Diet, mobility and death of Late Neolithic and Chalcolithic groups of the Cantabrian Region (northern Spain). A multidisciplinary approach towards studying the Los Avellanos I and II burial caves.

Borja González-Rabanal[1]*, Ana B. Marín-Arroyo[1], Jennifer R. Jones[2], Lucía Agudo Pérez[1], Cristina Vega-Maeso[3], Manuel R. González-Morales[4],

*corresponding author

borja.gonzalezrabanal@unican.es

[1]Grupo de I+D+i EVOADAPTA (Evolución Humana y Adaptaciones Económicas y Ecológicas durante la Prehistoria). Dpto. Ciencias Históricas. Universidad de Cantabria. Av/Los Castros 44, 39005 Santander, Spain.

[2]School of Natural Sciences, University of Central Lancashire, Preston, PR1 2HE, UK

[3]Facultad de Humanidades y Ciencias Sociales. Universidad Internacional Isabel I de Castilla. C/ Fernán González 76, 09003 Burgos. Spain.

[4]Instituto Internacional de Investigaciones Prehistóricas de Cantabria (Universidad de Cantabria, Banco Santander, Gobierno de Cantabria). Avda. de los Castros 52. 39005 Santander, Cantabria. Spain.

borja.gonzalezrabanal@unican.es https://orcid.org/0000-0002-1802-994X

marinab@unican.es http://orcid.org/0000-0003-3353-5581

jjones30@uclan.ac.uk https://orcid.org/0000-0002-9247-7994

lucia.agudoperez@unican.es

cvegamaeso@gmail.com https://orcid.org/0000-0002-5329-9726

manuelramon.gonzalez@unican.es http://orcid.org/0000-0001-7277-7837

Abstract

This paper reconstructs the diet and lifeways of Late Neolithic and Chalcolithic farming groups in the Cantabrian Region (northern Spain) using human remains found at Los Avellanos I and II (Alfoz de Lloredo, Cantabria). A bioarchaeological study was conducted, alongside radiocarbon dating and stable isotope analyses ($\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$) of human (n=7) and animal (n=3) bone collagen. Both caves were used as a burial location between the 4th and 3rd millennium cal. BC. Taphonomic analysis of the human remains shows post-depositional activity within both sites after the burial. The $\delta^{13}C$ and $\delta^{15}N$ results show that the prehistoric individuals ate a predominantly terrestrial diet, with animal protein from meat and likely dairy products being an important resource. Despite the proximity to the coastline, the $\delta^{13}C$ and $\delta^{15}N$ values demonstrate that marine resources were not being consumed in any great quantity by these Late Neolithic and Chalcolithic individuals. The $\delta^{34}S$ results show heterogeneity among the people buried in both caves. The majority of individuals had higher $\delta^{34}S$ values typical of living in coastal areas, but three individuals had lower $\delta^{34}S$ values, indicative of living further inland for at least some of their lives, suggesting human mobility between inland and coastal areas.

Keywords

Late Neolithic/Chalcolithic, Cantabrian Region, Los Avellanos I and II, human remains, Carbon, nitrogen and sulphur isotopes

1. Introduction

During the Neolithic and Chalcolithic farming groups of the Cantabrian Region buried their dead in megalithic structures or burial caves (Ontañón and Armendáriz, 2005). Over 1,300 megaliths are documented (Arias et al., 2006), although in most of these there is a notable absence of human remains due to alkaline and acidic soils, which can cause extreme degradation of biological materials, and only a few sites in the region have human bones preserved for these periods (Mujika and Armendáriz, 1991; Armendáriz and Teira, 2008). Despite these challenges, burial caves constitute a valuable and underexplored record of funerary practices during the 3rd and 4th millennia cal. BC, and can be used to study the lifeways of these farming groups (Zapata, 1995; Alday and Mujika, 1999; Muñoz and Morlote, 2000; Arias and Ontañón, 2008; Noval, 2013; Vega Maeso, 2017).

Stable isotopes analysis ($\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$) of human bone collagen can provide valuable information about the diet and mobility of farming societies across Europe (Richards, 2000; Nehlich et al., 2012; Fontanalls-Coll et al., 2017; Goude et al., 2019). The application of this methodology in Spain is relatively recent. Initial isotopic studies in the Cantabrian Region explored the dietary behaviour of Mesolithic individuals at the sites of Los Canes, Poza l'Egua, Colomba, J3, La Braña Arintero, Cotero de la Mina (Neolithic) and La Garma A (Bronze Age) (Arias, 2005; Arias and Schulting, 2010). During the last decade this scientific technique has been increasingly applied to other archaeological sites in this region to explore the origin and spread of farming practices at sites including Santimamiñe, Pico Ramos (Sarasketa-Gartzia et al., 2018), El Abrigo de La Castañera (Jones et al., 2019a), Ondarre (Fernández-Crespo et al., 2017) or Karea (Aranburu-Mendizabal et al., 2018) and, in the adjacent regions of Galicia in Cova do Santo (López-Costas et al., 2015), Burgos in Fuente Celada, El Arroyal I, El Hornazo and Ferrocarril-La Dehesa sites (Jones et al., 2019a) and Álava province, from remains at Fuente Hoz, Kurtzebide (Sarasketa-Gartzia et al., 2019), La Atayuela (Fernández-Crespo et al., 2018), Las Yurdinas II, Los Husos, Peña Larga, El Sotillo, Alto de la Huesera, La Chabola de la Hechicera and Longar (Fernández-Crespo and Schulting 2017). A recent review of $\delta^{13}C$ and $\delta^{15}N$ evidence available from the Iberian Peninsula has demonstrated high variability in Mesolithic diets, and heterogeneity in Neolithic diets, with a broad spectrum of resources being used, demonstrating the need to understand sites within their local contexts (Cubas et al., 2018). In this study, $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ analysis of human and animal bone collagen have been employed to explore the diet and mobility patterns of the Cantabrian Late Neolithic and Chalcolithic populations from Los Avellanos I and II.

Stable carbon and nitrogen isotopes of bone collagen reflect the food consumed by an individual over the last 10–15 years of their life and reflects long-term average diet (Hedges et al., 2007; Katzenberg, 2008). The $\delta^{13}C$ values can distinguish between terrestrial, marine and freshwater sources of dietary protein (Schulting and Richards 2002). In addition, this method is also useful in determining C_3 and C_4 photosynthetic pathways and therefore, the types of plants being consumed (Van der Merwe, 1982). Concerning $\delta^{15}N$ values, these are related to the trophic level of the food chain in which the analysed specimen feeds. Consumer $\delta^{15}N$ values are 3–4‰ higher than the values of the prey (Schoeninger and DeNiro 1984; Bocherens and Drucker, 2003; Hedges and

Reynard, 2007). Thus, $\delta^{15}N$ values can help to differentiate between herbivores, omnivores or carnivores. Marine ecosystems have a higher number of trophic levels than terrestrial environments (Minawaga and Wada, 1984).

Sulphur stable isotope analysis has been traditionally used for palaeodietary reconstruction (Richards et al., 2003), supplementing $\delta^{13}C$ and $\delta^{15}N$ evidence. The $\delta^{34}S$ values can help to identify aquatic resource consumption and especially can distinguish between freshwater or marine food webs (Privat et al. 2007). Additionally, sulphur stable isotope analysis has also been applied to investigate human mobility (Nehlich et al., 2012) and animals transhumance (Goude et al., 2019) with values directly linked to local geology, soil type, proximity to the sea and rainfall (Nehlich, 2015). Oceanic sulphur is re-deposited as rain over coastal platforms, being able to reach 30 km distance to the coast due to the sea spray effect (Cortecci et al., 2002). This means that it can be used to differentiate between coastal locations and different terrestrial ecosystems (Nehlich, 2015), something that has been observed within wild fauna in the Cantabrian Region (Jones et al., 2019b).

2. Material and methods

2.1. The Los Avellanos I and II burial caves

The sites of Los Avellanos I and II are located in the central-western part of Cantabria province (northern Iberia) in the town of La Busta, municipality of Alfoz de Lloredo (Figure 1). Both caves are situated in a small calcareous hill, six kilometres from the present shoreline, which dominates a plain delimited to the north and west by Monte Barbecha and to the south and east by the Saja river. The human remains from Los Avellanos I and II studied here are curated at the Museum of Prehistory and Archaeology of Cantabria (MUPAC).

