



Reconstruction of human subsistence and husbandry strategies from the Iberian Early Neolithic: A stable isotope approach

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Abstract

Objectives: The Early Neolithic involved an important social and economic shift that can be tested not only with the material culture, but also through biomolecular approaches. The Iberian Peninsula presents few Early Neolithic sites where fauna and humans can be analyzed together from an isotopic perspective. Here we present an isotopic study on the site of Cueva de Chaves as an example for understanding the dietary and economical changes that took place during Early Neolithic in Iberia.

Material and methods: Here we apply carbon and nitrogen stable isotope analysis to bone collagen from 4 humans and 64 faunal samples from 14 different species. The large dataset belongs to the same unique chrono-cultural context secured by 20 radiocarbon dates. Three direct new radiocarbon dates were carried out on the human remains analyzed.

Results: Faunal isotope values show no significant differences between wild and domestic herbivores, although the latter have more homogeneous values. Domestic pigs, potentially considered omnivorous, also show signatures of a herbivore diet. Human isotopic results show a diet mainly based on terrestrial C₃ resources and possibly high meat consumption. The only individual found buried with a special funerary treatment presents a slightly different protein intake, when taking into account the long contemporaneous baseline analyzed.

Discussion: Similar values between wild and domestic species could be the result of common feeding resources and/or grazing on the same parts of the landscape. The herbivore diet seen amongst domestic pigs rules out feeding on household leftovers. High meat consumption by humans would support the hypothesis of the existence of a specialized animal husbandry management community in which agriculture was not intensively developed. Our results suggest that the development of agricultural practices and animal husbandry were not necessarily associated together in the early stages of the Western Mediterranean Neolithic.

KEYWORDS

animal management, cardiac, carbon and nitrogen stable isotopes, funerary practices, domestication, radiocarbon dating

1 | INTRODUCTION

The rise of the Neolithic involved important cultural, economic, genetic and environmental changes in many places, including the Western

Mediterranean (Salazar-García and García-Puchol, 2017a). These changes are relatively easy to prove throughout the archaeological record. The so-called Neolithic package normally includes an increase of material culture including first pottery and polished stone, and then

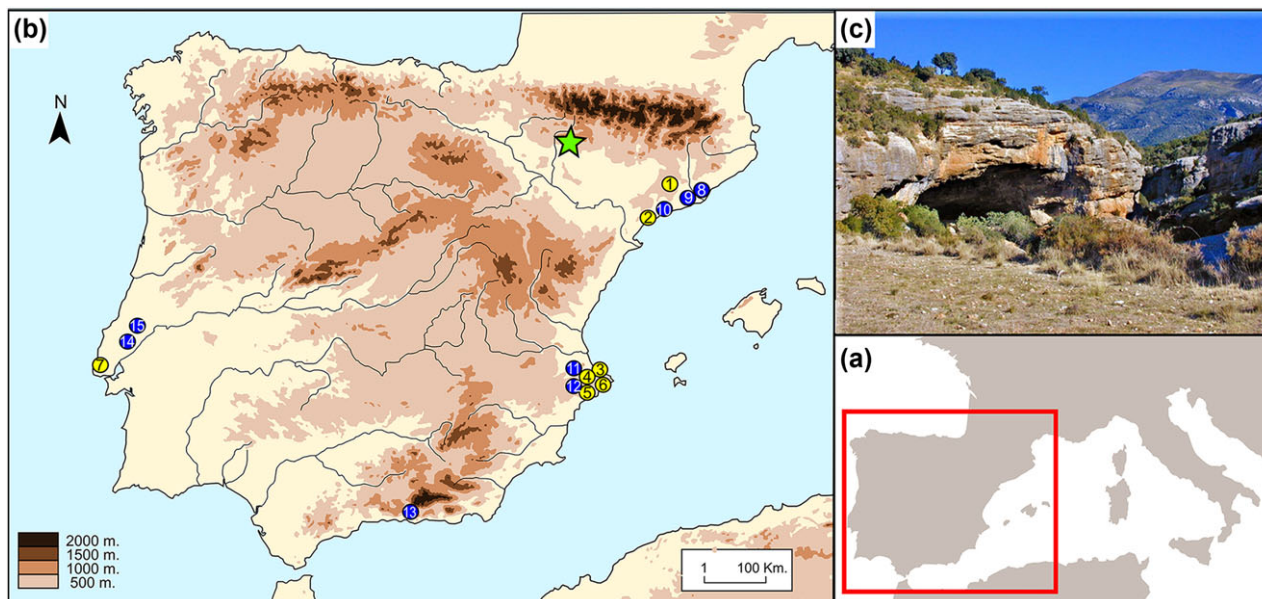


FIGURE 1 Location map. (a) Location of the Iberian Peninsula inside Western Europe; (b) Map of the Iberian Peninsula with the Earliest Cardial Neolithic sites but without human remains from this chronology (yellow dots: 1: Guixeres de Vilobí; 2: Cavet; 3: Barranquet; 4: Cova d'en Pardo; 5: Mas d'Is; 6: Cova de les Cendres; 7: Lápia das Lameiras) and sites with Cardial human remains directly dated (blue dots: 8: Plaça de la Vila de Madrid; 9: Cova Bonica; 10: Cova Foradada; 11: Cova de l'Or; 12: Cova de la Sarsa; 13: Cueva de Nerja; 14: Galeria da Cisterna and 15: Gruta do Caldeirão.) The star shows the location of Cueva de Chaves (c) Cueva de Chaves [Color figure can be viewed at wileyonlinelibrary.com]

domestication of animals and cereals (Edwards et al., 2007; Guilaine and Manen, 2007; Zapata, Peña-Chocarro, Pérez-Jordá, & Stika, 2004; Zilhão, 2001).

Different types of studies have shown the Fertile Crescent as the origin of the Neolithic cultures that spread throughout Europe and northern Africa (Lemmen, Gronenborn, & Wirtz, 2011; Zeder, 2008). The demographic expansion spread towards the Balkan Peninsula, where the Neolithic is then genetically and culturally differentiated into two population groups (Fernández et al., 2014; Olalde et al., 2015). One of these groups followed the Danube river and resulted in the LBK ware culture (*Linearbandkeramik*), which eventually spread throughout Central Europe between 5500 and 4900 cal BC (Manning et al., 2014). The other group spread faster through Western Europe by the Mediterranean coast and led to the *Impressa* ware culture (between 5800 and 5400 cal BC), and the Cardial ware culture (between 5500 and 4900 cal BC) (Binder and Sénépart, 2010). The Cardial expansion seemed to reach the Iberian Peninsula first (Gamba et al., 2012), although the presence of some vestiges of *Impressa* ware has been suggested at some coastal sites (Bernabeu, Molina, Esquembre, Ortega, Boronat, 2009). In any case, it is clear that the arrival of farming practices to Iberia arrived mainly through maritime colonization (Isern, Zilhão, Fort, & Ammerman, 2017; Zilhão, 2001). This maritime pioneering is in agreement with the fact that the first Neolithic sites are situated in the coastal region and have Cardial pottery (Bernabeu, García-Puchol, & Orozco-Köhler, 2018), whereas inland Early Neolithic sites occur later and show no Cardial pottery (Rojo-Guerra, Kunst, Garrido-Pena, & García-Martínez de Lagrán, 2006).

1.1 | Cueva de Chaves and its importance in the neolithization of Iberia

Cueva de Chaves is a cave located in the northeast of Iberia, at 663 m. a.s.l. (metres above sea level) in the Prepyrenean mountain range of Sierra de Guara (Bastarás, Huesca, Aragón; UTM: 735325.00 X; 4678636.00 Y; ETRS 89, Datum 30) (Figure 1). The site was excavated between 1984 and 2007 under the direction of Pilar Utrilla (Paleolithic levels) and Vicente Baldellou (Neolithic levels). The cave has about 225 m of extension, of which 110 m were potentially inhabitable (Baldellou, 2012). Cueva de Chaves was occupied during the Paleolithic (Solutrean and Magdalenian), Neolithic and, sporadically, the Bronze Age and Late Roman periods. Neolithic deposits from levels Ia and Ib date to the Early Neolithic period (Ia 5600-5300 cal BC; Ib 5300-5000 cal BC). These two chronologically consecutive levels have in them domestic fauna (Castaños, 2004), Cardial pottery (Baldellou, 2012; Utrilla and Laborda, 2018) and schematic rock art painted on pebbles (Utrilla and Baldellou, 2002, 2007) (Figure 2, Table 1).

