains described by Aranzadi (1929) currently lost. Apart from a complete cranium and mandible (Figure 3). Aranzadi (1929) and Aranzadi and Barandiarán (1935) described that there was a human femoral head, a human molar, a subadult vertebra, a phalanx and a small clavicle.

Table 3. Age-at-death determination for individuals from Lumentxa based on the dentition.

Individual	Label	Anatomical región	Side	Age group/category	State of wear ^a	Age range ^a	Age range ^b	Age range ^c
1	L.14H.1	maxilla	R	non-adult	-	-	3-5	3.5-4.5
	L.16H.160.1	maxilla	L		-	-	3-5	3.5-4.5
	L.28K.1198.rev	mandible	R + L		-	-	3-5	3.5-4.5
3	L.14H.5	mandible	R	young adult	B1	18-21	>15	18-21
4	L.14Z.455.2	mandible	R	adult	F/G	30-35/35-40	>35	25-35
5	L.11F.110	maxilla	L	adult	H/>H	40-50/>50	>35	35-45
	L.14Z.480.1	mandible	R + L		I/>I	45-55/>55	>35	35-45

^aBased on Lovejoy (1985).

^bBased on Buikstra and Ubelaker (1994).

^cBased on Brothwell (1981).

Table 4. C14 dates of the human remains of Lumentxa.

Individual	Anatomical region	Label	Archaeological context	Laboratory number	C:N proportion	Radiocarbon age (BP)	Calendar calibrated results (95% probability)*		Reference
							BCE age	BP age	
Individual 1	Cranium fragment	L.22H.REV.46 ²	Trench cleaning (see main text)	Beta-493404	3.3	3,550 ± 30	2,009-1,772	3,958-3,721	This study
Individual 4	Fibula	L.28F.220.10.L7 ²	IIB	Beta-493405	3.2	4,780 ± 30	3,641-3,519	5,590-5,468	This study
	Vertebra	L.32F.198.11.L5 ²	IIB	CNA 5113.1.1	3.0	4,810 ± 35	3,656-3,521	5,605-5,470	This study
	Premolar	L.14Z.455.2		CNA	-	No collagen			
Individual 5	Rib fragment	L.26F.240.5.L10 ²	IIC	Ua-12665	-	5,105 ± 80	4,147-3,700	6,096-5,649	Arribas Pastor and Berganza Gochi, 2018; García-Sagastibelza et al., 2018
Individual 6	Vertebra	L.18G.208,5.184.L8 ²	IIB	CNA 5114.1.1	-	6,110 ± 35	5,208-4,943	7,157-6,892	This study
	Fibula	L.10B.80 ¹	III	OxA-18236	2.9	6,122 ± 38	5,209-4,959	7,158-6,908	Arias Cabal, 2012b; Arias and Cubas, 2018

* Calibrated using Oxcal v.4.3 software (Bronk Ramsey, 1998; 2009) and Intcal13 calibration curve (Reimer et al. 2013).

¹Recovered during the first period of excavation (1926-1929).

² Recovered in the third period of excavation (1984-1993).

Table 5. Taphonomic modifications of human skeletal remains from Lumentxa.

Individual	NISP	Modifications							
		Burned	Tooth Marks	Root	Trampling	Biochemical	MN	Cementation	Rodent
1	11				X	X	X		
2	2								
1-2	5					X	X		
3	6			X		X	X		
4	24	X	X	X	X	X	X	X	
5	110			X		X	X	X	
6	9							X	
7	3		X				X		
non-assigned	43		X			X	X	X	X
Modification									
NISP - (%) total - (%) no dental remains									
		Burned	Tooth Marks	Root	Trampling	Biochemical	MN	Cementation	Rodent
		2-0.94-1.07	3-1.41-1.60	4-1.88-2.14	3-1.41-1.6	32-15.02-17.11	29-13.62-15.51	7-3.29-3.74	1/0.47/0.53

Table 6. Standardised and non-standardised cross-sectional geometric properties of the Lumentxa right male humerus (label: L.28F.240,5.1.L9) and left male femur (label: L.28G.253,5.9.L9).

Anatomical region	Side	Section level	%CA	Zp (non-standardised)	Zp (standardised)
Humerus	Right	35%	73.38	1519.86	588.09
Femur	Left	50%	74.49	3089.15	1195.31

Maximum length of the femur: 419 mm.

For variable definition see supplementary Table 1.

Polar section modulus (Z_p) is measured in mm³.