2.1.1. Los Avellanos I

The entrance of the cave, oriented towards SE, is four meters wide and two meters high, leading to a vestibule where the archaeological assemblage was encountered at surface level (Muñoz et al., 1993) (Figure 2). The site was surveyed in the 1960s by the Sanz de Sautuola Archaeological Group, who undertook exploratory excavations, although the results of this were not published in detail (Begines and García Cáraves, 1966). During those works, the excavators documented the presence of human remains, lithic industry (highlighting a stemmed and winged lithic point) and a pottery collection consisting of 156 fragments. Of these, 14 are wheel-thrown ceramics and indicate use of the cave in historical times, possibly the medieval period. The rest of the pottery collection, attributed to the Chalcolithic and Bronze Age, comprises of handmade vessels, which have been placed into 20 groups according to their typological, technological and decorative characteristics. This collection, due to its surface deposition in a karstic context, has a high level of fragmentation and more than 20% of the potsherds are covered with calcareous concretions. However, the shape of three vessels can be determined. Vessel 1 is made up of 31 fragments which are part of an ovoid pot decorated using incised lines and small impressions. A single greyish polished fragment allows the reconstruction of part of Vessel 2, a closed profile with high carinated shoulder. Finally, 27 pieces make up the upper profile of a big storage pot, Vessel 3, with a convex moulding below the rim (Vega Maeso, 2017). The human remains were found disarticulated and spread across the surface of the cave floor, partially buried, and mixed with other archaeological materials (Begines and García Cáraves, 1966).

2.1.2. Los Avellanos II

This cave is tunnel-shaped, with two narrow mouths oriented to the south and east, respectively (Figure 2). The archaeological remains were found in a small room to the east of the entrance (three meters wide and two meters high). The site was discovered and excavated during the 1970s by local amateurs, without stratigraphic precision and the cave was subsequently used as cattle stable in modern times. Among the materials included in the Regional Archaeological Inventory of Cantabria were numerous fragments of human remains, as well as a polished axe, that today is missing from the archive. No data about the disposition of these human bones were documented during these amateur excavations (Muñoz et al., 1988) and no subsequent archaeological campaigns have taken place in the cave.

2.2. Bioarchaeological analysis of the human remains

Anthropological and taphonomic analyses were conducted at the Museum of Prehistory and Archaeology of Cantabria (MUPAC). Firstly, taxonomical and anatomical identification was undertaken with the help of anthropological atlases (Scheuer and Black, 2000; White and Folkens, 2005). The sex of the individuals was estimated based on the skull and coxal morphological landmarks including; the mastoid process, supraorbital ridge and nuchal crest in the occipital bone, and the greater sciatic notch in the coxal bones (Buikstra and Ubelaker, 1994). The age of the individuals was determined using cranial suture closure (Meindl and Lovejoy, 1985) and the fusion of epiphyses (Scheuer and Black, 2000). Age classes were defined according to Buikstra and Ubelaker (1994). Pathologies were identified using recognised palaeopathological guidelines (Aufderheide et al., 1998; Lovell and Grauer, 2018). Dental calculus was estimated based on the degrees proposed by Dobney and Brothwell (1987).

The taphonomic analysis was carried out through the identification of the different biostratinomic and diagenetic modifications on the skeletal remains using macroscopic observations (Botella et al., 2000; Fernández-Jalvo and Andrews, 2016). To assess the skeletal representation of the assemblages, several quantification units were applied: Number of Remains (NR), Minimum Number of Elements (MNE) and Minimum Number of Individuals (MNI) following Lyman (1994). Additionally, two indexes to determine the degree of fragmentation and the preservation of the assemblage were calculated: Fragmentation Ratio (FR) and Bone Representation Index (BRI). The FR is obtained by dividing the NR by the MNE (Richardson, 1980). It is measured around the value 1. The further from the value 1 is, the more fragmented the assemblage is (Marín-Arroyo, 2010). The BRI was calculated to estimate representation of each bone in the total sample, based on the ratio between the Number of Observed Bones (NOB) and Number of Theoretical Bones (NTB), according to the MNI represented (Bello and Andrews, 2006).

2.3. Radiocarbon dating

Prior to this work, radiocarbon dates were obtained from two individuals at Los Avellanos I. These dates were taken to contextualise the ceramic vessels found at the site, and the results provided evidence of two funerary episodes: one during the Late Neolithic and the another during the Chalcolithic (Vega Maeso, 2017).

In this research, four human individuals and one faunal remain were selected to date the burial context from Los Avellanos II. The selection of the human samples from the archaeological record was based on the following criteria: 1) the bone that provided the greater MNI according to side, age and size; 2) long bones with a dense cortical to ensure the high-quality standard of collagen preservation and 3) well-preserved remains not affected by taphonomic processes to avoid any contamination. The dates were calibrated in OxCal v4.4.2 (Bronk Ramsey, 2009) using the IntCal20 calibration curve (Reimer et al., 2020). All results are presented at a 95.4% probability. The results were modelled using Bayesian statistics in OxCal v4.4.2 (Bronk Ramsey, 2017). This was achieved by placing them within a single phase with start and end boundaries. T-type outlier model was adopted with an initial 5% probability for each determination to be an outlier. A date function was used to estimate the duration of the burial phases. An order function was used to calculate the probability that one PDF (Probability Distribution Function) predated another, providing information to assess synchronicity and temporal overlap of burial phases in each of the two sites through convergence and agreement tests.

2.4. Collagen extraction and stable isotope analysis

Samples from seven humans and three animals were taken for analysis from both caves. At Los Avellanos I three humans and one animal was analysed, and at Los Avellanos II, four humans and two animals were sampled. Bone collagen was extracted at the Institute of Biomedicine and Biotechnology facilities at the University of Cantabria (IBBTEC). Prior to the radiocarbon dating, a subsample of all specimens was analysed for stable isotope analysis, which also established the state of collagen preservation, and all subsequently dated specimens had >1% collagen, which is conductive to achieving a successful radiocarbon date.

Collagen extraction was undertaken following procedures outlined in Richards and Hedges (1999). Bone fragments were cleaned by abrasion to remove any possible surface contamination, before demineralisation in 0.5M HCL at 6-8 °C. Samples were then washed using de-ionised water. Samples were gelatinised in a weak acidic solution (pH3 HCL) at 70 °C for 48 hours, then filtered with 5–8 μm Ezee® filters, before freezing. Finally, the samples were lyophilised, and the extracted collagen was stored in Eppendorf tubes. Samples were analysed for $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ at Iso-Analytical (Crewe, UK). The $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ values are reported relative to the International V-PDB, AIR and VCDT standards. One sample from each site (AV02 and AVE04) were analysed in duplicate to control for analytical precision, which was 0.06‰ or better for both $\delta^{13}C$ and $\delta^{15}N$. The following established bone collagen quality indicators were used: % collagen (>1), %C (30-44%), %N (11-16%), %S (0.15-0.35%), C:N (2.9-3.6), C:S (600 ± 300) and N:S (200 ± 100) (DeNiro, 1985; Ambrose, 1990; Van Klinken, 1999; Nehlich and Richards, 2009).

3. Results

3.1. Bioarchaeological results

The skeletal profile representation of the human remains from Los Avellanos I and II are presented in Table 1. The human bone assemblage at Los Avellanos I is composed of 158 NR belonging to 107 MNE and 6 MNI. The assemblage contains a minimum of three adults, based on the temporal bones (petrous portion) and three children, based on coxal bones. In total, one infant (0-3 years), two children (3-12 years), one young adult (20-35 years) and two middle aged adults (35-50 years) were identified. The sex of the individuals was only possible to determine in the adults. Two were female, and one was male. No postcranial pathologies were noted in the skeletal remains from Los Avellanos I. Only four individuals (3 adults and 1 child) had dental calculus adhering to their teeth, as well as periodontal disease. All of the individuals had supragingival tartar deposits in their lingual and buccal surfaces, with a slight and mild layer of calculus corresponding to the degrees 1 and 2, according to Dobney and Brothwell (1987). The dental calculus from these individuals was sampled for further analysis and will be discussed in future publications.

At Los Avellanos II, the bone assemblage is composed of 109 NR belonging to 72 MNE and 4 MNI based on femur bones considering the side, size and age of the specimens. This group is composed of three middle aged adults (35-50 years) and one young aged adult (20-35 years). Sex estimation was only possible to establish for two individuals, with one being male, one female and the remaining two were undeterminable. Pathological analyses indicated a relatively good health status of the people buried at the site. Two arthropathies in the axial skeleton region were observed within four vertebrae and in one fragment of pelvis probably belonging to the same individual. No other pathologies were identified in the human skeletons, except for a supragingival calculus deposit in the lingual surface (degree 2) of an adult individual.

The human remains were well-preserved at both sites. In general, the human bones were relatively complete, although some fragmentation of remains was noted, especially the skull at Los Avellanos I and the skull, os coxae and long bones at Los Avellanos II (Table 1). The FR is 1.5 for both Los Avellanos I and II, which demonstrates the low fragmentation of the assemblages. The BRI values indicate a poor skeletal representation of elements at both sites (Figure 3), indicating that, only 8.5% of the expected bones according to the minimum number of individuals represented were preserved at Los Avellanos I and II. The most frequently represented elements are coxal bones (100%), skull, mandible and sacrum-coccyx (67%) and maxillae (50%) at Los Avellanos I and, at Los Avellanos II, coxal bones (100%), skull, femur, tibia and ulna (75%) and humerus (50%). There is a predominance of bones typically associated with secondary deposition (such as skull, pelvis and long bones), with scarcity or absence of short bones with low bone-density such as phalanges, carpals, tarsals, patella or metacarpal and metatarsal bones (Figure 3). Teeth, which are the hardest tissue in the human skeleton, also showed a low representation within the deposit, considering the number of individuals recognised. Some preservation differences between both caves were noted. At Los Avellanos I, long bones had practically disappeared from the record, whereas at Los Avellanos II they were represented by 50% of the expected number. Similarly, at Los Avellanos I there are more axial bones represented.