Cueva de Chaves represents an interesting case study, as it is located inland but its radiocarbon dates show the use of the cave mostly as a settlement during the early stages of the Neolithic colonization of Iberia, overlapping with short-life radiocarbon dates from other nearby Cardial coastal Early Neolithic sites such as Guixeres de Vilobí, El Cavet (Martins et al., 2015), Cova de les Cendres, Cova d'En Pardo, Barranquet, Mas D'Is (Bernabeu et al., 2009), Cueva de Nerja (García-Borja, Aura Tortosa, Jordá Pardo, & Salazar García, 2014), Caldeirão (Zilhão, 1992), Galeria da Cisterna-Almolda (Martins et al., 2015; Zilhão, 2001) and Lapias das Lameiras (Davis and Simões, 2016). Moreover, only few sites in Iberia have human remains recovered from Cardial levels that have been directly dated: Caldeirão

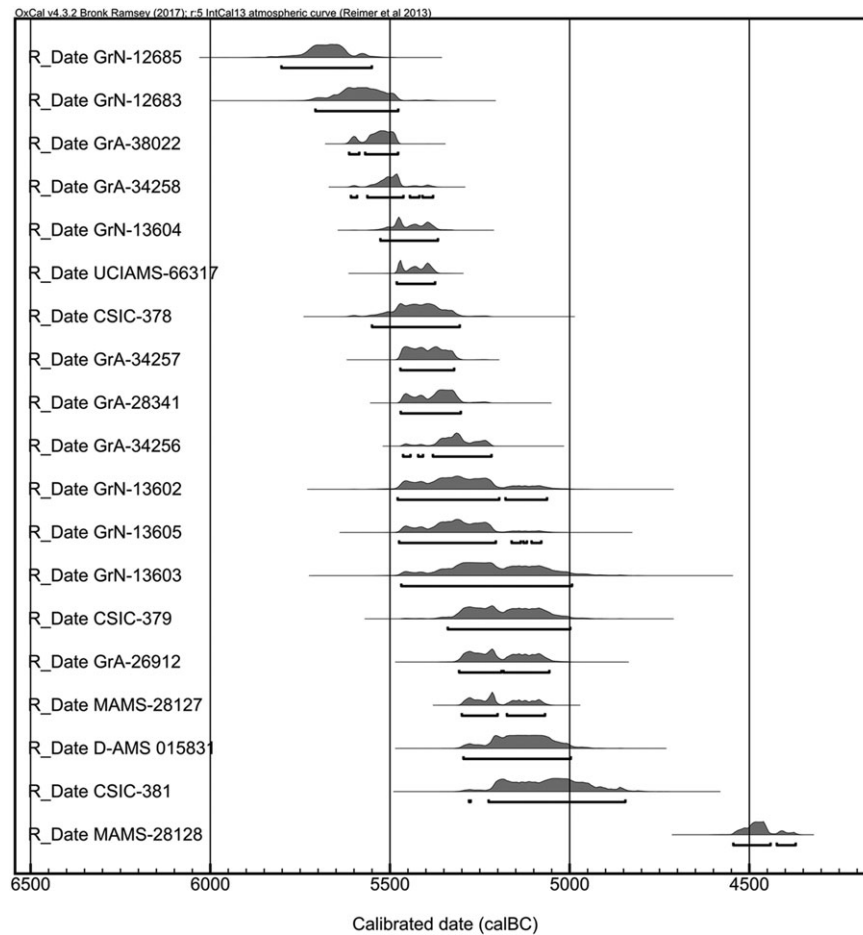


FIGURE 2 AMS radiocarbon dates from Cueva de Chaves. All dates have been calibrated with OxCal v4.2.3 and using the IntCal13 calibration curve (Bronk Ramsey, 2009; Reimer et al., 2013)

TABLE 1 AMS radiocarbon dates from the Early Neolithic levels of Cueva de Chaves, calibrated with OxCal v4.2.3 using the IntCal13 calibration curve (Bronk Ramsey, 2009; Reimer et al., 2013)

Lab code	Sample	^{14}C age	1 σ Cal BC	2 σ Cal BC	Reference
GrN-12685	charcoal	6770 \pm 70	5723-5627	5799-5550	Baldellou, 2012
GrN-12683	charcoal	6650 \pm 80	5634-5515	5707-5478	Baldellou, 2012
GrA-38022	<i>Ovis aries</i>	6580 \pm 35	5550-5486	5614-5479	Baldellou, 2012
GrA-34258	charcoal	6530 \pm 40	5528-5473	5609-5380	Baldellou, 2012
GrN-13604	charcoal	6490 \pm 40	5487-5379	5527-5368	Baldellou, 2012
UCIAMS-66317	<i>Ovis aries</i>	6470 \pm 25	5479-5382	5481-5374	Baldellou, 2012
CSIC-378	charcoal	6460 \pm 70	5483-5363	5549-5306	Baldellou, 2012
GrA-34257	charcoal	6410 \pm 40	5468-5357	5471-5322	Baldellou, 2012
GrA-28341	acorn	6380 \pm 40	5464-5315	5471-5303	Baldellou, 2012
GrA-34256	charcoal	6335 \pm 40	5367-5295	5464-5218	Baldellou, 2012
GrN-13602	charcoal	6330 \pm 90	5465-5216	5478-5063	Baldellou, 2012
GrN-13605	charcoal	6330 \pm 70	5374-5219	5474-5079	Baldellou, 2012
GrN-13603	charcoal	6260 \pm 100	5325-5062	5469-4991	Baldellou, 2012
CSIC-379	charcoal	6230 \pm 70	5299-5076	5340-4999	Baldellou, 2012
GrA-26912	human	6230 \pm 45	5298-5079	5308-5057	Baldellou, 2012
MAMS 29127	human	6227 \pm 28	5292-5081	5299-5070	This article
D-AMS 015831	human	6180 \pm 54	5213-5057	5296-4998	This article
CSIC-381	charcoal	6120 \pm 70	5207-4963	5281-4845	Baldellou, 2012
MAMS 28128	human	5645 \pm 31	4518-4452	4544-4373	This article

