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RESEARCH

Isotopic Evidence for Mobility in the Copper and Bronze Age Cemetery of Humanejos (Parla, Madrid): a Diachronic Approach Using Biological and Archaeological Variables

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Abstract

Over the last several decades, the application of aDNA and strontium isotope analyses on archaeologically recovered human remains has provided new avenues for the investigation of mobility in past societies. Data on human mobility can be valuable in the reconstruction of prehistoric residential patterns and kinship systems, which are at the center of human social organization and vary across time and space. In this paper, we aim to contribute to our understanding of mobility, residence, and kinship patterns in late Prehistoric Iberia (*c.* 3300–1400BC) by providing new strontium data on 44 individuals from the site of Humanejos (Parla, Madrid). The study presented here is multi-proxy and looks at these new data by interweaving biological, chronological, and archaeological information. This analysis found that 7/44 individuals buried at Humanejos could be identified as non-local to the necropolis. Although more men ($n=5$) than women ($n=2$) were found in the non-local category, and more non-local individuals were identified in the pre-Bell Beaker ($n=5$) than in Bell Beaker ($n=1$) or Bronze Age ($n=1$), we find no statistically significant differences concerning sex or time period. This contrasts with other archaeological datasets for late prehistoric Europe which suggest higher female mobility, female exogamy, and male-centered residential patterns were common. At Humanejos, we have also identified one non-local female whose exceptional Beaker grave goods suggest she was an individual of special status, leading to additional questions about the relationships between gender, mobility, and social position in this region and time period.

Keywords Mobility · Strontium isotopes · Iberia · Late Prehistory · Residential patterns · Sex

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Introduction

Over the past several decades, the application of aDNA and strontium isotope ($^{87}Sr/^{86}Sr$) analyses on archaeologically recovered human remains has provided new avenues of investigations into prehistoric societies. Although aDNA and strontium isotopic analyses work at two different scales, the results obtained through both techniques allow researchers to investigate mobility in the past, and, in some cases, make inferences about residential patterns and/or kinship (for Sr see for example Price et al., 1994; for aDNA see Haak et al., 2008; for a discussion on the interpretation of mobility see Reiter & Frei, 2019). In some regions of Europe, statistically significant findings of greater female mobility during the Neolithic, Copper, and/or Bronze Ages have been interpreted as a consequence of patrilocal residential patterns — whether these findings are from $^{87}Sr/^{86}Sr$ analyses (*cf.* Bentley et al., 2002, 2012; Knipper et al., 2017), from aDNA analyses (*cf.* Schroeder et al., 2019; Dulias et al., 2022; Villalba-Mouco et al., 2022), or from a combination the two (Sjögren et al., 2020). At times these interpretations of female migration as evidence of patrilocality (residence) are linked to patrilineality (descent) and may even be seen as indications of patriarchy (power) (Mittnik et al., 2019; Sjögren et al., 2020). Such interpretative leaps (from patrilocal residence to patrilineality descent to patriarchy) have been criticized by some researchers who argue that more data, and more caution, are needed before linking these three elements (*cf.* Furholt, 2018, 2019, 2021; Frieman & Hofmann, 2019; Frieman et al., 2019; Hrncir et al., 2020; Hofmann et al., 2021: 527–529; Brück, 2021; Ensor, 2021a, 2021b).

For late prehistoric research in the Iberian Peninsula on human mobility (see Díaz-del-Río et al., 2021 for review), many researchers do not interpret evidence of non-local individuals in terms of marriage, residence, and/or kinship patterns, either at the site, regional, or extra-regional level (Fernández-Crespo et al., 2020: 7; Cintas-Peña and García-Sanjuán, 2022). The lack of these interpretive frameworks may be primary due to the commingled and fragmentary nature of many late prehistoric burials in the Iberian Peninsula which leads to a scarcity of information about the sex and age of many interred individuals (*i.e.* Waterman et al., 2014; Díaz-Zorita Bonilla et al., 2018; Valera et al., 2020). However, this may be changing as more genomic data is obtained and combined with other evidence. For example, recently Villalba-Mouco et al. (2022) conclude that the Bronze Age El Argar society practiced female exogamy and was patrilineally and virilocally organized based upon genetic data and funerary practices.