Several different taphonomic modifications were observed on the human bones. Calcite concretions and water dissolution affected bone surfaces of 39% and 47% respectively of the skeletal remains at Los Avellanos I, and 28% and 80% at Los Avellanos II. Other taphonomic alterations were noted such as manganese staining or bacterial attack have been recognised in 9% and 19% of the NR respectively from Los Avellanos I and, 43% and 61% of the NR at Los Avellanos II. No evidence of human manipulation of the bones, such as cut marks, anthropic breakage or thermoalterations were identified. Long bones, from both sites, presented recent fractures characterised by mixed-right angles, transverse profile, jagged edge and a circumference value of one (Villa and Mahieu, 1991).

3.2. Radiocarbon dating and Bayesian modelling

All the samples yielded well-preserved collagen, as shown in Table 4. When calibrated, six of the eight dates performed coincide with the first half of 3rd millennium cal BC (Table 2), consistent with the Chalcolithic period at the Cantabrian Region (Ontañón Peredo, 2003), while two dates are located in different cultural periods. One in the second half of 4th millennium cal BC, corresponding to the Late Neolithic and, the last one, performed in a cow femur, in the Middle Ages (884-975 cal BC). To achieve the Bayesian modelling radiocarbon date of the Middle Ages was excluded. In the two sequences, convergence was greater than 96.7% and the model agreement index close to 91.6%.

A model with two phases for Los Avellanos I and a single phase for Los Avellanos II was built (Figure 4) and expressed at 68.3% and 95.4% probabilities (Table 3). No outliers were found. At Los Avellanos I for the Late Neolithic phase, the model provides a start date between 4835–3373 cal. BC (at 95.4% probability), ending at 3472-2673 cal. BC (95.4%). The duration of the phase is 1362 years (95.4%). For the Chalcolithic phase, the start date is between 3472–2673 (95.4%), ending between 2859-1267 (95.4%). The timespan of this phase would be 1390 years (95.4%).

At Los Avellanos II, for the Chalcolithic phase, the model gives a start date between 3165-2690 (95.4%), ending between 2861-2357 (95.4%). The duration of the phase is 509 years (95.4%). Therefore, the first burial episode was documented at Los Avellanos I, in the Late Neolithic between 4154-2792 cal. BC, while during Chalcolithic phase both caves were used as a burial place contemporaneously between 3390-2000 and 3020-2511 cal. BC, respectively.

3.3. Carbon and nitrogen stable isotope results

The stable isotope values for the humans and animals from Los Avellanos I and II are reported in Table 4 and plotted in Figure 5. Collagen extraction was carried out successfully in all the samples with % Collagen >1. The C:N values ranged between 3.1-3.2. Sample SUC364 showed %C (23.6%) and %N (8.6%) below the threshold accepted, although the yield, the elemental ratio and the isotopic results were consistent with others within the assemblage. However, this sample has been excluded from the discussion. Therefore, quality standards indicate generally good collagen preservation within the assemblages (Ambrose, 1993; Van Klinken, 1999).

All human specimens sampled were biologically assessed to be adult. The humans analysed from Los Avellanos I (n= 3) belong to the Late Neolithic and Chalcolithic periods and had $\delta^{13}C$ values ranging between -21.3‰ and -20.9‰ and $\delta^{15}N$ values between 8.7‰ and 9.3‰. The individuals from Los Avellanos II (n=3), dating to the Chalcolithic, had $\delta^{13}C$ values ranging between -21‰ and -20.5‰ and $\delta^{15}N$ values ranging between 8.8‰ and 9.3‰. Three faunal specimens were available to sample from these sites (Table 4). The ovicaprid from Los Avellanos I had a $\delta^{13}C$ value of -21.4‰ and a $\delta^{15}N$ value of 4.7‰. The cow from Los Avellanos II had a $\delta^{13}C$ value of -21.9‰ and a $\delta^{15}N$ value of 4.4‰. The juvenile pig from Los Avellanos II had a $\delta^{13}C$ value of -17.6‰ and a $\delta^{15}N$ value of 7.1‰. This pig was assessed to be juvenile because its M_3 tooth was not erupted yet. According to Silver (1969) this tooth erupts between 17-22 months, so this individual is younger than 17 months. Only the cow from Los Avellanos II (SUC363) was directly dated, and it constitutes a more later intrusion during the Middle Ages so that the contemporaneity of the faunal assemblage cannot be demonstrated.

3.4. Sulphur stable isotope results

The $\delta^{34}S$ analysis of the individuals from Los Avellanos I and II was undertaken to explore whether all of the individuals had consistently lived in the same location as each other during their lives (Figure 6). The human remains from Los Avellanos I yielded $\delta^{34}S$ values of 4.6‰, 9.6‰ and 13.5‰. These results reflect very diverse $\delta^{34}S$ signatures within the burials. For Los Avellanos II, three of the humans had $\delta^{34}S$ values ranging between 13.4‰ and 14.8‰, which are more homogeneous than at Los Avellanos I. A further Chalcolithic individual from Los Avellanos II (SUC365) had a lower $\delta^{34}S$ value of 10.5‰.

The three faunal samples also had $\delta^{34}S$ values of 13.7‰ (ovicaprid), 14.8‰ (*Bos taurus*) and 14.6‰ (*Sus domesticus*).

4. Discussion

4.1. Burial contexts at Los Avellanos I and II

Radiocarbon dates carried out at Los Avellanos I and II have provided a precise chronology of the use of the sites as funerary locations, which is consistent with previous burial caves recorded in the Cantabrian Region (Ontañón and Armendáriz, 2005). Los Avellanos I was used as a burial site during Late Neolithic and Chalcolithic, whereas Los Avellanos II was used predominantly during the Chalcolithic. Both sites have evidence of human occupation during the Middle Ages. The presence of medieval vessels at Los Avellanos I, as well as the radiocarbon date from Los Avellanos II corroborate the use of the sites during that time. Burials on the floor of the caves are relatively common during the Middle Ages in Cantabria, especially in Visigothic times (Hierro Gárate, 2011). During the Late Neolithic and the Chalcolithic, the use of caves as places of collective burial was common in this area, constituting a homogeneous funerary practice. Both sexes and practically all the age classes were represented at Los Avellanos I and II, as seen in most of the contemporary burial caves in the region (Ontañón and Armendáriz, 2005). In these contexts, it has been suggested that these caves were used for primary burials that were later displaced, but no taphonomic research has been carried out on these assemblages. Preservation differences among anatomical elements reveal the poor preservation of the funerary record and scarcity or absence of short and low density bones at Los Avellanos I and II. Three possible explanations could produce the skeletal representation seen within both deposits: 1) the use of the caves as a place of secondary burials. The disarticulation observed by the excavators is typical of secondary depositions, but it is difficult to establish if the remains were moved to the cave after the bodies were skeletonised elsewhere or if these were primary burials inside the cave and later remobilised by humans for giving access to new burials. 2) a differential preservation of the skeletal remains due to attrition processes affecting the low-density bones. The taphonomic results demonstrated that significant post-depositional processes were occurring within both caves. Breakage patterns appear to be related to diagenetic modifications at the sites, constituting the most probable causes of the assemblage fragmentation. These modifications are typical of surface deposits and karstic systems, where the water circulation and the humidity of environment stimulate these types of processes (Brugal, 1994) and 3) a preservation bias related to the collection of the remains, typical in amateur and old excavations where the more visible and diagnostic bones are recovered, and the short bones left at the sites. Therefore, taphonomic analysis is a key tool for interpreting surface funerary deposits affected by post-depositional activities (González-Rabanal et al., 2017).

4.2. Dietary behaviour of the individuals at Los Avellanos I and II

The human groups from Los Avellanos I and II showed a low number of pathological lesions, which could indicate a relatively good health status and living conditions of the individuals analysed. However, the small sample size may bias these results, and a great variety of stress markers are not necessarily visible in the skeleton. Degenerative arthropathies were identified in an adult individual. This could be explained by the more advanced age and the physical activity performed during its life. The most common condition was the presence of supragingival dental calculus in 5 of the 10 individuals studied, as well as periodontal disease in 4 of them. Diets that are high in protein can result in greater quantities of calculus formation due to the increased alkalinity of the oral environment (Hillson, 1979). Still, numerous factors can affect the production of dental calculus in living individuals (Lieverse, 1999). For these individuals, both diet and a poor dental hygiene could produce the tartar seen in their teeth.