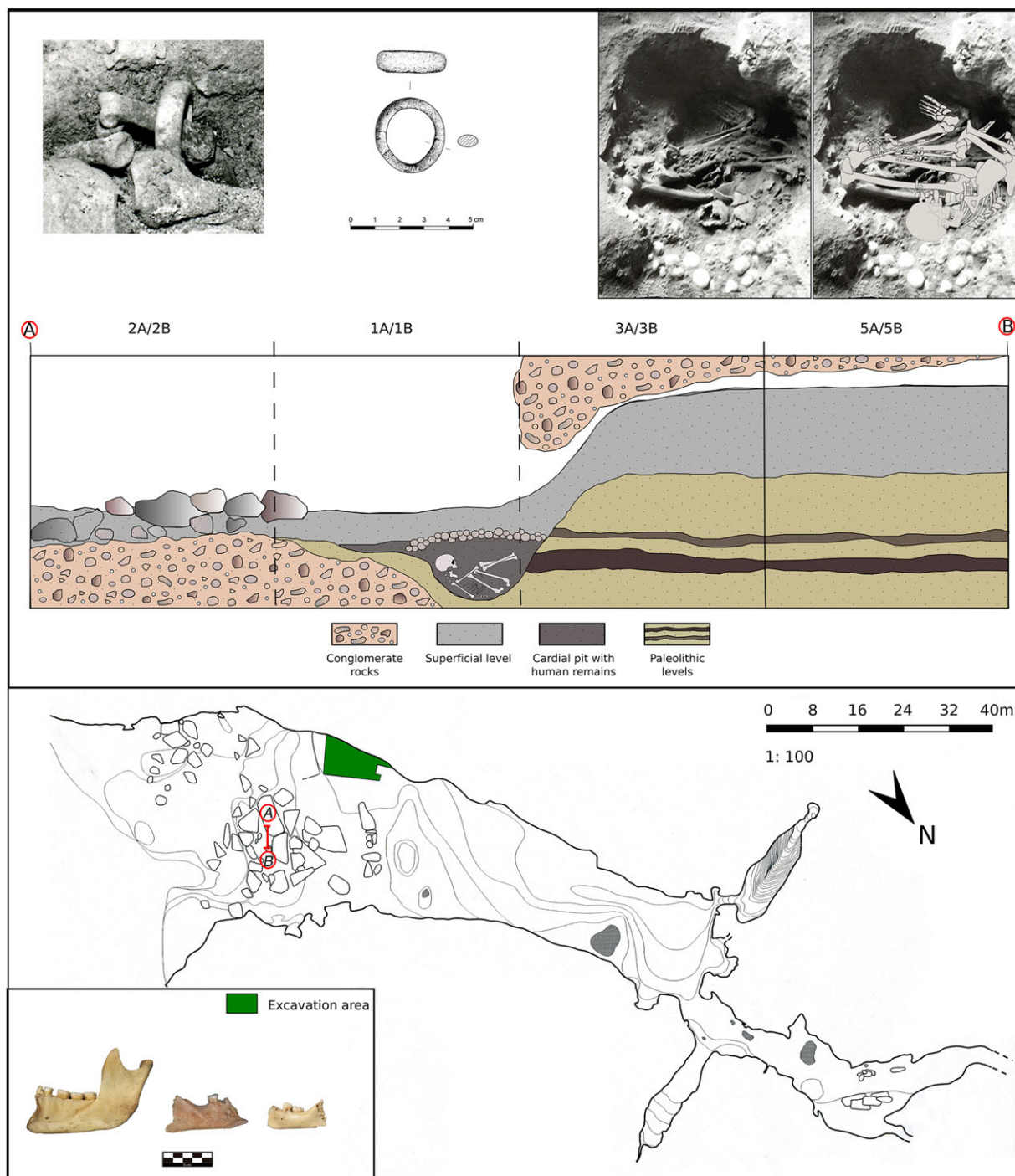


FIGURE 3 Early Neolithic human remains from Cueva de Chaves and their position in the topography. (a) Early Neolithic human remains sampled and recovered from the excavation area reflected in the topography; (b) Stratigraphic profile in the area where the Cardial burial was found; and (c) Detailed picture of the ring recovered from the Cardial burial and the archaeological drawing detailing the position of the skeleton [Color figure can be viewed at wileyonlinelibrary.com]

(Zilhão, 1992), Galería da Cisterna-Almonda (Martins et al., 2015), Cova de la Sarsa (García-Borja, Salazar-García, Pérez, Pardo, & Casanova, 2011), Cova de l'Or (Olalde et al., 2015), Cova Foradada (Oms, Cebrià, Morales, & Pedro, 2015), Vila de Madrid (Pou, Martí, Jordana, Malgosa, & Gibaja, 2010), Cova Bonica (Oms et al., 2017), Cueva de Nerja (Salazar-García, Pérez-Ripoll, García-Borja, & Jordá Pardo, 2017b) and now Cueva de Chaves. Of all of these sites, only Cueva de Chaves has an individual in complete anatomical articulation. This individual was buried in a pit with a flexed position, had an associated

ring, and was covered by red pigment and pebbles. All these features could be representative of the less well known Cardial funerary rituals (Utrilla, Lorenzo, Baldellou, Sopena, & Ayuso, 2008) (Figure 3).

Cueva de Chaves was mostly a habitat settlement, although it also had some areas dedicated to funerary practices. Besides the funerary area (Utrilla et al., 2008), evidence of different daily activities typical of a Neolithic community have been discovered inside the cave, shedding light on the broad Neolithic lifestyle: evidence of hunting (Castaños, 2004; Domingo, 2009), butchery and harvest activities

(Domingo, 2014; López García, 1992; López García and López-Sáez, 2000; Mazzucco, Clemente-Conte, Gassiot, & Gibaja, 2015), schematic art representations in pebbles, (Utrilla and Baldellou, 2002, 2007), fireplaces and storage structures (Alcolea, Utrilla, Piqué, Laborda, & Mazo, 2017; Sánchez, 2013). Many of these tasks can be recorded separately, and evidence of most of them together usually happen only in open-air settlements such as La Draga (Bosch, Chinchilla, & Tarrús, 2011) and Guixeres de Vilobí (Oms, Esteve, Mestres, Martín, & Martins, 2014a). In this sense, it is considered that Cueva de Chaves is mainly an example of a settlement located inside a cave (Alcolea et al., 2017). Moreover, the environmental conditions of the cave resulted in conservation of its archaeological material, making Cueva de Chaves an essential site to understand the neolithization process of Iberia. Unfortunately, the Neolithic levels were intentionally destroyed in 2007 to build an illegal enclosure for animals of a private hunting ground situated around the cave, so almost nothing is left at the archaeological site (Sentence num. 00255/2016 11/11/16).

1.2 | Isotopic analysis for dietary and environmental reconstructions

The use of carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) stable isotope ratios from bone collagen gives a quantitative assessment of protein consumption (e.g., Lee-Thorp, 2008). Stable isotope analysis of Early Neolithic remains has proved useful to establish the socio-economic impact of farming (e.g., Arias, 2007; Lillie and Richards, 2000; Lubell, Jackes, Schwarcz, Knyf, & Meiklejohn, 1994; Schulting, 1998). This quantitative dietary approach has been useful in establishing subsistence patterns of the first farmers, as well as shedding light on animal and plant management practises at the time (e.g., Balasse et al., 2014, 2016; Navarrete et al., 2017).

The $\delta^{13}\text{C}$ measurement is suitable to distinguish between protein from marine and terrestrial resources (Schoeninger and De Niro, 1984), as well as proteins from plants with different photosynthetic pathways (C_3 and C_4) (Van der Merwe, 1982) and different environments (Goude and Fontugne, 2016). Estuarine aquatic resources, commonly consumed in the Western Mediterranean might have lower $\delta^{13}\text{C}$ values than expected (e.g., Salazar-García et al., 2014), so special care should be taken interpreting their consumption in the region. In addition, $\delta^{15}\text{N}$ values can be used to establish the trophic level a specific organism holds in the food chain of its environment, with an overall agreed estimated increase of 3-5‰ per trophic step (Bocherens and Drucker, 2003). Using the same principles, it is also possible to detect domestic species-specific feeding (Navarrete et al., 2017) and manuring practises due to high $\delta^{15}\text{N}$ values (Bogaard, Heaton, Poulton, & Merbach, 2007; Bogaard et al., 2013). Analyzing the values of fauna and humans together can offer more information about aspects of the ecology of the first anthropic ecosystems during the onset of the Neolithic. Here we have reconstructed dietary habits and trophic structure of the Early Neolithic ecosystem from Cueva de Chaves.

The main limitation of stable isotope analysis in bone collagen is that it mainly reflects protein consumption, resulting in a considerable amount of animal proteins masking plant food consumption (Hedges and Reynard, 2007). Another aspect to take into consideration is

collagen turnover, which is low during adulthood and therefore reflects an average diet of the last years before the individual died (Hedges, Clement, Thomas, & O'Connell, 2007; Hill, 1998). Subadult individuals could still show a breastfeeding or weaning isotopic signal (Herrscher, Goude, & Metz, 2017), as well as having isotopic values that reflect a narrower window of time before death because of their faster collagen turnover (Valentin, 2002).

2 | MATERIAL AND METHODS

This study focuses on the Early Neolithic levels Ia (5600-5300 cal BC) and Ib (5300-5000 cal BC). Both levels are consecutive to each other and show no radiocarbon discontinuity when considering short-life dates (Table 1, Figure 2). New and previous direct human radiocarbon dates overall confirm this. Therefore, materials from both levels have been considered as one common Early Neolithic assemblage, and samples were taken indifferently from both.