Information on mobility alone can only offer a compartmentalized reconstruction of the lives of prehistoric peoples. A more complete and more complex picture needs to also include other datasets and contextual information related to the funerary record. Rubin (1975) defines the sex-gender system as “the set of arrangements by which a society transform biological sexuality into products of human activity, and in which these transformed sexual needs are satisfied” (Rubin, 1975: 159). Thus, the sex-gender system is one of the basic principles that structures society and, as such, is a worthy topic of investigation into prehistoric social organization. With the proper datasets, these investigations could lead to insights into marriage and residency systems as well as gender-based power dynamics. However, without multiple lines of evidence, caution must be exercised when inferring that any particular residence pattern existed based upon, for example, a simple distinction between individuals whose strontium ratio lie within, or outside of, the calculated local range. Additionally, kinship is a dynamic social institution which changes over time. Therefore, research into these patterns in prehistoric communities must include a diachronic perspective which can only be achieved with careful radiocarbon chronology, or other detailed dating strategies.

Thus, in this paper, we aim to contribute to the analysis of prehistoric mobility and, by extension, kinship, by interweaving three types of data: (i) biological data obtained via skeletal analysis (age-at-death, biological sex, isotopic evidence of life history), (ii) diachronic perspective as evidenced from radiocarbon dates, and (iii) archaeological contextual information. The focus of these analyses will be the archaeological site of Humanejos (Madrid) (Fig. 1), a Chalcolithic and Bronze Age site located in central Iberia. The rich datasets from Humanejos provide us with the possibility of a more nuanced understanding of mobility at a local scale, as well as contributing to the construction of a more detailed and much needed regional isoscape (Díaz-del-Río et al. 2021). Additionally, these data can improve our understanding of prehistoric mobility in Iberia as a whole. The fact that Humanejos is one of the few sites with a substantial sample for both Copper and Early Bronze Age individuals in Iberia makes it ideal for period-based comparisons. This is important because the transition from the Copper to the Bronze Age is known to have had key,

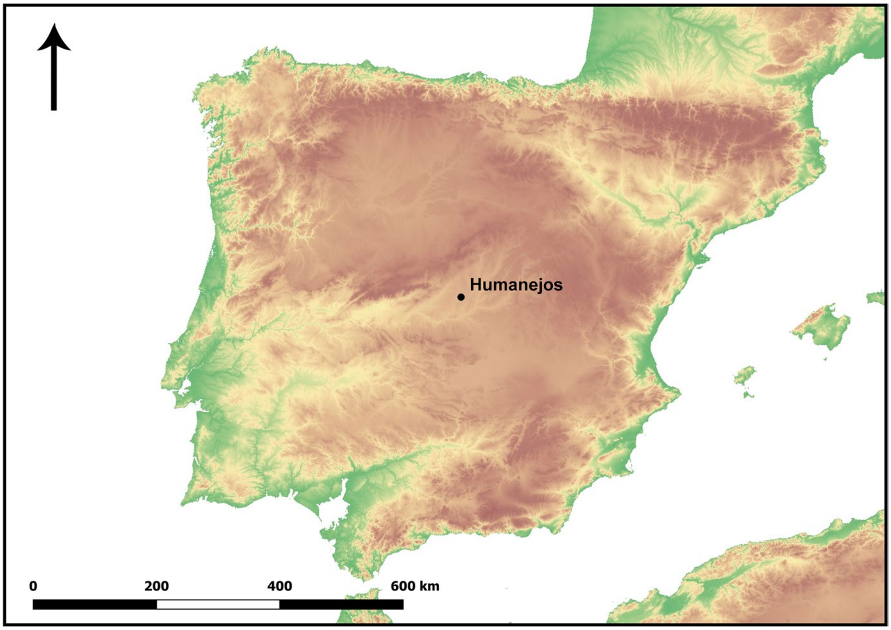

Fig. 1 Location of Humanejos in Iberia

and sometimes radical changes, in locational, subsistence and material patterns in a time period in which aDNA analyses have suggested sweeping transformations in the genetic makeup of human populations.