The isotopic results of the Late Neolithic/Chalcolithic individuals from Los Avellanos I and II show homogeneity in their diet (Figure 5). The scarcity of faunal remains recovered in both burial caves means that few specimens were available to create a local baseline. However, the faunal isotopic values obtained from other regional Neolithic and Chalcolithic contexts at the sites of El Mirón, Santimamiñe and Pico Ramos (Stevens et al., 2014; Sarasketa-Gartzia et al., 2018) have been used as regional reference baseline (Figure 7). The $\delta^{13}C$ values from the individuals buried at Los Avellanos I and II are consistent with typical values for a terrestrial C_3 North Iberian ecosystem during the Holocene (e.g. Sarasketa-Gartzia et al., 2018; 2019, Jones et al., 2019a, Fernández-Crespo et al., 2018; Villalba-Mouco et al., 2018a; 2018b; 2019a). These Late Neolithic and Chalcolithic humans studied in the Cantabrian Region have $\delta^{15}N$ values 3–4‰ higher than the herbivores, which is the common relationship established between consumers and prey (Minagawa and Wada, 1984; Hedges and Reynard 2007) and suggest that the prehistoric humans from Los Avellanos I and II were eating a mixed C_3 diet that included animal protein. Regarding the sources of dietary protein consumed, recent research using molecular and isotopic analysis of lipids from pottery in the sites of Los Gitanos, Los Canes and Cova Eirós have provided a high frequency of dairy products and animal fats in these vessels (Cubas et al., 2020), suggesting that dairying, as well as meat consumption, was an important aspect of the economy for early farmers in the Cantabrian Region. Other studies of Late Neolithic and Chalcolithic diets in northern Iberia show similar results for $\delta^{13}C$ and $\delta^{15}N$ isotopic values (Figure 7). This is the case of Cotero de la Mina, Santimamiñe, Pico Ramos and Karea (Arias, 2005; Sarasketa-Gartzia et al., 2018; Aranburu-Mendizabal et al., 2018) and the caves and megaliths from La Rioja Alavesa (Fernández-Crespo and Schulting 2017; Fernández-Crespo et al., 2018). In summary, the diet of Cantabrian Neolithic and Chalcolithic populations was relatively homogenous, at least, in terms of the quantity of animal protein consumed, which mirrors trends seen in the wider Iberian Peninsula during these periods (Cubas et al., 2018).

Archaeozoological analysis carried out in Late Neolithic, and Chalcolithic sites of the Cantabrian Region have shown a predominance of the domestic species over the wild animals (Ontañón, 2003; Altuna y Mariezkurrena, 2009), with domestics percentages between 55% and 95% of NR, depending on the site. There are some exceptions as Urtiaga, Herriko Barra, Mazaculos II A2 and the lower stratigraphical units from Los Gitanos with a higher presence of wild fauna, especially red deer (Marín-Arroyo and González Morales, 2009; Altuna y Mariezkurrena, 2009). Regarding the livestock represented, there is a diversity of bovids, ovicaprines and swine species. The most abundant one are ovicaprines (with percentages above 50% of the NR), but in some sites, cattle or pig are the most common species, as seen in the Chalcolithic levels of El Mirón (Altuna and Mariezkurrena, 2012) or at El Abrigo de La Castañera (Vega Maeso et al. 2016). Despite the variety of frequencies noted, these species constitute the most probable animal protein source consumed by these farming groups.

Assessing the relative contributions of animal and plants in the diet, using $\delta^{13}C$ and $\delta^{15}N$ analysis, is complex. A major limitation of stable isotope analysis is that it is biased towards representing protein consumed, and over inflates the importance of resources that are higher in protein, which can mask the contribution of both domestic and wild plants in the diet of an individual (Hedges and Reynard 2007). Regarding possible plant resources that would have been available, wheat and barley are the most common cereals during the Neolithic-Chalcolithic in the Iberian Peninsula (Buxó and Piqué 2008). Direct radiocarbon dates of cereal seeds from El Mirón, Kobaederra and Pico Ramos demonstrate the early cultivation of these cereals since the second half of the 5th millennium cal BC (Zapata, 2005; Peña-Chocarro et al., 2005; Zapata et al., 2007). Cereal pollen and seeds have also been documented in other sites including Arangas, Los Gitanos, Lumentxa and Herriko Barra during the 4th/5th millennium cal BC (Zapata, 2002; Iriarte et al., 2005; Ontañón et al., 2013). It is possible that pulses, such as peas, lentils and fava beans, which appeared in the Iberian Peninsula from the Early Neolithic onwards (Zapata et al., 2004), were also a diet component at that time. Wild plant species as hazelnuts, acorns or fruits from *Rosaceae* family, were also exploited during the Neolithic/Chalcolithic at the Cantabrian Region sites of Arangas, El Carabión or Los Gitanos (López López-Dóriga, 2016).

The $\delta^{13}C$ values of humans had no measurable signals of C_4 plants consumption, such as millets. This is no surprise given that the first carpological and anthracological evidence of millet in Iberia dates to the Middle Bronze Age, although they were not systematically exploited until Late Bronze Age and Iron Age (Moreno-Larrazabal et al., 2015). In the Cantabrian Region, macroremains of millet (*Setaria italica*) were discovered in Kobaederra (Level 1) and Arenaza (Layer 9) chronologically assigned to the Chalcolithic and Early Bronze Age, respectively (Zapata, 2002). However, these seeds have not been directly dated and are part of archaeological sequences with reported stratigraphical issues and could potentially belong to a more recent intrusion. In the neighbouring region of La Rioja Alavesa, isotopic evidence of C_4 plant consumption is documented during the Iron Age at La Hoya village where millets were introduced to infants and young children during the weaning process, probably in porridge made with cooking grains mixed with water or milk (Fernández-Crespo et al., 2019). The juvenile pig at Los Avellanos II had an elevated $\delta^{13}C$ value of-17.6‰. Elevated $\delta^{13}C$ values can be associated with the consumption of C_4 plants, such as millet, but could also be due to the consumption of marine foods. In the latter case, elevated $\delta^{15}N$ values would also be expected. The pig studied at Los Avellanos II has $\delta^{15}N$ value of 7.1‰, which is lower than would be anticipated for pigs consuming marine protein (observed to be around 10-12‰ in archaeological specimens [Jones and Mulville 2016; 2018]). In this instance, the pig in question may have consumed some C_4 plants to produce that elevated $\delta^{13}C$ value. Only three prehistoric pigs found at El Abrigo de La Castañera have been analysed in the region. They are attributed to the Bronze Age and had $\delta^{13}C$ values ranging between -21.2‰ and -23‰ and $\delta^{15}N$ values between 3‰ and 5.2‰, which indicate of a predominantly C_3 diet rich in plant matter, with one pig (or boar) living in the forest (Jones et al., 2019a). The Los Avellanos II pig was not directly dated and could derive from a much later chronological period, which may explain why it has a diet that included C_4 plants. The presence of faunal bones dating to the Middle Ages demonstrates that there was activity in the cave after the Prehistoric burials. A similar situation occurred with a dog specimen found at Pico Ramos (Sarasketa-Gartzia et al., 2018), whose remains were recovered from Level 1, which constituted a disturbed and mixed stratigraphical unit with modern materials (Zapata, 1995).

There is no evidence from the $\delta^{13}C$ and $\delta^{15}N$ values for marine or freshwater resource consumption by the individuals analysed at Los Avellanos I and II, despite their relative proximity to the sea. This data supports the absence of aquatic foods found among vessels from Neolithic sites of the Cantabrian Region (Cubas et al., 2020). A rapid shift from consumption of marine protein towards the use of domesticated species, and in particular dairying, has been seen in coastal and insular locations in Europe (Cramp et al. 2014). Thus, Los Avellanos may be reflecting this wider pattern. Despite these findings, evidence of the use of marine and freshwater resources during the Neolithic/Chalcolithic sites is documented in the Cantabrian Region. Marine molluscs were found in considerable quantities in Neolithic contexts at the sites of Arenillas, Santimamiñe, Kobaederra, Pico Ramos, Los Gitanos and Mazaculos II (Zapata, 1995; González Morales 1995; Bohígas and Muñoz, 2002; Gutiérrez-Zugasti, 2009; Álvarez-Fernández et al., 2011). Marine birds in Herriko Barra (Elorza, 1993) and marine fish in Herriko Barra, Los Gitanos and Santimamiñe (Roselló and Morales, 2011; Álvarez-Fernández et al., 2014). However, recent reanalysis of some of these contexts and dates achieved in shells suggest that these belong to older chronologies and could be attributed to the Mesolithic (Zapata et al., 2007; Soares et al., 2016). The isotopic evidence suggests that, if marine resources were consumed at Los Avellanos, it was not in sufficient quantities to be registered in the long-term bone collagen record and would suggest either an infrequent or occasional use of marine resources.