2.1 | Human and faunal remains

Initially, the MNI (minimum number of individuals) recovered from Cueva de Chaves was 8, based on the number of mandibles. One of the individuals was found in correct anatomical position and buried in a pit. The other seven were found disarticulated and commingled with other archaeological material, some of them in superficial levels (Figure 3). Because of this unclear attribution of the human remains, all skeletal material that defined the MNI (seven mandibles and one rib from the isolated individual) was directly radiocarbon dated. A total of 4 of the individuals were dated to the Early Neolithic period: three adults and one subadult. Three of them (two adults and the subadult) date from the beginning of the Early Neolithic, and one adult individual dates to the end of the Early Neolithic (Table 1, Figure 2). This last individual was included in the isotopic analysis, but the results are to be considered with caution because the date is more recent than those of the remaining individuals. The subadult individual (S-UCT 21023) was estimated to be around 4 years old, according to its dental eruption pattern (Ubelaker, 1989); no other subadult remains were found to help infer more aspects about individual health and lifestyle. Mandible S-UCT 21025 belongs to an adult individual; presenting a robust appearance (pronounced gonion and chin) associated with male traits, a molar wear pattern corresponds with 25-35 years of age (following Brothwell, 1981), and shows neither *antemortem* dental loss nor caries, although dental calculus is present. Mandible S-UCT 19600 shows a more gracile aspect, although only one fragment of the mandibular body is present and thus makes it impossible to determinate sex. However, the molar wear pattern corresponds to an individual of 25-35 years of age (Brothwell, 1981), as seen in the only tooth present (M1), and *antemortem* loss is observed by alveolar reabsorption of P2, M2 and M3 on the right side of the mandible. The individual found in correct anatomical position (S-UCT 21024) was identified as an adult male based on morphology of the innominate (Utrilla et al., 2008), and his pubic symphyseal surface corresponds to Todd's (1920) Phase IX, which corresponds to 44-50 years of age. His mandible also shows a heavy wear, in this case corresponding to 33-45 years of age

TABLE 2 NR (number of remains) and MNI (minimum number of individuals) faunal remains by taxa categories from Cueva de Chaves (information extracted from Castaños, 2004)

	Cueva de Chaves (Ia) NR	Cueva de Chaves (Ia) MNI	Cueva de Chaves (Ib) NR	Cueva de Chaves (Ib) MNI	Total NR	Total MNI
<i>Bos taurus</i>	235	12	200	14	435	26
<i>Ovis/Capra</i>	1967	68	4196	120	6163	188
<i>Sus domesticus</i>	504	37	713	41	1217	78
<i>Canis familiaris</i>	15	1	21	1	40	2
<i>Equus ferus</i>	5	1	7	2	12	3
<i>Bos primigenius</i>	5	2	7	1	12	9
<i>Capra pyrenaica</i>	55	5	123	11	178	16
<i>Cervus elaphus</i>	393	14	664	13	1057	27
<i>Capreolus capreolus</i>	20	3	58	6	78	9
<i>Sus ferus</i>	46	7	108	13	154	20
<i>Canis lupus</i>	5	1	2	2	7	3
<i>Vulpes vulpes</i>	57	11	55	9	112	20
<i>Ursis arctos</i>	15	1	13	2	28	3
<i>Felis silvestris</i>	7	2	19	2	26	4
<i>Lynx pardina</i>	4	1	6	1	10	2
<i>Meles meles</i>	47	4	77	7	124	11
<i>Martes sp.</i>	7	3	8	1	15	4
<i>Oryctolagus cuniculus</i>	1156	58	1796	96	2952	154
<i>Lepus granatensis</i>	89	15	45	5	134	20
TOTAL	4632	246	8122	347	12754	593

according to Brothwell (1981), and also shows *antemortem* loss of both third molars as well as caries in one of the second molars and dental calculus on one incisor.

The Neolithic levels from Cueva de Chaves have the highest amount of faunal remains when compared to other Early Neolithic sites from Iberia (Castaños, 2004). Both domestic and wild species recovered from the Early Neolithic levels show an equal percentage of representation: 49.6% of the total remains are domestic, and 51.4% are wild (Castaños, 2004) (Table 2). For this study a total of 64 faunal remains of 14 different taxa were selected following the classification of Castaños (2004). The taxa analyzed consists of: *Ovis/Capra*, *Sus domesticus*, *Bos taurus*, *Capra pyrenaica*, *Capreolus capreolus*, *Equus caballus*, *Cervus elaphus*, *Meles meles*, *Vulpes vulpes*, *Canis sp.*, *Buteo buteo*, *Felis silvestris*, *Oryctolagus cuniculus* and *Lepus granatensis*. Only adult faunal specimens have been sampled in order to avoid altered values due to suckling or weaning effects (Fogel, Tuross, & Owsley, 1989; Fuller, Fuller, Harris, & Hedges, 2006). *Canis sp.* and *Felis silvestris* are considered as carnivores because of the lack of evidence to define them as either domestic or wild. We have followed Castaños (2004) for determination of domestic or wild *Sus* specimens, but ruled out subadult specimens, which are impossible to distinguish between domestic and wild, as well as large-sized pig remains following Navarrete and Saña (2017).

2.2 | Isotopic analysis

Isotope analysis of the Cueva de Chaves samples was carried out at the Stable Isotope Laboratories of the University of Cape Town (South Africa). A total of 68 samples were cleaned by removing the

bone outer layer by mechanical abrasion using a 220 Dremel 3500 drill. Collagen extraction for carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) isotope analysis was done following the Longin (1971) method with the addition of an ultrafiltration step (Brown, Nelson, Vogel, & Southon, 1988). Approximately 300 mg of cleaned bone samples from each specimen were demineralized in 0.5M HCl solution at 5 °C until fully demineralization. Demineralized samples were rinsed three times with deionized water until pH became neutral. The samples were gelatinized at 70 °C for 48 hr using a heater block (FMH instruments, South Africa). This solution was filtered with a 9 ml EZEE-filter (Elkay, United Kingdom) to remove small (<8 μm) particles and ultrafiltered with 30 kDa ultrafilters (Amicon, Germany) using a centrifuge (Thermo Fisher Scientific Megafuge 16, USA) at 2500 rpm during variable times depending on the filtering speed of each sample. The final solution was then frozen and lyophilized for 48 hr. Finally, duplicate about 0.5 mg of collagen per sample was weighed into tin capsules, and loaded into the mass spectrometer.

The carbon and nitrogen isotope ratio measurements were performed using a Finnigan Delta plus XP continuous-flow isotope ratio mass spectrometer (Thermo Fisher Scientific, USA) after being combusted in an elemental analyser Flash EA 1112 interfaced with it (Thermo Fisher Scientific, USA). Stable Carbon isotope ratios were expressed relative to the VPDB scale (Vienna Pee Dee Belemnite), and stable Nitrogen isotope ratios were measured relative to the AIR scale (atmospheric N_2), using the delta notation (δ) in parts per thousand (‰). Repeated analysis of internal and international standards determined an analytical precision of 0.1‰ (1 σ) or less for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$. All analyses were carried out in duplicate.

TABLE 3 Cueva de Chaves S-UCT code, species, sampled bone, archaeological level, biological age group, $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ average values, collagen control indicators (%C, %N, C:N elemental) and radiocarbon dates