The Site of Humanejos

Humanejos (Parla, Madrid) spans an estimated area of 20 ha, although the full original extension of the site is not known. During the course of excavations which took place between 2008 and 2012, a total of 2405 features were identified, consisting mainly of pits, postholes, dwellings, and burials. At the site, there are two different types of structures: funerary and domestic, and both of them present a chronological range of *c.* 3300 to 1400 cal BC, which spans the pre-Beaker Copper Age into the Middle Bronze Age (Garrido-Pena et al., 2019; Garrido-Pena et al., 2020).The necropolis comprises 106 burials, including 41 Pre-Beaker Copper Age (*c.* 3300–2500 cal BC) tombs, 14 Beaker and Non-Beaker Copper Age tombs (*c.* 2500–2000 cal BC), and 36 Bronze Age tombs (*c.* 2000–1400 cal BC) (Fig. 2). The minimum number of individuals for the complete necropolis is 160.

The analyses presented in this paper come from burials of different typology and chronology within the funerary sequences defined in the prehistoric necropolis of Humanejos (3300–1400 cal BC). Of the adult individuals, we have sampled 38% of the pre-Beakers (65% of those suitable for sampling), 70% of the Beaker and Non-Beaker Copper Age (82% of those suitable for sampling), and 44% of the Bronze

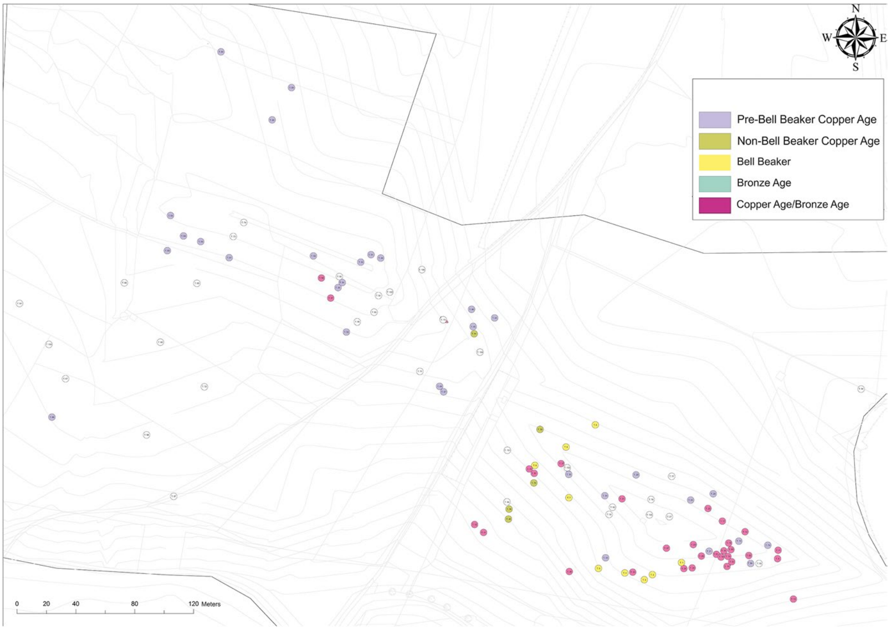

Fig. 2 Plan of the necropolis. This image can be expanded in the online version

Age (78% of those suitable for sampling). As aforementioned, the main chronological phases of this cemetery start with the pre-Beaker Copper Age at the end of the 4th millennium BC. This time period is characterized by variability in funerary treatments. For example, there is variation in the number of individuals inhumed in each tomb and the associated grave goods. The 41 tombs include single ($n=24$, 58%), double ($n=8$, 19%), and multiple ($n=9$, 22%) interments, which may contain a large repertoire of grave goods, or be completely empty. The oldest burials exhibit secondary deposits, in which human bones are mixed with faunal remains (and sometimes complete specimens such as dogs). No less than 51% ($n=21$) of the pre-Beaker tombs have grave goods, which are mainly composed of plain pottery, flint, and stone objects, such as arrowheads or flat axes, and adornments, specially made of variscite. From 2700–2600 BC, copper metallic objects are added to the funerary assemblages in certain tombs with unusual wealth –something unique in the pre-Beaker record (Garrido-Pena et al., 2020). Funerary structures for this period are however very limited, being restricted to simple pits of varying sizes and depths.