4.4. Inland-Coastal movements at Los Avellanos I and II

The application of $\delta^{34}S$ analysis can be used to inform on population dynamics such as the movement of individuals. Within this study, four humans and three faunal specimens had values within the same range (13.4-14.8‰), indicative of all of them living in the same geographical location. Three individuals from Los Avellanos I and II fell outside this range (SUC359, SUC360 and SUC365), which suggests that they had spent at least a large proportion of their time living in an area that was lower in $\delta^{34}S$, causing them to have lower $\delta^{34}S$ values than the leading group.

It is likely that the main group of humans and animals with higher $\delta^{34}S$ values were predominantly living near the coast, with sulphur signatures affected by the sea spray effect, which typically produces elevated $\delta^{34}S$ values (Nehlich, 2015). The three humans with lower $\delta^{34}S$ signatures could be reflecting an isotopic signal typical of inland territories, as $\delta^{34}S$ values decrease with distance from the coast. A likely location of origin of these people could be further south, towards the North Castillian Plateau, an inland region with a cool and dry continental climate.

Little evidence of contact in these periods between the inland inhabitants of the North Castilian plateau and the Cantabrian coast has been recorded until recently. However, new multidisciplinary studies suggest that there was more contact between coastal and inland regions than previously thought. One male individual buried at the inland site of Arroyal I (Burgos) had a $\delta^{34}S$ that suggested it had lived in an area influenced by the sea spray effect, probably from the Cantabrian Region, which hints mobility between these regions during the Chalcolithic (Jones et al., 2019a). In the nearby inland archaeological site of El Hornazo (Burgos) a seashell was documented (Gutiérrez-Zugasti et al., 2014), which also supports the idea of contact between inland and coastal regions. Additionally, the stemmed and winged lithic point collected at Los Avellanos I is made of tabular flint, a raw material that does not exist in the surroundings of this site (Ontañón Peredo, 2003), but is expected in the northern Burgos area. Similarly, the closest typological parallels of vessels 2 and 3 from Los Avellanos I are found in the middle valley of the Arlanzón river, in the sites of El Púlpito, El Hornazo and Fuente Celada (Carmona Ballestero, 2013). The raw material used in the manufacture of these pots is compatible with the clay sources found in the surroundings of Los Avellanos, so it is likely that these similarities are related to possible movements of ideas and people.

Studies of vessels motifs have also been used to suggest there was a movement of people, possibly women, during the Early Bronze Age along with the Cantabrian Region

(Vega Maeso 2017). Human genetic studies also indicate a great scale on the movements of populations from Late Neolithic to Bronze Age in Iberia (Olalde et al., 2018; 2019; Villalba-Mouco et al., 2019b). Recent $^{87}Sr/^{86}Sr$ analysis at the sites of Pico Ramos and Santimamiñe showed evidence of mobility between the Pyrenees and the Cantabrian coast (Sarasketa-Gartzia et al., 2018). This body of evidence suggests that intra-regional movements, among farming populations, might have been common during these periods and regions along with the Cantabrian Region, with the Castilian Plateau, and even with the Pyrenees.

4.5. Social or sexual differentiation in mobility and diet

To date, no evidence of social or sex divisions based on $\delta^{13}C$ and $\delta^{15}N$ analysis have been observed between Neolithic and Chalcolithic individuals in the Cantabrian Region. Both the male and the female skeletons from Los Avellanos showed homogeneity in the diet. The $\delta^{34}S$ analysis of individuals also shows similar behaviour of both sexes. One man and one woman had lower $\delta^{34}S$ values, potentially from inland areas, which suggests that both men and women migrated to this region, although an analysis of a larger population would help to explore this further. This contrasts with evidence of individuals buried in caves or megalithic monuments in the neighbouring area of La Rioja Alavesa, where differences between the isotopic signatures ($\delta^{13}C$ and $\delta^{15}N$) of individuals were noted. The varying dietary behaviour of individuals was attributed as being due to differential social status, an economic specialisation among members of the same or different communities practising other economic activities and funerary practices (Fernández-Crespo and Schulting, 2017). Within the La Atayuela multiple pit grave, differences in the $\delta^{13}C$ values between the sepulchral contexts were observed, as well as an isotopic differentiation by sex and age. These results were interpreted as showing differential access to resources by women and children, that could indicate a possible sexual division of labour (Fernández-Crespo et al., 2018). Further research exploring burials at other sites in the Cantabrian Region is needed, to examine possible similarities or differences in the behaviour of males and females of these early farming populations on an inter- and intra-regional basis.

5. Conclusions

A multidisciplinary approach using radiocarbon dating, bioarchaeological research and stable isotope analysis has allowed gaining insights into aspects of life and death of farming societies in the Cantabrian Region. It has been proved that integrating different methodologies helps to study and interpret funerary surface deposits from old and amateur excavations curated at museums. Los Avellanos I and II were used as burial caves during the Late Neolithic and Chalcolithic periods ($3^{rd}/4^{th}$ millennia cal. BC). This funerary tradition is firmly rooted in the Cantabrian Region during the Recent Prehistory, and it constitutes a rich but practically ignored record to draw on in future studies. Osteoarchaeological results suggest that both males and females, were buried in these caves, with adults of varying ages and juveniles being represented. Both assemblages showed a poor preservation of the remains, as well as several post-depositional taphonomic processes. The humans buried at these caves consumed a mainly C_3 terrestrial diet, including animal protein (meat and likely dairy products).

Contemporaneous regional sites show a homogeneous pattern based on a contribution of terrestrial proteins, from both agriculture and livestock. The $\delta^{13}C$ and $\delta^{15}N$ analysis suggest that marine resources were not being consumed in sufficient quantities to affect their longer-term isotopic signature, meaning that if they were being consumed, then it was on an infrequent or occasional basis, and were insignificant in comparison to domestic resources. A main group of individuals from both caves had $\delta^{34}S$ values consistent with living locally, close to the coast. The sulphur values of three individuals are typical of spending prolonged periods in non-coastal areas, probably from inland territories like the North Castillian Plateau, and suggests a certain degree of population mobility. DNA analysis of these populations, which is currently in progress, will be a key tool to clarify population dynamics and movement in the region. Further work using stable isotope analysis of incremental human dentine would also be useful to explore diet changes during the year or seasonal mobility related to animal transhumance. Additionally, dental calculus analysis, which is currently being undertaken, will expand on our knowledge of wild and domestic plant resource consumption by these farming populations.

To sum up, this study has helped to understand the emergence of the first farming societies and the end of the hunter-gatherer lifestyle in Northern Spain. Nevertheless, further work is needed, especially on studying Early Neolithic human remains to enhance the understanding of the process of Neolithization in this particular region.

Acknowledgements

This study is part of BGR's Doctoral dissertation, supervised by ABMA and MRGM. This research is funded by the research projects of the Spanish Economy, Industry and Competitiveness Ministry HAR2016-75605-R (Cambio global, respuestas locales: impacto del cambio climático en las sociedades terminales de cazadores recolectores y el inicio de las economías productivas) to MRGM and HAR2017-84997-P and Santander Talent Atraction for Research (STAR1) to ABMA. The authors would like to thank Consejería de Universidades, Igualdad, Cultura y Deporte of the Cantabrian Regional Government for allowing the study and sampling of the remains from Los Avellanos I and II. Thank you also to R. Ontañón, A. Chauvin and the Museum of Prehistory and Archaeology of Cantabria (MUPAC) for providing access to their facilities, as well as the use of pictures of the archaeological materials curated. We also wish to express our gratitude to I. Varela and C. Revilla (IBBTEC, University of Cantabria) for the use of their laboratory facilities to carry out the collagen extraction and for laboratory assistance. Finally, we also thanks to two anonymous reviewers for their constructive comments that improved the manuscript.

References

Alday, A., Mujika, J. A., 1999. Nuevos datos de cronología absoluta concerniente al Holoceno Medio en el área vasca. In: El Mundo indígena (XXIV Congreso Nacional de Arqueología) (pp. 95–106). Murcia: Instituto de Patrimonio Histórico.

Altuna, J., Mariezkurrena, K. 2009. Tipos de cabañas ganaderas durante el Neolítico del País Vasco y zonas próximas. *Archaeofauna*, (18), 137-157.

Altuna, J., Mariezkurrena, K., 2012. Macromammalian remains from the Holocene levels of El Mirón cave. *El Mirón cave, Cantabrian Spain: The site and its Holocene archaeological record*, 288-318.

Álvarez-Fernández, E., Chauvin, A., Cubas, M., Arias, P., Ontañón-Peredo, R., 2011. Mollusc shell sizes in archaeological contexts in northern Spain (13200 to 2600 cal BC): New data from La Garma A and Los Gitanos (Cantabria). Archaeometry 53(5), 963–985.