S-UCT code	Species	Sampled bone	Archaeological level	Age group	Average $\delta^{13}\text{C}$ ‰	Average $\delta^{15}\text{N}$ ‰	C (%)	N (%)	C: N Elemental	Radiocarbon date (uncalibrated)
18534	<i>Ovis aries/ Capra hircus</i>	tibia	lb	adult	-19.9	3.9	40.4	13.8	3.4	-
18538	<i>Ovis aries/ Capra hircus</i>	radius	lb	adult	-19.6	4.7	41.2	14.9	3.2	-
18537	<i>Ovis aries/ Capra hircus</i>	innominate	lb	adult	-19.5	4.6	43.0	15.5	3.2	-
18536	<i>Ovis aries/ Capra hircus</i>	phalanx	lb	adult	-19.7	4.8	38.6	13.4	3.4	-
18535	<i>Ovis aries/ Capra hircus</i>	calcaneus	lb	adult	-19.8	3.4	42.7	15.3	3.3	-
18533	<i>Ovis aries/ Capra hircus</i>	tibia	lb	adult	-19.6	3.7	40.1	14.4	3.2	-
18540	<i>Ovis aries</i>	talus	lb	adult	-19.5	4.7	41.0	14.7	3.2	-
18539	<i>Ovis aries</i>	talus	lb	adult	-20.1	3.5	41.5	14.5	3.3	-
18541	<i>Ovis aries</i>	talus	lb	adult	-19.9	5.3	39.8	13.7	3.4	-
18580	<i>Bos taurus</i>	mandible	la	adult	-19.6	6.2	40.6	14.2	3.3	-
18581	<i>Bos taurus</i>	innominate	la	adult	-19.6	3.7	41.3	14.5	3.3	-
18582	<i>Bos taurus</i>	tarsus	la	adult	-19.1	5.4	42.5	15.5	3.2	-
18583	<i>Bos taurus</i>	calcaneus	lb	adult	-19.8	4.4	43.0	15.6	3.2	-
18584	<i>Bos taurus</i>	humerus	lb	adult	-19.6	5.1	34.4	11.6	3.5	-
18585	<i>Bos taurus</i>	cranial fragment	lb	adult	-20.1	3.4	32.8	11.3	3.4	-
18569	<i>Cervus elaphus</i>	radius	lb	adult	-20.1	3.9	41.0	14.5	3.3	-
18571	<i>Cervus elaphus</i>	femur	lb	adult	-20.2	3.7	41.7	14.8	3.3	-
18570	<i>Cervus elaphus</i>	humerus	lb	adult	-20.1	4.4	40.0	13.9	3.4	-
18572	<i>Cervus elaphus</i>	humerus	la	adult	-20.0	3.4	39.5	13.9	3.3	-
18573	<i>Cervus elaphus</i>	humerus	la	adult	-19.9	3.1	42.7	15.4	3.2	-
18574	<i>Cervus elaphus</i>	mandible	la	adult	-18.8	4.6	41.2	15.0	3.3	-
18544	<i>Capreolus capreolus</i>	scapula	lb	adult	-20.9	4.8	38.9	13.3	3.4	-
18545	<i>Capreolus capreolus</i>	talus	lb	adult	-19.1	4.7	40.8	14.0	3.4	-
18543	<i>Capreolus capreolus</i>	scapula	lb	adult	-19.9	3.9	41.9	14.4	3.4	-
18542	<i>Capreolus capreolus</i>	metapodia	la	adult	-20.1	3.7	43.2	15.5	3.2	-
18575	<i>Capra pyrenaica</i>	cranial fragment	la	adult	-19.7	3.5	41.6	14.7	3.3	-
18578	<i>Capra pyrenaica</i>	metapodia	lb	adult	-19.5	3.9	42.8	14.9	3.3	-
18579	<i>Capra pyrenaica</i>	humerus	lb	adult	-19.5	2.7	39.4	13.9	3.3	-
18576	<i>Capra pyrenaica</i>	innominate	la	adult	-19.6	2.7	39.4	13.9	3.3	-
18577	<i>Capra pyrenaica</i>	scapula	lb	adult	-19.5	3.3	41.0	14.2	3.4	-
18549	<i>Equus caballus</i>	talus	lb	adult	-21.1	5.1	41.3	14.6	3.3	-
18550	<i>Equus caballus</i>	phalanx	lb	adult	-20.1	3.4	36.3	12.7	3.3	-
18547	<i>Equus caballus</i>	radius	la	adult	-21.2	5.1	41.1	14.4	3.3	-
18546	<i>Equus caballus</i>	metapodia	la	adult	-20.4	3.7	28.1	9.8	3.3	-
18548	<i>Equus caballus</i>	calcaneus	lb	adult	-21.0	5.1	41.8	14.6	3.3	-
18568	<i>Oryctolagus cuniculus</i>	femur	la	adult	-20.2	0.9	38.2	13.6	3.3	-
18564	<i>Oryctolagus cuniculus</i>	femur	la	adult	-21.9	1.4	42.4	14.6	3.4	-
18565	<i>Oryctolagus cuniculus</i>	femur	la	adult	-21.1	5.4	40.7	14.6	3.3	-
18566	<i>Oryctolagus cuniculus</i>	femur	la	adult	-22.0	5.5	35.9	12.3	3.4	-
18567	<i>Oryctolagus cuniculus</i>	femur	la	adult	-21.5	4.7	41.9	14.5	3.4	-
18559	<i>Lepus granatensis</i>	metapodia	la	adult	-21.6	2.5	42.4	15.2	3.3	-
18560	<i>Lepus granatensis</i>	tibia	la	adult	-22.0	2.8	42.0	15.1	3.2	-
18561	<i>Lepus granatensis</i>	innominate	la	adult	-20.8	5.5	43.3	15.7	3.2	-
18563	<i>Lepus granatensis</i>	tibia	la	adult	-21.9	2.7	69.3	15.3	5.3	-
18554	<i>Sus domesticus</i>	calcaneus	la	adult	-20.5	3.6	35.8	12.4	3.4	-
18551	<i>Sus domesticus</i>	humerus	la	adult	-20.6	4.5	42.0	15.1	3.2	-
18552	<i>Sus domesticus</i>	maxilla	la	adult	-20.2	5.8	38.4	13.1	3.4	-
18553	<i>Sus domesticus</i>	radius	la	adult	-19.5	5.3	39.5	13.6	3.4	-
18555	<i>Sus domesticus</i>	calcaneus	la	adult	-19.9	4.1	42.4	15.2	3.2	-

(Continues)

TABLE 3 (Continued)

S-UCT code	Species	Sampled bone	Archaeological level	Age group	Average $\delta^{13}\text{C}$ ‰	Average $\delta^{15}\text{N}$ ‰	C (%)	N (%)	C: N Elemental	Radiocarbon date (uncalibrated)
18586	<i>Meles meles</i>	radius	lb	adult	-18.3	8.0	43.4	15.6	3.2	-
18587	<i>Meles meles</i>	calcaneus	lb	adult	-18.3	7.9	42.0	15.1	3.2	-
18588	<i>Meles meles</i>	vertebra	lb	adult	-18.1	7.5	42.1	15.2	3.2	-
18594	<i>Meles meles</i>	mandible	la	adult	-18.3	7.6	43.9	15.5	3.3	-
18597	<i>Meles meles</i>	femur	la	adult	-17.7	9.7	42.7	15.1	3.3	-
18590	<i>Canis sp.</i>	metatarsus	la	adult	-19.4	5.8	41.8	14.8	3.3	-
18591	<i>Canis sp.</i>	metatarsus	la	adult	-19.5	6.0	40.6	14.2	3.3	-
18592	<i>Canis sp.</i>	scapula	la	adult	-18.2	7.6	42.6	15.4	3.2	-
18593	<i>Canis sp.</i>	tibia	la	adult	-19.3	9.9	43.4	15.3	3.3	-
18525	<i>Felis silvestris</i>	ulna	lb	adult	-19.1	6.8	42.0	15.0	3.3	-
18526	<i>Felis silvestris</i>	tibia	lb	adult	-18.6	4.7	42.5	15.1	3.3	-
18527	<i>Felis silvestris</i>	humerus	lb	adult	-19.5	6.5	42.7	15.1	3.3	-
18596	<i>Felis silvestris</i>	long bone diaphysis	la	adult	-18.9	6.2	41.7	15.2	3.2	-
18595	<i>Vulpes vulpes</i>	cranial fragment	la	adult	-18.2	7.9	42.0	15.2	3.2	-
18589	<i>Buteo buteo</i>	radius	la	adult	-20.0	8.8	42.7	15.2	3.3	-
19600	<i>Homo sapiens</i>	mandible	la	adult	-19.1	9.0	37.7	13.2	3.3	5645 ± 31
21023	<i>Homo sapiens</i>	mandible	la	infant	-19.1	8.8	40.2	13.8	3.4	6180 ± 54
21024	<i>Homo sapiens</i> (84C)	phalanx	la	adult	-18.5	10.6	44.0	15.6	3.3	6230 ± 45
21025	<i>Homo sapiens</i>	mandible	la	adult	-19.4	9.5	44.3	16.0	3.3	6227 ± 28

3 | RESULTS

Bone samples from 4 humans and 64 animals were analyzed from the Early Neolithic levels of Cueva de Chaves. The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results are presented in Table 3 and plotted in Figure 4. All the samples from Cueva de Chaves yielded enough collagen from the >30 kDa fraction for analysis in duplicate, and %C (around ≥ 30), %N (around ≥ 10) and C:N ratio (2.9–3.6) values indicate a good collagen quality, according to Ambrose (1993), De Niro (1985), and Van Klinken (1999). The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values were obtained from the >30 kDa fraction of the lyophilized collagen.