By contrast, the nine Beaker tombs from Humanejos (Garrido-Pena et al., 2019; Garrido-Pena et al., 2022) show a great variety of structures that range from simple pits to complex structures with funerary chambers, antechamber, and post holes. In addition, two hypogea with large, stepped access shafts were uncovered. Without any doubt, the Beaker necropolis at Humanejos stands out as one of the richest and most spectacular funerary assemblages discovered in recent decades in Western Europe, with 56 vessels, 34 metallic objects (including a copper halberd, Palmela points, tanged daggers, awls, a flat axe, and gold adornments, four wrist-guards), eight V-perforated buttons, and 62 bone and ivory beads. As for the funerary treatment, eight of the nine tombs contained primary deposits, while in one of them, only a small fragment of bone was recovered, together with several complete Beaker vessels. Of the eight tombs with primary deposits, four of them are individual, three double, and one has a multiple interment. Due to a detailed series of radiocarbon dates from the necropolis (82 samples), it has been possible to distinguish five burials which are contemporaries to the Beaker graves but lack Beaker objects. These are mainly individual tombs lacking any grave goods — although a double and a multiple grave were also recovered.

Finally, 36 tombs were dated in the first half of the second millennium BC. The Bronze Age tombs are mostly individual graves ($n=26$, 72%), and only on very rare occasions do they have some type of grave goods. Funerary structures for this period are simple pits, although some burials in *pithoi* were also found.

Material and Methods

Biological Selection Criteria

Human individuals were selected for analysis based on four criteria: (i) individuals which have clear chronological affiliations, (ii) individuals who were skeletally identified as adults, (iii) individuals whose biological sex had been determined, and (iv) individuals who had intact second molars, as this specific tooth is formed between the third and seventh year (Al-Qahtani et al., 2010) and can be used to identify migration after childhood using strontium isotopes. In the sample, we also included two infant individuals that had been sampled in previous research, and whose sex had been previously determined by aDNA. In order to offer a diachronic perspective, we selected 19 individuals from Pre-Beaker Copper Age (PBCA, *c.* 3300–2500 cal BC), 14 individuals from Beaker and Non-Beaker Copper Age (BCA-NBCA, *c.* 2500–2000 cal BC), and 11 individuals from Early and Middle Bronze Age (EBA-MBA, *c.* 2500–1400 cal BC) (Table 1). The chronological assignment of the individuals to these periods had previously been established through both radiocarbon dates and material culture (*cf.* Garrido-Pena et al., 2019; Garrido-Pena et al., 2020; Garrido-Pena et al., 2022) (Fig. 3). In the only two cases for which the temporality of individuals — 193.1, burial 22, and 770.2, burial 61 — was not clear, we obtained additional radiocarbon dates on the skeletons. The obtained dates, published in this paper for the first time, are 3215 ± 24 BP and 3914 ± 22 BP (Table 2), allowing us to include them in the EBA-MBA, and BBCA-NBCA periods, respectively.

Biological sex was determined by the morphological characters of the pelvis (Bruzek, 2002) and the skull (Ferembach et al., 1980). For ten individuals, the biological sex was also determined by DNA. In all, 28 individuals were identified as males or likely males (M/M?) (63.6%) and 16 individuals were identified as females or likely females (F/F?) (36.4%). Across the sampled time periods, the number of M/M? is 11 in PBCA, eight in NBCA-BCA, and nine in EBA-MBA, while the number of F/F? is eight in PBCA, six in NBCA-BBCA, and two in EBA-MBA (Table 3). The estimation of age for the non-adults was based on teeth calcification and eruption patterns (Ubelaker, 1978); our sample includes 42 adults and two non-adults (44 humans in all).

Identifying Non-locals Using Strontium Isotopes

Humans and animals consuming water, plants, and animal products from the same geographic landscapes should present similar $^{87}Sr/^{86}Sr$ isotope values in their hard tissues. This is because strontium isotopes move from the lithosphere into plants via water and soil and the strontium isotope ratios found in plants will reflect aspects of the local geology (Faure and Powell 1972; Gilli et al. 2009). Unlike carbon, nitrogen, or oxygen isotopes, ^{87}Sr and ^{86}Sr isotopes undergo minimal fractionation when moving from consumed to consumer (Lewis et al. 2017), thus animals eating local plants, or consuming animals that consumed local plants will all exhibit the same $^{87}Sr/^{86}Sr$ ratios in their body tissues. These strontium isotopes are ultimately stored in teeth and bone during formation where strontium substitutes for calcium (Bentley 2006; Ericson 1985; Schroeder et al. 1972). The fact that these $^{87}Sr/^{86}Sr$ ratios are stored in hard tissues allows researchers to use these values to identify human and animal non-locals in prehistoric settings when these individuals exhibit non-local $^{87}Sr/^{86}Sr$ values (Beard and Johnson 2000; Bentley 2006; Price et al. 2002; Price et al. 2012). However, this method can only quantify a *minimum estimate of mobility* as it is not possible to detect animals or humans who come from distant landscapes that share similar bioavailable