Álvarez-Fernández, E., Altuna, J., Barrera-Melado, I., Cubas, M., Fernández-Gómez, M. J., Fernández, R., Gruet, Y., Mariezkurrena, K., Ontañón, R., 2014. Évolution de l'exploitation des ressources animales dans la région cantabrique entre 4500 et 2000 cal

BC: La grotte de Los Gitanos (Cantabrie, Espagne). Comptes Rendus Palevol. 13, 307–316.

Ambrose, S.H., 1990. Preparation and characterization of bone and tooth for isotopic analysis. J. Arch. Sci. 17, 431-451.

Aranburu-Mendizabal, A., Sarasketa-Gartzia, I., Arrizabalaga, A., Salazar-García, D. C., Taldea, A. A., Iriarte-Chiapusso, M. J., 2018. El yacimiento calcolítico de Karea en el contexto de las cuevas sepulcrales de Gipuzkoa (País Vasco). Munibe Antropologia-Arkeologia 69, 177-190.

Arias, P., 2005. Determinaciones de isotopos estables en restos humanos de la región cantábrica. aportación al estudio de la dieta de las poblaciones del Mesolítico y Neolítico. Munibe Antropologia-Arkeologia (Homenaje a Jesús Altuna) 57, 359-374.

Arias, P., Ontañón, R., 2008. Zona arqueológica de La Garma (Omoño, Ribamontán al Monte). Campañas 2000-2003. Actuaciones arqueológicas en Cantabria 2000-2003, Gobierno de Cantabria, Santander, 43-60.

Arias, P., Schulting, R. J., 2010. Análisis de isótopos estables sobre los restos humanos de La Braña-Arintero. In: Vidal, J. M., Prada, M. E. (Eds), Aproximación a la dieta de los grupos mesolíticos de la cordillera cantábrica. Los Hombres Mesolíticos de la cueva La Braña-Arintero (Valdelugueros, León), Estudios y Catálogos de la Junta de Castilla y León, 130-137.

Arias, P., Armendariz, A., Teira, L., 2006. The megalithic complex in Cantabrian Spain. In Rodríguez Casal, A (Ed.), Le mégalithisme atlantique: The Atlantic megaliths. Acts of the XIVth UISPP Congress, BAR Int. Ser. 1521, 11–29. Oxford: Archaeopress.

Armendáriz, A., Teira, L., 2008. El megalitismo en la Marina Occidental de Cantabria. Excavación arqueológica del dolmen El Cotero de la Mina (San Vicente de la Barquera). VI Campaña (2000). In Actuaciones arqueológicas en Cantabria 2000-2003 (pp. 107-110). Consejería de Cultura, Educación y Deporte.

Aufderheide, A.C., Rodríguez-Martín, C., Langsjoen, O., 2006. The Cambridge encyclopedia of human paleopathology. Cambridge University Press, Cambridge.

Begines, A., García Cáraves, J. M., 1966. Hallazgos del Bronce I en dos cuevas de Santander. Actas del IX Congreso Nacional de Arqueología, 122-126. Zaragoza.

Bello, S., Andrews, P., 2006. The intrinsic pattern of preservation of human skeletal and its influence on interpretation of funerary behaviors. In Gowland, R., Knusel, C. (Eds.), Social archaeology of funerary remains, Oxbow Books, 1-13.

Bocherens, H., Drucker, D.G., 2003. Trophic level isotopic enrichment of carbon and nitrogen in bone collagen: case studies from recent and ancient terrestrial ecosystems. International J. Osteoarch. 13, 46-53.

Bohígas R., Muñoz Fernández E., 2002. Excavaciones arqueológicas de urgencia en el Covacho de Arenillas (Islares, CastroUrdiales). In: Ontañón, R. (Ed.), Actuaciones Arqueológicas en Cantabria 1987-1999. Santander: Arqueología de Gestión, Gobierno de Cantabria, 45-47.

Botella, M.C., Alemán, I., Jiménez, S. A., 2000. Los huesos humanos. Manipulación y alteraciones. Edicions Bellaterra, Barcelona.

Bronk Ramsey, C., 2009. Bayesian analysis of radiocarbon dates. Radiocarbon 51 (1), 337-360.

Bronk Ramsey, C., 2017. Methods for summarizing radiocarbon datasets. *Radiocarbon*, *59*(6), 1809-1833.

Brugal, J. P., 1994. Introduction generale: action de l'eau sur les ossements et les assemblages fossils. Artefacts 9, 121-129.

Buikstra, J.E., Ubelaker, D.H., 1994. Standards for Data Collection from Human Skeletal Remains. Arkansas Archaeological Survey Research Series.

Buxó, R., Piqué, R., 2008. Arqueobotánica: los usos de las plantas en la Península Ibérica. Grupo Planeta (GBS).

Carmona Ballestero, E., 2013. El Calcolítico en la Cuenca Media del Arlanzón. Comunidades campesinas, procesos históricos y transformaciones. Oxford: BAR Int. Ser. 2559, Archaeopress.

Cortecci, G., Dinelli, E., Bencini, A., Adorni-Braccesi, A., La Ruffa, G., 2002. Natural and anthropogenic SO4 sources in the Arno river catchment, northern Tuscany, Italy: a chemical and isotopic reconnaissance. Appl. Geochem. 17, 79–92.

Cramp, L.J., Jones, J., Sheridan, A., Smyth, J., Whelton, H., Mulville, J., Sharples, N., Evershed, R.P., 2014. Immediate replacement of fishing with dairying by the earliest farmers of the northeast Atlantic archipelagos. Proceedings of the Royal Society B: Biological Sciences, 281(1780), 2013-2372.

Cubas, M., Peyroteo-Stjerna, R., Fontanals-Coll, M., Llorente-Rodríguez, L., Lucquin, A., Craig, O. E., Colonese, A. C., 2019. Long-term dietary change in Atlantic and Mediterranean Iberia with the introduction of agriculture: a stable isotope perspective. Archaeol. Anthropol. Sci. 11(8), 3825-3836.

Cubas, M., Lucquin, A., Robson, H.K., …Craig, O. E., 2020. Latitudinal gradient in dairy production with the introduction of farming in Atlantic Europe. Nat. Commun. 11(1), 1-9. https://doi.org/10.1038/s41467-020-15907-4

DeNiro, M.J., 1985. Postmortem preservation and alteration of in vivo bone collagen isotope ratios in relation to palaeodietary reconstruction. Nature, 317 (6040), 806-809.

Dobney, K., Brothwell, D. 1987. A method for evaluating the amount of dental calculus on teeth from archaeological sites. J. Archaeol. Sci. 14(4), 343-351.

Elorza, M., 1993. ¿Pingüinos en Zarautz? Sobre el hallazgo de la especie extinta *Pinguinus impennis* en el yacimiento de Herriko Barra. Aranzadiana 114, 71–73.

Fernandez-Crespo, T., Schulting, R. J., 2017. Living different lives: early social differentiation identified through linking mortuary and isotopic variability in Late Neolithic/Early Chalcolithic north-central Spain. PloS one 12(9), 1-19.

Fernández-Crespo, T., Mujika, J. A., Ordoño, J., 2017. Aproximación al patrón alimentario de los inhumados en la cista de la Edad del Bronce de Ondarre (Aralar, Guipúzcoa) a través del análisis de isótopos estables de carbono y nitrógeno sobre colágeno óseo. Trabajos de Prehistoria 73(2), 325-334.

Fernández-Crespo, T., Ordoño, J., Barandiarán, I., Andrés, M. T., Schulting, R. J., 2018. The Bell Beaker multiple burial pit of La Atalayuela (La Rioja, Spain): stable isotope insights into diet, identity and mortuary practices in Chalcolithic Iberia. Archaeol. Anthropol. Sci. 11(8), 3733-3749.

Fernández-Crespo, T., Ordoño, J., Bogaard, A., Llanos, A., Schulting, R., 2019. A snapshot of subsistence in Iron Age Iberia: The case of La Hoya village. J. Archaeol. Sci.: Rep 28, 102037.

Fernandez-Jalvo, Y., Andrews, P., 2016. Atlas of taphonomic identifications: 1001+ images of fossil and recent mammal bone modification. Springer.

Fontanals-Coll, M., Eulàlia Subirà, M., Díaz-Zorita Bonilla, M., Gibaja, J. F., 2017. First insight into the Neolithic subsistence economy in the north-east Iberian Peninsula: paleodietary reconstruction through stable isotopes. Am. J. Phys. Anthropol. 162(1), 36-50.

González-Morales, M. R., 1995. Memoria de los trabajos de limpieza y toma de muestras en los yacimientos de las cuevas de Mazaculos y El Espinoso (La Franca, Ribadedeva) y La Llana (Andrín, Llanes) en 1993. Excavaciones arqueológicas en Asturias 1991–1994, 65–78. Principado de Asturias, Oviedo.