Herbivore $\delta^{13}\text{C}$ values range between -22.0‰ and -18.8‰ with a mean value of -20.2 ± 0.8 [1σ] ‰. The taxa with the smallest $\delta^{13}\text{C}$ values are rabbits and hares, which usually present ^{13}C -depleted values in the region (Salazar-García et al., 2014; Villalba-Mouco et al., 2018), and show a high deviation. Herbivore $\delta^{15}\text{N}$ values range between 0.9‰ and 6.2‰, with a mean value of 4.0 ± 1.1 [1σ] ‰, defining the trophic baseline of the ecosystem foodweb. In this case, rabbit and hares also present the lowest values and the highest deviation of $\delta^{15}\text{N}$ values (see Table 1, Figure 3). These herbivore $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values are consistent with typical values for a terrestrial C_3 European ecosystem (De Niro and

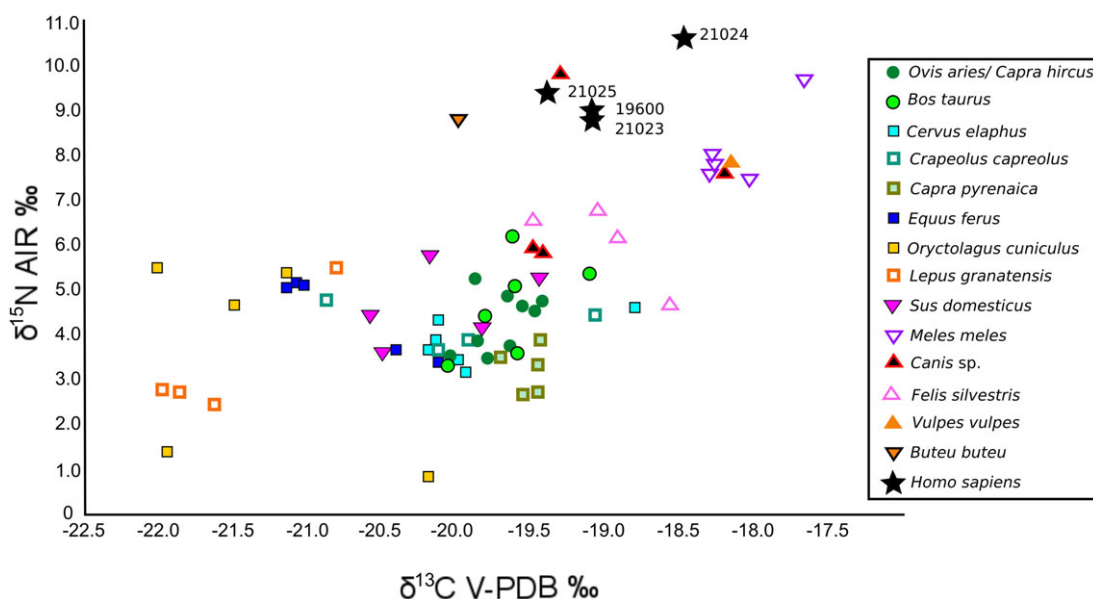


FIGURE 4 Scatter plot of human and fauna bone collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values from Cueva de Chaves. The X and Y axes are plotted at different scales in order to make all the samples more visible [Color figure can be viewed at wileyonlinelibrary.com]

Epstein, 1978; Schwarcz and Schoeninger, 1991). If we divide the sample between domestic (*Ovis/Capra* and *Bos taurus*; $\delta^{13}\text{C}$ mean: -19.7 ± 0.2 [1 σ] ‰; $\delta^{15}\text{N}$ mean: 4.4 ± 0.8 [1 σ] ‰) and non-lagomorph wild herbivores (*Cervus elaphus*, *Capreolus capreolus*, *Capra pyrenaica* and *Equus caballus*; $\delta^{13}\text{C}$ mean: -20.0 ± 0.6 [1 σ] ‰; $\delta^{15}\text{N}$ mean: 3.9 ± 0.8 [1 σ] ‰), they show no differences in $\delta^{13}\text{C}$ ($p = 0.074$) nor $\delta^{15}\text{N}$ ($p = 0.086$) values.

Domestic pig livestock (*Sus domesticus*) were classically considered as potential omnivores. Their $\delta^{13}\text{C}$ values range between -20.6‰ and -19.5‰ , with a mean value of -20.1 ± 0.5 [1 σ] ‰ and place them in the same range as all other medium- and large-sized herbivores. Their $\delta^{15}\text{N}$ values range between 3.6‰ and 5.8‰ , with a mean value of 4.7 ± 0.9 [1 σ] ‰, which does not show the increase expected for a change of trophic level (Bocherens and Drucker, 2003; Minagawa and Wada, 1986). A nonparametric Mann Whitney test indicates no significance differences between the means for herbivores (not including ^{13}C -depleted lagomorphs) and pigs in $\delta^{13}\text{C}$ ($p: 0.260$) or in $\delta^{15}\text{N}$ ($p: 0.236$).

Carnivore $\delta^{13}\text{C}$ values range between -20.0‰ and -17.7‰ , with a mean value of -18.8 ± 0.7 [1 σ] ‰, and their $\delta^{15}\text{N}$ values range between 4.7‰ and 9.9‰ , with a mean value of 7.4 ± 1.4 [1 σ] ‰. These values position them in a higher trophic level than both herbivores and potential omnivores. Overall, the non-parametric Mann Whitney test shows significant differences between pigs and carnivores in $\delta^{13}\text{C}$ ($p: 0.004$) and $\delta^{15}\text{N}$ ($p: 0.003$) values. However, the non-parametric Kruskal Wallis test reveals significant differences in $\delta^{13}\text{C}$ values between *Canis sp.*, *Felis silvestris*, and *Meles meles* ($p: 0.043$). Dunn's Post Hoc test also shows further significant differences between *Meles meles* and *Felis silvestris* ($p: 0.033$) and between *Meles meles* and *Canis sp.* ($p: 0.033$). These significant differences can define the specific diet of each species. Only *Felis silvestris* and *Canis sp.* appear to have an isotopically similar diet (Dunn's Post Hoc test $p: 1.000$). The non-parametric Kruskal Wallis test reveals no significant differences in $\delta^{15}\text{N}$ values between *Canis sp.*, *Felis silvestris*, and *Meles meles* ($p: 0.089$). *Vulpes vulpes* and *Buteo buteu* are not included in the statistical analysis because of their low sample number.

The four human $\delta^{13}\text{C}$ values (including the subadult individual) range between -19.4‰ and -18.5‰ , with a mean value of -19.0 ± 0.4 [1 σ] ‰, and the $\delta^{15}\text{N}$ values are between 8.8‰ and 10.6‰ , with a mean value of 9.5 ± 0.8 [1 σ] ‰. These average values portray a terrestrial diet based mainly on C_3 terrestrial resources, and defines the highest values of the local trophic ecosystem foodweb. Of interest is that the only individual recovered from an actual Cardial burial shows higher $\delta^{13}\text{C}$ (by 0.7‰) and $\delta^{15}\text{N}$ (by 1.5‰) values than the average from the other three individuals. In any case, because of the low number of samples, these results need to be interpreted with caution (Figure 4).

4 | DISCUSSION

4.1 | Wild and domestic herbivores

No significant differences were found between wild and domestic herbivores. These similar values could point towards a possible common plant resource consumption for both wild and domestic herbivores. Different environmental factors may have an effect on stable isotope values (Drücker et al., 2003; Goude and Fontugne, 2016). The

$\delta^{13}\text{C}$ values help to distinguish between open or close-forested environments, with the plants that grow in closed environments showing lower $\delta^{13}\text{C}$ values (O'Leary, 1981; Tieszen, 1991); the $\delta^{15}\text{N}$ values increase due to arid conditions or vary depending on soil type (Ambrose, 1993; Handley et al., 1999). Therefore, another possible explanation for these similar values between wild and domestic species could be linked to a shared environment and/or the use of the same parts of the landscape for grazing. These data could suggest foddering domestic animals with wild plants. The use of wild plants such as *Juniperus* for foddering was previously suggested by an anthracological study in the most recent Early Neolithic level (Alcolea et al., 2017). The use of *Juniperus* as fodder has been documented in the Central Pyrenees (Villar and Fernández, 2000) and in ovicaprine coprolites from the prehistoric La Fangade archaeological site in France (Bouby, 2014; Chabal et al., 2009).

In either scenario, the use of wild plant species as fodder for domestic animals reflect that the population relied more on animal husbandry than agricultural practices. This hypothesis is in agreement with palynological studies that suggest a low impact of crop management at the site except during the last stages of the Early Neolithic (López García and López Sáez, 2000). Some authors suggest that this could be the result of not having potential agricultural fields close to Cueva de Chaves (Mazzucco et al., 2015). In this sense, the absence of grains makes it isotopically difficult to test if manuring practices played an important role in the early stages of Iberian Neolithic agriculture. However, the fact that both wild and domestic animals have a similar $\delta^{15}\text{N}$ values suggests that no manure signal is present (Bogaard, Heaton, Poulton, & Merbach, 2007; Bogaard et al., 2013).