Table 1 Individuals sampled and information related to period, type of burial, MNI, sex, and age. PBCA: Pre Beaker Copper Age; BBCA and NBCA: Beaker Copper Age and Non Beaker Copper Age; EBA and MBE: Early Bronze Age and Middle Bronze Age

Period	Burial	MNI	Type of burial	UE/Individual	Sex	Age
PBCA	20	3	Simple pit	194.1 (ind 1)	M?	Adult
	20	3	Simple pit	194.1 (ind 2)	M	Adult
	20	3	Simple pit	194.1(ind 3)	M?	Adult
	68	1	Simple pit	1638.2	M	Adult
	53	1	Simple pit	1097.2	M	Adult
	49	4	Simple pit	1166.4	F?	Adult
	51	1	Simple pit	1169.2	M	Adult
	48	2	Simple pit	1309.2	M	Adult
	48	2	Simple pit	1309.4	F	Adult
	44	2	Simple pit	1355.4	F	Adult
	45	1	Simple pit	1356.2	F	Adult
	65	2	Simple pit	1701.2	F?	Adult
	21	1	Simple pit	1778.2	M	Adult
	60	1	Simple pit	2226.4	M	Adult
	66	2	Pit with post holes	1709.2	M	Adult
	66	2	Pit with post holes	1709.4	F	Adult
	33	2	Simple pit	2002.2	M	Adult
	34	2	Simple pit	422.4	F	Adult
	34	2	Simple pit	422.5	F	Adult
BBCA and NBCA	39	1	Simple pit	638.2	M	Adult
	76	1	Simple pit	537.2	F	Adult
	7	5	Pit with post holes and corridor	455.9	M	YA 15 yr
	38	6	Simple pit	1461.4	F	Adult
	38	6	Simple pit	1461.8	F	YA 15 yr ± 3 yr
	38	6	Simple pit	1461.5	M	Child 11 y ± 2.5 yr
	38	6	Simple pit	1461.7	M	Child 12 y ± 2.5 yr
	38	6	Simple pit	1461.2	M	Adult
	61	2	Simple pit	770.2	F?	adult
	1	2	Stone structure	1853.4	M	Adult
	1	2	Stone structure	1853.5	F	Adult
	4	1	Pit with post holes	1964.3	F	Adult
	5	2	Hypogeum	2014.3	M	Adult
	5	2	Hypogeum	2014.4	M	Adult

Table 1 (continued)

Period	Burial	MNI	Type of burial	UE/Individual	Sex	Age
EBA and MBE	15	3	Simple pit	39.2	M	Adult
	15	3	Simple pit	39.3	F	Adult
	18	1	Simple pit	44.3	M	Adult
	17	1	Simple pit	187.2	M	Adult
	24	1	Complex pit	1816.2	M	Adult
	14	1	Simple pit	1750.2	F	Adult
	10	1	Simple pit	1725.5	M?	Adult
	30	1	Simple pit	1961.2	M	Adult
	82	1	Simple pit	129.2	M	Adult
	31	1	Simple pit	3274	M	YA 15–18 yr
	22	1	Simple pit	193.1	M?	Adult

$^{87}Sr/^{86}Sr$ values. This method is best applied to landscapes with geological diversity across transversable areas, as we can assume that migration in was commonly over shorter distances (Waterman, 2023). The landscape around central Madrid, and throughout the Iberian Peninsula in general, provides geological diversity that makes this methodology profitable in prehistoric studies (Díaz-del-Río et al., 2022; James et al., 2022).