González Rabanal, B., González Morales, M. R., Marín Arroyo, A. B., 2017. La tafonomía como marco metodológico para interpretar depósitos funerarios superficiales: estudio de la cueva sepulcral de El Espinoso (Ribadedeva, Asturias). Trabajos de Prehistoria 74 (2), 278-295.

Goude, G., Salazar-García, D.C., Power, R.C., Terrom, J., Rivollat, M., Deguilloux, M.F., Pemonge, M.H., Le Bailly, M., Andre, G., Coutelas, A. and Hauzeur, A., 2019. A multidisciplinary approach to Neolithic life reconstruction. J. Archaeol. Method Theory 26(2), 537-560.

Gutiérrez-Zugasti, F. I. (2009). La explotación de moluscos y otros recursos litorales en la región cantábrica durante el Pleistoceno final y el Holoceno inicial. Santander.

Gutiérrez Zugasti, F. I., Carmona Ballestero, E., Cuenca Solana, D., Pascual Blanco, S., Vega y Miguel, J. J., 2014. El papel de los moluscos de agua dulce durante el Calcolítico en la Meseta. una visión desde el yacimiento de El Hornazo (Villimar, Burgos). In Cantillo Duarte. J. S., Bernal Casasola, D., Ramos Muñoz, J., (Eds.), Molusco y púrpura en contextos arqueológicos atlánticomediterráneos: nuevos datos y reflexiones en clave de proceso histórico, Universidad de Cádiz, 107–116.

Hedges, R. E., Reynard, L. M., 2007. Nitrogen isotopes and the trophic level of humans in archaeology. J. Archaeol. Sci. 34(8), 1240–1251.

Hedges, R.E.M., Clement, J. G., Thomas, C. D. L., O'Connell, T. C., 2007. Collagen turnover in the adult femoral mid-shaft: modeled from anthropogenic radiocarbon tracer measurements. Am. J. Phys. Anthropol. 133, 808–816.

Hierro Gárate, J. A., 2011. La utilización sepulcral de las cuevas en época visigoda: los casos de Las Penas, La Garma y El Portillo del Arenal (Cantabria). Munibe Antropologia-Arkeologia 62, 351-402.

Hillson, S. W., 1979. Diet and dental disease. World Archaeol. 2,147–162.

Iriarte, M. J., Mujika, J. A., & Tarriño, A., 2005. Herriko Barra (Zarautz–Gipuzcoa): Caractérisation industrielle et économique des premiers groupes de producteurs sur le littoral basque. In Unité et diversité des processus de néolithisation sur la façade atlantique de l'Europe, Mémoire 36, 127–136. Paris: Société Préhistorique Française.

Jones, J. R., Mulville, J., 2016. Isotopic and zooarchaeological approaches towards understanding aquatic resource use in human economies and animal management in the prehistoric Scottish North Atlantic Islands. J. Archaeol. Sci.: Rep. 6, 665-677.

Jones, J. R., Mulville, J. A., 2018. Norse animal husbandry in liminal environments: Stable isotope evidence from the Scottish north Atlantic islands. Environmental Archaeol, 23(4), 338-351.

Jones, J. R., Maeso, C. V., Ballestero, E. C., Martín, L. V., Arceo, M. E. D., Marín-Arroyo, A. B., 2019a. Investigating prehistoric diet and lifeways of early farmers in central northern Spain (3000–1500 CAL BC) using stable isotope techniques. Archaeol. Anthropol. Sci. 11(8), 3979-3994.

Jones, J. R., Richards, M. P., Reade, H., de Quirós, F. B., Marín-Arroyo, A. B., 2019b. Multi-Isotope investigations of ungulate bones and teeth from El Castillo and Covalejos caves (Cantabria, Spain): Implications for paleoenvironment reconstructions across the Middle-Upper Palaeolithic transition. J. Archaeol. Sci.: Rep. 23, 1029-1042.

Katzenberg M. A., 2008. Stable Isotope Analysis: A tool for studying past diet, demography, and life history. In: Katzenberg M. A., Saunders S. R., (Eds), Biological Anthropology of the Human Skeleton, Wiley, 413-441.

Lieverse, A. R., 1999. Diet and the aetiology of dental calculus. Int. J.of osteoarchaeol. *9*(4), 219-232.

López-Costas, O., Müldner, G., Cortizas, A. M., 2015. Diet and lifestyle in Bronze Age Northwest Spain: the collective burial of Cova do Santo. J. Archaeol. Sci. 55, 209-218.

López López-Dóriga, I., 2016. The use of plants during the Mesolithic and the Neolithic in the Atlantic coast of the Iberian peninsula. Universidad de Cantabria.

Lovell, N. C., Grauer, A. L., 2018. Analysis and Interpretation of Trauma in Skeletal Remains. In: Katzenberg, M. A., Grauer, A. L. (Eds.), Biological Anthropology of the Human Skeleton, Third Edition, John Wiley & Sons, Hoboken, 335-383.

Lyman, R. L., 1994. Quantitative Units and Terminology in Zooarchaeology. Am. Antiq. 59 (1), 36-71.

Marín-Arroyo, A. B., González Morales, M. R. 2009. Comportamiento económico de los últimos cazadores-recolectores y primeras evidencias de domesticación en el occidente de Asturias. La Cueva da Mazaculos II. Trab. Prehist, 66(1), 4.

Marín-Arroyo, A. B., 2010. Arqueozoología en el cantábrico oriental durante la transición Pleistoceno/Holoceno. La Cueva del Mirón. PUbliCan. Santander.

Meindl, R. S., Lovejoy, C. O., 1985. Ectocranial suture closure: a revised method for the determination of skeletal age at death based on the lateral-anterior sutures. Am. J. Phys. Anthropol. 68(1), 57-66.

Minagawa, M., Wada, E., 1984. Stepwise enrichment of ^{15}N along food chains: further evidence and the relation between $\delta^{15}N$ and animal age. Geochim. Cosmochim. Acta 48(5), 1135-1140.

Moreno-Larrazabal, A., Teira-Brión, A., Sopelana-Salcedo, I., Arranz-Otaegui, A., Zapata, L., 2015. Ethnobotany of millet cultivation in the north of the Iberian Peninsula. Veg. Hist. Archaeobot. 24 (4), 541–554.

Mujika, J. A., Armendáriz, A., 1991. Excavaciones en la estación megalítica de Murumendi (Beasain, Gipuzkoa). Munibe Antropologia-Arkeologia 43, 105-165.

Muñoz, E., Morlote, J. M., 2000. Documentación arqueológica de la cueva del Calero II y la Sima del Portillo del Arenal, en Piélagos. In Ontañón-Peredo, R., (Ed.), Actuaciones arqueológicas en Cantabria 1984–1999, 263–266. Santander: Consejería de Cultura, Turismo y Deporte.

Muñoz, E., San Miguel, C., CAEAP, 1988. Carta Arqueológica de Cantabria. Ed. Tantín, Santander.

Muñoz, E., Gómez, J. San Miguel, C., 1993. Catálogo topográfico de las cavidades con interés arqueológico: Ruiloba-Besaya (Zona III). Boletín Cántabro de Espeleología 9, 57-73.

Nehlich, O., 2015. The application of sulphur isotope analyses in archaeological research: a review. Earth Sci. Rev. 142, 1–17.

Nehlich, O., Richards M. P., 2009. Establishing collagen quality criteria for sulphur isotope analysis of archaeological bone collagen. Archaeol. Anthropol. Sci. 1(1), 59–75.

Nehlich, O., Fuller, B. T., Márquez-Grant, N., Richards, M. P., 2012. Investigation of diachronic dietary patterns on the islands of Ibiza and Formentera, Spain: evidence from sulfur stable isotope ratio analysis. Am. J. Phys. Anthropol. 149, 115–124.

Noval, M., 2014. Excavación arqueológica en la cueva de El Toral III (Andrín, Llanes). Excavaciones arqueológicas en Asturias, 381-384.

Olalde, I., Brace, S., Allentoft, M. E., Armit, I., Kristiansen, K., Booth, T., … Reich, D., 2018. The Beaker phenomenon and the genomic transformation of northwest Europe. Nat. 555(7695), 190-196. https://doi.org/10.1038/nature25738

Olalde, I., Mallick, S., Patterson, N., Rohland, N., Villalba-mouco, V., Silva, M., … Reich, D., 2019. The genomic history of the Iberian Peninsula over the past 8000 years. Sci. Rep. 363(6432).

Ontañón Peredo, R., 2003. Caminos hacia la complejidad. El Calcolítico en la región cantábrica. Servicio de Publicaciones de la Universidad de Cantabria, Santander.

Ontañón, R., Armendáriz. A., 2005. Cuevas y megalitos: los contextos sepulcrales colectivos en la Prehistoria reciente cantábrica. Munibe Antropologia-Arkeologia (57), 275-286.