The Cueva de Chaves domestic herbivore data also present little dispersion. Specifically, domestic ovicaprids show the smallest dispersion in both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values and suggest a common environment and feeding that could be associated with stabling practices to protect the livestock from the wild carnivores as described for other Iberian Early Neolithic sites (Oms et al., 2014b; Saña et al., 2015). This common feeding/environment would imply the absence of sheep flocks or transhumance activities amongst the Early Neolithic community living in the cave (Martín et al., 2015). However, since bulk bone collagen reflects an average of the last years of life, it is difficult to find differences in isotopic values resulting from the seasonal movements between environments; sequential $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ isotopic analysis of teeth would be necessary to prove the absence of these types of husbandry practices (Tornero et al., 2016, 2018). Even so, non-transhumance activities would be in agreement with the characteristics of a big settlement such as Cueva de Chaves, and would confirm that it was not a site for short residence periods as is typical for mountain sites linked to sheep-herding activities (Rojo-Guerra et al., 2013).

Isotopic tests between wild and domestic herbivores have been carried out in order to test differences in husbandry management practices in other contemporary Iberian sites such as La Draga or Cova de Frare (Navarrete et al., 2017). At the first site, the domestic fauna showed higher $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values (Navarrete et al., 2017). These slight isotopic differences could suggest different feeding strategies, such as using agricultural crops as one of the potential fodders for domestic species. The reason for these higher $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values could be the use of natural fertilizers. Although the presence of

crops in La Draga is clear (Antolín, 2016; Antolín and Buxó, 2011;), the increase in $\delta^{15}\text{N}$ values is quite low to propose an intensive manuring effect (Bogaard et al., 2013). However, the other Early Neolithic site, Cova de Frare, presents no isotopic differences between wild and domestic herbivores (Navarrete et al., 2017), likewise as observed at Cueva de Chaves.

4.2 | Omnivores: Pig livestock

Suids are omnivores with a flexible ecological niche because of their opportunistic feeding (Macdonald and Barrett, 1993; Schley and Roper, 2003). Humans have taken advantage of this to feed domestic pigs (*Sus domesticus*) with whatever suited them. As a result, the diet of pigs has proved to reflect many aspects of human community structure in both prehistoric (Madgwick, Mulville, & Stevens, 2012) and historic periods (Halley and Rosvold, 2014). In this sense, two main management models for pig husbandry have been proposed. The first one is based on a free-range management where pigs feed on their own and most of the diet comes from plants (Madgwick et al., 2012), resulting in an herbivorous isotopic signal. The other one is the household management one, where pigs feed on leftovers and human debris and therefore commonly show a mixed isotopic signature resulting from combining the different types of foods consumed by humans in each case (Balasse et al. 2016; Madgwick et al., 2012; Müldner and Richards, 2005; Privat, O'Connell, & Richards, 2002; Richards, Fuller, & Molleson, 2006). Some authors consider that both suid husbandry management models can occur simultaneously in what is called a "household model" with mixed diets only depending on the size of livestock (Navarrete et al., 2017). Other authors argue that pig management practices change according to the chrono-cultural period, showing more household feeding of pigs in historic rather than prehistoric times (Madgwick et al., 2012).

Domestic pigs from Cueva de Chaves show a significant difference in their $\delta^{13}\text{C}$ ($p: 0.007$) and $\delta^{15}\text{N}$ ($p: 0.007$) values with carnivores, but no significant difference with herbivores from the same ecosystem ($\delta^{13}\text{C} = p: 0.237$; $\delta^{15}\text{N} = p: 0.203$). Having the same $\delta^{15}\text{N}$ range as herbivores shows they are in a same trophic level, ruling out a significant input of animal protein in their diet (Bocherens and Drucker 2003). The $\delta^{15}\text{N}$ values are also the same for ruminant and non-ruminant herbivores, suggesting that isotopic digestive fractionation could cause an incorrect herbivore profile in pigs (Halley and Rosvold, 2014; Hedges, 2003). This herbivore trophic attribution would be compatible with a free-range pig husbandry management similar to what is proposed for the Early Neolithic Iberian sites of Cova del Frare and Serra de Mas Bonet (Navarrete et al., 2017). However, and contrary to what is observed at these sites, Cueva de Chaves has a large-sized pig livestock, more similar to the one from La Draga where an herbivore pig diet has also been suggested (Navarrete et al., 2017). Furthermore, Cueva de Chaves is one of the biggest pig husbandry communities in the Iberian Early Neolithic according to the number of pig remains recovered ($n = 1217$) (Castaños, 2004), followed by La Draga ($n = 1048$) (Saña, 2011), and shows mostly an infant and juvenile specimen slaughtering pattern as at La Draga (Saña, 2011). This kind of husbandry management is more usual in a household model (Halstead and Isaakidou, 2011), where number of

pigs is limited by pig size, which is bigger as a result of feeding them with animal fat and protein in order to slaughter them earlier (Balasse et al., 2016).

All these aforementioned traits lead us to propose, a controlled and limited dispersion range for suid husbandry, or their keeping in an enclosure where they would be fed only plant foods (Hadjikoumis, 2012; Halstead and Isaakidou, 2011). In this sense, anthracological evidence shows the importance of acorns in Cueva de Chaves during the older Early Neolithic level (Alcolea et al., 2017; Zapata, Baldellou, & Utrilla, 2008) when the presence of a woodland environment is suggested (Alcolea et al., 2017). The consumption of acorns could have decreased over time (Hamilton et al., 2009), parallel to the woodland clearing at the recent Early Neolithic level (Alcolea et al., 2017).

It is also necessary to consider that, as ethnography shows (Halstead and Isaakidou, 2011), a fattening diet based on animal products could take place at the end of the pig's life and would therefore not be shown in the collagen bulk signature. However, it seems that the overall introduction of leftover feeding of pigs happened over time, linked to the complexity of the settlements (Madgwick et al., 2012). An even bigger dataset would be required to get more in-depth information on pig management in the Neolithic levels from Cueva de Chaves.

4.3 | Wild and domestic carnivores

The canine data show the highest dispersion inside the carnivore group. This could be translated into a heterogeneous feeding pattern that could be linked to their wild or domestic status. Two of them (S-UCT 18592 and S-UCT 18593) are closer to the human isotopic values and could be associated to domestic adscription, because in that case most of their diet depends on human provided or leftover foods (Reitsema, Kozłowski, & Makowiecki, 2013). This would be in agreement with the dog surrogacy hypothesis, which considers dogs to be a good proxy to recover information on prehistoric human diet whenever human remains are not available (e.g., Guiry and Grimes, 2013). The other two canine values (S-UCT 18590 and S-UCT 18591) show lower values than expected for a full carnivore diet but could be in agreement with a high consumption of depleted ^{13}C and ^{15}N rabbits and hares and their wild adscription. It is also important to highlight that wolves are a highly mobile species and they can reflect the isotopic values from different environments (Blanco, 2017).

In the case of wild cats (*Felis silvestris*) their $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values do not show clear evidence of household feeding, suggesting a combination of human leftover and small prey hunting in their diet. Regarding other wild carnivores, only the data for one *Vulpes vulpes* is positioned inside the range of *Meles meles*. While *Vulpes vulpes* mainly feed on rabbits (López-Martín, 2017), *Meles meles* eat mainly earthworms but have a huge range of food resources including rabbits (Virgós, 2005), which are abundant in the Early Neolithic levels of Cueva de Chaves (Castaños, 2004). Because the *Meles meles* $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values are very close to those of *Vulpes vulpes*, it could be argued that the specimens analyzed consumed abundant rabbit. The problem when looking at the Chaves baseline is that rabbits have lower $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values than what would fit the pattern if *Vulpes vulpes* and *Meles meles* were mainly consuming them, so it is possible that both