In this project, $^{87}Sr/^{86}Sr$ values were obtained from 60 samples. Thus, Humanejos becomes the fourth most sampled prehistoric site in Iberia (after Camino del Molino, Perdigões and Marroquíes, see Merner, 2017; Valera et al., 2020; Díaz-Zorita Bonilla et al., 2018, respectively). Of these samples, 44 were from the aforementioned prehistoric humans. Additionally, we were able to sample ten prehistoric animals recovered from Humanejos as well as five plants and one soil sample from the site.

A portion of these samples were processed at the University of Iowa Department of Earth and Environmental Sciences clean laboratory. First enamel surfaces were cleaned with acetone, and surface enamel was removed because of possible diagenetic contamination (Budd et al., 2000; Price et al., 2002). After cleaning, 3–5 mg of powdered enamel was collected with a Dremel tool. Before further processing plants were ashed in a muffle furnace. The soil was leached in 1 M NH4NO3 for 48 h and then centrifuged. Supernatant was then pipetted into new centrifuged tubes and evaporated (Willmes et al. 2014). Strontium was isolated in all samples with Eichrom Sr-spec ion-exchange resins using standard procedures (see Waight et al., 2002). Next $^{87}Sr/^{86}Sr$ ratios were measured using a Nu Plasma HR multicollector inductively coupled-plasma mass-spectrometer (MC-ICP-MS) in the Department of Geology at the University of Illinois at Urbana-Champaign using a sample-standard-bracketing measurement protocol wherein standards were run every six samples (Rehkämper et al. 2004). Other samples were processed at the University of Tübingen. For these chemical processing, protocol/s established by Bocherens et al. (1996) was followed.

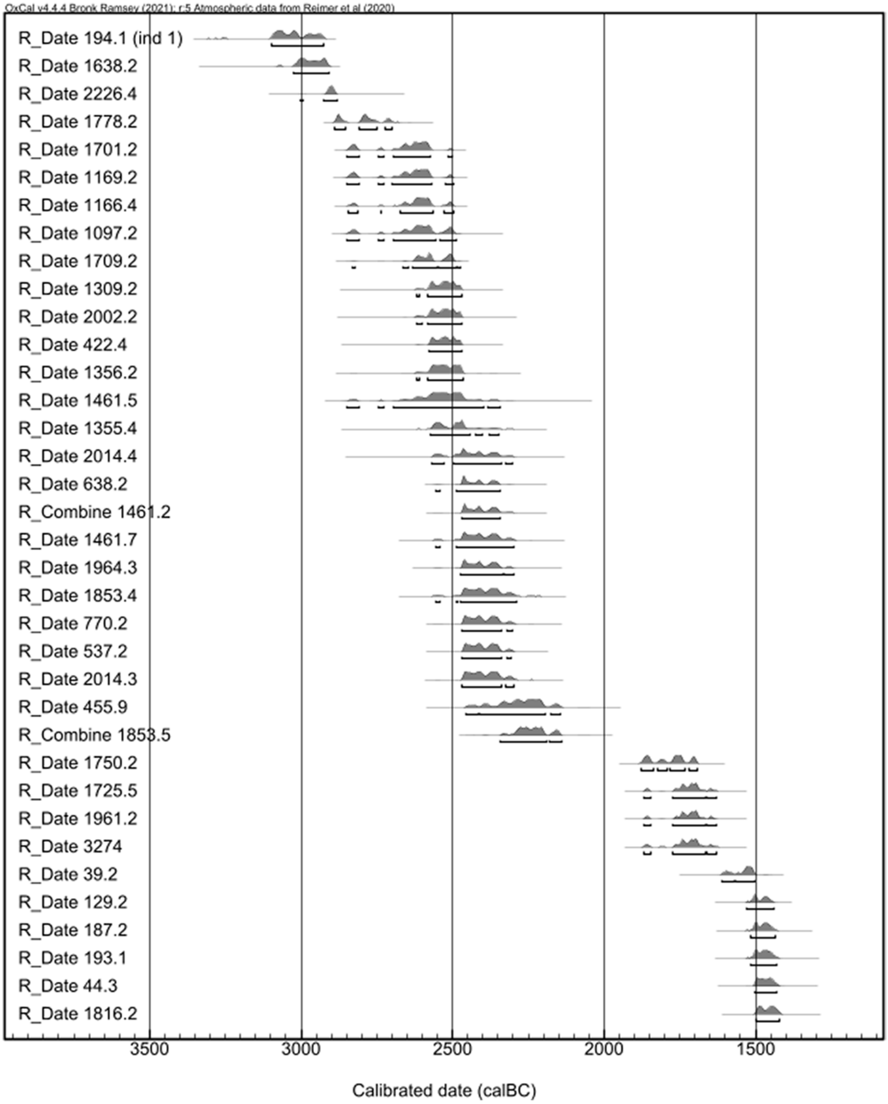

Fig. 3 Calibrated dates of the individuals included in this paper. Dates have been calibrated using IntCal 20, OxCal 4.4 Interface: version: 168