Ontañón-Peredo, R., Altuna, J., Á lvarez-Fernández, E., Chauvin, A., Cubas, M., Fernández, R., Gruet, Y., Iriarte, M. J., López-López Dóriga, I., Mariezkurrena, K., Zapata, L., (2013). Contribution à l'étude de la néolithisation dans la région Cantabrique: La grotte de Los Gitanos (Cantabrie, Espagne). In: Daire, M. Y., Dupont, C., Baudry, A., Billard, C., Large, J. M., Lespez, L., Normand, E., Scarre, C., (Eds.), Anciens peuplements littoraux et relations homme/milieu sur les côtes de l'Europe atlantique, BAR Int. Ser. 2570, 383–390. Oxford: Archaeopress.

Pena-Chocarro, L., Zapata, L., Iriarte, M. J., Morales, M. G., Straus, L. G., 2005. The oldest agriculture in northern Atlantic Spain: new evidence from El Mirón Cave (Ramales de la Victoria, Cantabria). J. Archaeol. Sci. 32(4), 579-587.

Privat, K. L., O'Connell, T. C., Hedges, R. E. M., 2007. The distinction between freshwater- and terrestrial-based diets: methodological concerns and archaeological applications of sulphur stable isotope analysis. J. Archaeol. Sci. 34, 1197–1204.

Reimer, P., Austin, W.E.N., Bard, E., Bayliss, A., Blackwell, P.G., Bronk Ramsey, C., Butzin, M., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Hajdas, I., Heaton, T.J., Hogg, A.G., Hughen, K.A., Kromer, B., Manning, S.W., Muscheler, R., Palmer, J.G., Pearson, C., van der Plicht, J., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Turney, C.S.M., Wacker, L., Adolphi, F., Büntgen, U., Capano, M., Fahrni, S., Fogtmann-Schulz, A., Friedrich, R., Köhler, P., Kudsk, S., Miyake, F., Olsen, J., Reinig, F., Sakamoto, M., Sookdeo, A., Talamo, S., 2020. The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). Radiocarbon 62.

Richards M. P., Hedges R. E. M., 1999. Stable isotope evidence for similarities in the types of marine foods used by late Mesolithic humans at sites along the Atlantic coast of Europe. J. Archaeol. Sci. 26, 717–722.

Richards, M. P., 2000. Human consumption of plant foods in the British Neolithic: direct evidence from bone stable isotopes. Plants in Neolithic Britain and beyond, 123-35.

Richards, M. P., Fuller, B. T., Sponheimer, M., Robinson, T., Ayliffe, L., 2003. Sulphur isotopes in palaeodietary studies: a review and results from a controlled feeding experiment. Int. J. Osteoarch. 13(1-2), 37-45.

Richardson, P. R. K., 1980. Carnivore damage to antelope bones and its archaeological implications. Palaeont. afr. 23, 109-125.

Roselló, E., Morales, A., 2011. Evidencias de pesca en las ocupaciones de Santimamiñe. In: López-Quintana, J. C. (Ed.), La cueva de Santimamiñe: Revisión y actualización (2004–2006), Kobie—Bizkaiko Arkeologi Indusketak–BAI 1, 239-246. Bilbao: Bizkaiko Foru Aldundia.

Sarasketa-Gartzia, I., Villalba-Mouco, V., Le Roux, P., Arrizabalaga, A., Salazar-García, D. C., (2018) Late Neolithic-Chalcolithic socio-economical dynamics in northern Iberia. A multi-isotope study on diet and provenance from Santimamiñe and Pico Ramos archaeological sites (Basque Country, Spain). Quat. Int. 481, 14-27.

Sarasketa-Gartzia, I., Villalba-Mouco, V., Le Roux, P., Arrizabalaga, Á., Salazar-García, D. C., 2019. Anthropic resource exploitation and use of the territory at the onset of social complexity in the Neolithic-Chalcolithic Western Pyrenees: a multi-isotope approach. Archaeol. Anthropol. Sci. 11(8), 3665-3680.

Scheuer, L.; Black, S., 2000. Developmental juvenile osteology. London. Elsevier Academic Press.

Schoeninger, M. J., DeNiro, M. J., 1984. Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals. Geochim. Cosmochim. Acta 48(4), 625-639.

Schulting R. J., Richards M. P., 2002. The wet, the wild and the domesticated: The Mesolithic Neolithic transition on the west coast of Scotland. Eur. J. Archaeol. 5, 147–189.

Silver, I. A. 1969. The ageing of domestic animals. Science in archaeology, 283-302.

Soares, A. M. M., Gutiérrez-Zugasti, F. I., González-Morales, M. R., Martins, J. M. M., Cuenca-Solana, D., Bailey, G. N., 2016. Marine radiocarbon reservoir effect in late Pleistocene and early Holocene coastal waters off northern Iberia. Radiocarbon 58(4), 869-883.

Stevens, R. E., Hermoso-Buxán, X. L., Marín-Arroyo, A. B., González-Morales, M. R., Straus, L. G., 2014. Investigation of Late Pleistocene and Early Holocene palaeoenvironmental change at El Mirón cave (Cantabria, Spain): insights from carbon and nitrogen isotope analyses of red deer. Palaeogeog. Palaeoclim, Palaeoecol. 414: 46–60.

Van der Merwe, N. J., 1982. Carbon isotopes, photosynthesis, and archaeology: Different pathways of photosynthesis cause characteristic changes in carbon isotope ratios that make possible the study of prehistoric human diets. American Scientist 70(6), 596-606.

van Klinken G. J., 1999. Bone collagen quality indicators for palaeodietary and radiocarbon measurements. J. Archaeol. Sci. 26, 687–695.

Vega Maeso, C., 2017. La cerámica inciso-impresa en el tránsito del III al II milenio cal. B.C. en la región Cantábrica Nadir Edic. Santander. https://doi.org/10.1128/AAC.03728-14

Vega-Maeso, C., Carmona-Ballestero, E., Sierra-Sainz-Aja, A., Marín-Arroyo, A. B. 2016. El Abrigo de la Castañera (Cantabria, Spain): A Chalcolithic cattle stable?. Quat. Int. 414, 226-235.

Villa, P.; Mahieu, E., 1991. Breakage patterns of human long bones. J. Human Evol. 21, 27-48.

Villalba-Mouco, V., Utrilla, P., Laborda, R., Lorenzo, J. I., Martínez-Labarga, C., Salazar-García, D. C., (2018a). Reconstruction of human subsistence and husbandry strategies from the Iberian Early Neolithic: A stable isotope approach. Am. J. Phys. Anthropol. 167(2), 257-271.

Villalba-Mouco, V., Sauqué, V., Sarasketa-Gartzia, I., Pastor, M. V., le Roux, P. J., Vicente, D., Utrilla, P., Salazar-García, D. C., 2018b. Territorial mobility and subsistence strategies during the Ebro Basin Late Neolithic-Chalcolithic: A multi-isotope approach from San Juan cave (Loarre, Spain). Quat. Int. 481, 28-41.

Villalba-Mouco, V., Sarasketa-Gartzia, I., Utrilla, P., Oms, F. X., Mazo, C., Mendiela, S., Cebrià, A., Salazar-García, D. C., 2019a. Stable isotope ratio analysis of bone collagen as indicator of different dietary habits and environmental conditions in northeastern Iberia during the 4th and 3rd millennium cal BC. Archaeol. Anthropol. Sci. 11(8), 3931-3947.

Villalba-Mouco, V., van de Loosdrecht, M. S., Posth, C., Mora, R., Martínez-Moreno, J., Rojo-Guerra, M., … Haak, W., 2019. Survival of Late Pleistocene Hunter-Gatherer Ancestry in the Iberian Peninsula. Curr. Biol. 29(7), 1169-1177.e7. https://doi.org/10.1016/j.cub.2019.02.006

White, T., Folkens, P., 2005. The human bone manual. Elsevier Academic Press.

Zapata, L., 1995. El depósito sepulcral calcolítico de la cueva de Pico Ramos (Muskiz, Bizkaia). Munibe Antropología-Arkeología 47, 33-197.

Zapata, L., 2002. La explotación de los recursos vegetales y el origen de la agricultura en el País Vasco: Análisis arqueobotánico de macrorrestos vegetales. Kobie Anejo 4. Bilbao: Diputación Foral de Bizkaia.

Zapata, L., 2005. Agricultura prehistórica en el País Vasco. Munibe Antropologia–Arkeologia (Homenaje a Jesús Altuna) 57(1), 553–561.

Zapata, L., Peña-Chocarro, L., Pérez-Jordá, G., Stika, H. P., 2004. Early neolithic agriculture in the Iberian Peninsula. J. World Prehist. 18(4), 283-32

Zapata, L., Milner, N., Rosello, E., 2007. Pico Ramos cave shell midden: the Mesolithic-Neolithic transition by the Bay of Biscay. In: Milner, N., Craig; O., Bailey, G. N., (Eds.), Shell middens in Atlantic Europe, 150-157. Oxford, Oxbow.