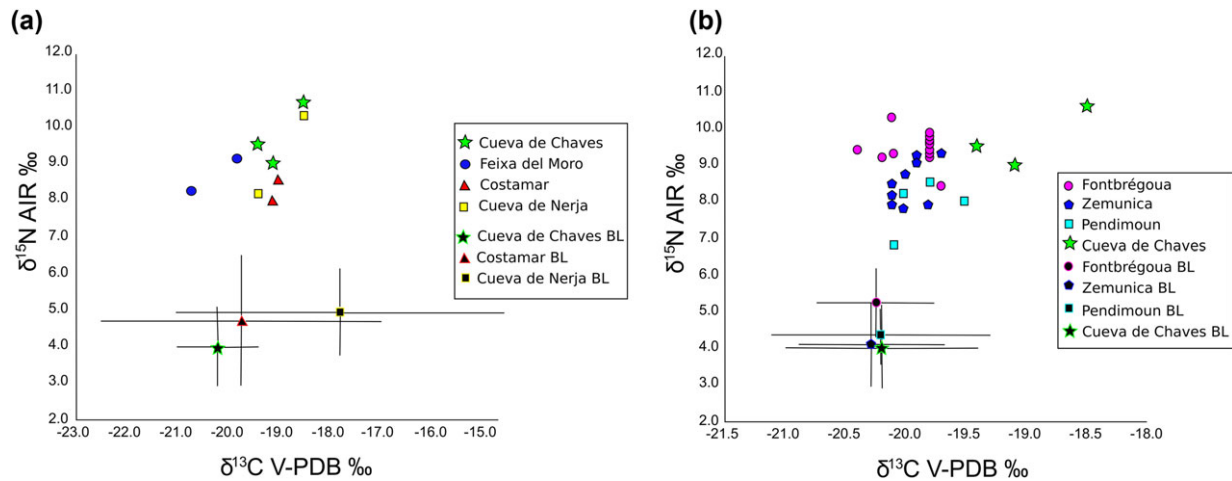


FIGURE 5 (a) Plot of bone collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of different Early Neolithic adult humans from Iberia [Costamar (Salazar-García, 2009); Cueva de Nerja (Salazar-García et al., 2017b); Feixa del Moro (Remolins et al., 2016) and Cueva de Chaves (this study)]; (b) Plot of bone collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of different Early Neolithic from the Western Mediterranean region [Fontbrégoua (France) (Le Bras-Goude et al., 2009), Pendimoun (Le Bras-Goude et al., 2006), 3: Zemunica (Croatia) (Guiry et al., 2017) and Cueva de Chaves (this study)]. The X and Y axes are plotted at different scales in order to make all the samples more visible. The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ baselines were calculated with contemporaneous herbivore data of each site when was available excluding domestic pigs. Subadult individuals were excluded; BL: Baseline [Color figure can be viewed at wileyonlinelibrary.com]

badgers and foxes also scavenged human refuse (López-Martín, 2017; Virgós, 2005). The addition of freshwater resources like amphibians or reptiles in the diet could be also compatible with the *Meles meles* isotopic values. The intermittent water flux of the ravines close to Cueva de Chaves (Ortega Becerril, 2010), however, makes the consumption of riverine fish less plausible.

4.4 | Human dietary reconstruction

Humans from Cueva de Chaves present isotopic values that show a protein diet based mainly on C_3 terrestrial resources. The $\delta^{15}\text{N}$ human values are 5.5‰ higher than herbivore values (wild and domestic) and 4.8‰ higher than the suid values. Because there are no significant isotopic differences between wild and domestic herbivores, it is difficult to know which of these resources humans relied on more. Perhaps little of the protein intake came from lagomorphs and horses, which show lower $\delta^{13}\text{C}$ values than what would be expected from the main protein source of the human diet. This would be compatible with the higher importance of domestic animal resources put forward by the zooarchaeological study (Castaños, 2004) (Table 2).

Regarding plant consumption, and keeping in mind the isotopic masking effect of animal protein on plant foods, the high $\delta^{15}\text{N}$ values could suggest that plant foods were not the central element of their protein diet, which would be based on animal resources (Bocherens and Drucker, 2003). Previous studies suggested a high consumption of plant resources at Cueva de Chaves based on the presence of a pit structure full of charred acorns dated back to the Early Neolithic (Zapata et al., 2008). However, isotopically it seems more probable that domestic animals (mainly suids) were fed acorns, which would have been consumed by humans only sporadically. Furthermore, there is no isotopic evidence whatsoever for the consumption of C_4 resources.

Looking at the human sample in more detail, there is a quite homogeneous group of three individuals, including the subadult individual who does not show a breastfeeding or weaning signal (Fuller et al., 2006). Amongst this first group the $\delta^{15}\text{N}$ values are high and can be explained by abundant meat consumption (higher by 5.1‰ in $\delta^{15}\text{N}$ values and by 1‰ in $\delta^{13}\text{C}$ values than herbivores). The single individual who does not cluster with the others is individual S-UCT 21024, whose body was recovered from an special burial. This individual shows higher $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values (by 6.6‰ and 1.7‰ higher than herbivores, respectively; 1.5‰ and 0.7‰ higher than the other humans, respectively) (Figure 4). For this individual, a small input of another type of protein resource could be suggested, perhaps marine or estuarine protein consumption in low quantities but enough as to be recorded in the isotopic collagen composition. Cueva de Chaves is located close to the Solencio ravine, which presents a torrential water flux, something likely not compatible with the extensive presence of freshwater fish. Moreover, the higher $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values at the same time is more common for marine than freshwater resource consumption (Lillie, Budd, & Potekhina, 2011). If this was the case and the individual had eaten marine or estuarine fish, as they are not available locally, this would be another point to support the existence of coastal-inland routes for this time period. This has been proposed previously by schematic rock art studies (Hernández Pérez, 2016; Utrilla and Baldellou, 2002) as well as by the huge set of Cardial pottery and marine shells used for Cardial decoration recovered at the site (Utrilla and Laborda, 2018).

When plotting together all the adult Early Neolithic humans from Iberia (3 sites, 9 adult humans including Cueva de Chaves), individual S-UCT 21024 from Cueva de Chaves shows the highest $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values only followed by one individual from Cueva de Nerja where a small C_4 input has been suggested (Salazar-García et al., 2017b) (Figure 5a). In contrast to Cueva de Nerja, no faunal remains have shown typical values from C_4 ecosystems at Cueva de Chaves,

so the hypothesis of marine protein intake is more plausible for this individual, as well as due to the presence of a higher $\delta^{15}\text{N}$ increase at Cueva de Chaves than at Cueva de Nerja in comparison to their respective faunal baselines. This would imply that the Cueva de Chaves first farmers arrived to the Iberian coast and penetrated fast into Iberia, and not through the Pyrenees as it was proposed in some works (Utrilla et al., 1998). Strontium isotope analysis in dental enamel could help to know more about the mobility of this Cardial individual with a special burial treatment during his life as long as the migration happened after the enamel mineralization and if the geology of the two areas (where the enamel mineralization took place and Cueva de Chaves) were different (Bentley 2013; Price, Burton, & Bentley, 2002).

At a broader scale encompassing the Western Mediterranean (Salazar-García, Fontanals-Coll, Goude, & Subirà, 2018), when plotting bone collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values from different Early Neolithic adult humans, we see how Chaves fits into the expected Early Neolithic mainly terrestrial protein diet intake. Even so, humans from different sites present variability and they cluster depending on their location and suggesting that human diets are not similar between all communities, although the baselines for each site show an overlap. In this sense, we observe again that individuals from Cueva de Chaves exhibit a trend that corresponds to the consumption of a significant quantity of food items with high $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values and individual S-UCT 21024 from Cueva de Chaves is also positioned in the highest top-right part of the graph, perhaps due to some marine or estuarine protein intake (Figure 5b). In any case, comparing only humans from different ecosystems should be done with caution, as variations in the ecosystem baselines of each site might result in incomparable data.

5 | CONCLUSIONS

This study represents one of the few Early Neolithic isotope analysis studies carried out on the Iberian Peninsula where humans and a large set of fauna coming from the same chrono-cultural context have been analyzed together. While the number of domestic animal remains reflects the importance of animal husbandry at inland early farming communities, animal dietary strategies show a basic husbandry management. Domestic and wild species showed similar values, suggesting the use of common resources or areas for grazing. Even the domestic pig showed an herbivorous diet, ruling out a human leftover feeding. The human isotopic dietary study shows a high animal protein intake by all individuals. This high meat consumption would be related to the existence of a specialized animal husbandry management community in which agriculture was not intensively developed. The values from one individual might reflect a slight isotopic signature of marine or estuarine protein intake at some point of the individual's life. There was no isotopic evidence for the consumption of C_4 resources either by humans or fauna.

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