Table 2 Radiocarbon dates of individuals 193.1 and 770.2. Dates have been calibrated with IntCal 20. OxCal 4.4 Interface: version: 168

Burial	Individual	Lab ID	BP	Cal (2σ)
22	193.1	Suerc-104562	3215 ± 24	1516–1430
61	770.2	Suerc-104563	3914 ± 22	2470–2304

Table 3 Males or likely males and females or likely females in each period

Period	M/M?		F/F?		Total
	n	%	*n*	%	
PBCA	11	57.9	8	42.1	19
NBCA and BBCA	8	57.1	6	42.9	14
EBA and MBA	9	81.8	2	18.2	11
Total	28	63.6	16	36.4	44

Estimating the Local Bioavailable $^{87}Sr/^{86}Sr$ Value Range

The selected small fauna, plants, and soil samples were chosen to estimate the local ^{87}Sr/^{86}Sr value range for the burial site itself, while the domesticated and wild large animals were expected to provide a larger value range of the surrounding region which may more appropriately reflect human values. Ideally, the local baseline should be established by mapping systematically the biologically available strontium ratios across regions, as Bentley and Knipper (2005) made in south Germany. However, this work is still to be done for the central region of Iberia, where Humanejos is located. Although not as precise due to the standard deviation errors, an alternative would be to develop "isoscapes," as suggested by Scafidi and Knudson (2020). In the case of central Iberia, an isoscape model was carried out recently by Díaz-del-Río et al. (2022), whose data we compare and combine with our own results.

In this paper, the estimated local bioavailable ^{87}Sr/^{86}Sr isotope range for the Humanejos (Fig. 4) was first calculated by taking 2 SD of the mean of all sampled fauna, five plant samples, and one soil sample (Bentley et al., 2004; Price et al., 2002). This provided a very narrow local baseline (0.710–0.712) and resulted in more than 50% of the sampled humans being identified as non-locals. As these calculations were drawn from a limited number of fauna and environmental samples, and soil and plants can produce values reflecting very narrow geologic features rather than the regional landscape, it seemed likely that this local value range was unsuitably narrow. In order to expand our sample of fauna, we included the ^{87}Sr/^{86}Sr values for animals analyzed in Díaz-del-Río et al. (2017) with the animals from Humanejos. The Díaz-del-Río et al. (2017) dataset was produced using wild and domesticated faunal samples from several sites around Madrid that are broadly contemporaneous with Humanejos. With this expanded sample, we were able to calculate a local ^{87}Sr/^{86}Sr range for Humanejos that appears to be a more natural fit the data with a 0.7085–0.7125 range. This range also fits with the suggested regional values from the isoscape model in Díaz-del-Río et al. (2022). Strontium isotopic analyses can only identify a minimum number of non-locals as people can move from one landscape to another (even across vast distances) which share the same ^{87}Sr/^{86}Sr signatures. Thus, we must interpret any results from using this local ^{87}Sr/^{86}Sr range as only identifying the minimum number of non-locals from Humanejos.

Statistical Analyses

Some researchers have argued that using the dichotomy of “local” versus “non-local” is problematic, and potentially arbitrary due to the geological variation of some landscapes. The use of statistical tests such as Students *t* test (Knipper et al., 2017) or Levene’s test (Bentley et al., 2021) may also be of value as they allow researchers to identify statistical differences in the mean, or the variance, of the samples and can be used as another way to compare the mobility of sampled groups. For example, if the variation is larger within the male values, we could suggest that it is a case of female-centered residential patterns (*cf.* matrilocality), while if the variations were larger for female individuals, it might be a case of male-centered residential patterns (*cf.* patrilocality). Since not all researchers employ the same system, and in order to make this study comparable

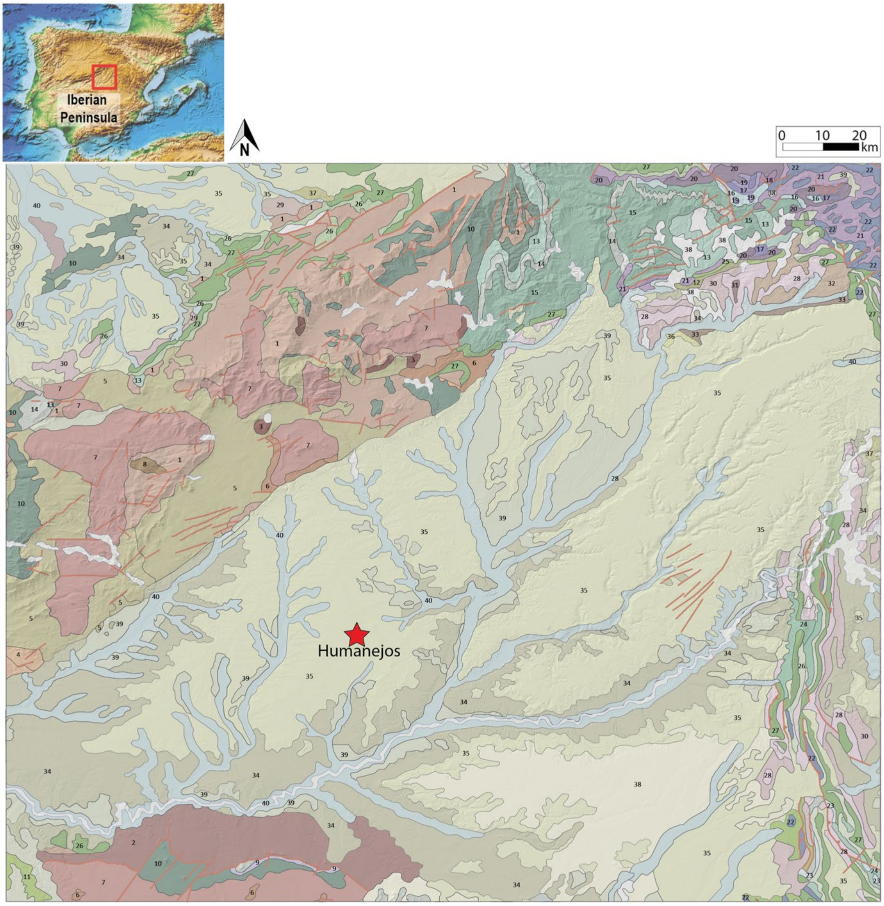

Fig. 4 Geological map where Humanejos is located. Author: Juan Cárdenas Párraga, scale 1:1.000.000, modified from IGME, Geological map of the Iberian Peninsula, Balearic, and Canary Islands

Geological map legend

19	Sandstones, conglomerates, dolomites, limestones, clays and gypsums
18	Conglomerates, sandstones, clays, limestones, dolomites, and gypsum.
17	Lutites, sandstones, conglomerates and vulcanites or limestones
16	Ampelites, quartzites, lithites and volcanoclastic rocks
15	Slates, sandstones, quartzites and limestones or volcaniclastic rocks
14	Orthoquartzites, sandstones and shales
13	Conglomerates, sandstones, quartzites and slates
12	Slates and/or sandy shale
11	Limestone and dolomite
10	Slate, grauwacca or arkoses conglomerates and limestones
9	Quartzites, gneisses, schists, slates and graywackes
8	Slates, greywackes, conglomerates or porphyroids
Hercynian Plutonic Rocks	
Epizonal	
7	Biotitic granitoids
6	Two-mica granitoids
Epi-mesozonal	
5	Biotitic granitoids
4	Two-mica granitoids
Mesocatazonal	
3	Two-mica granitoids
2	Migmatitic anatectic complexes
Pre-Hercynian Plutonic Rocks	
Mesocatazonal	
1	Calco-alkaline and peraluminous granitoids
40	Gravels, sands, clays and silts.
39	Conglomerates, gravels, sands, sandstones, silts and clays. Fluvial and marine terraces
38	Conglomerates, sandstones, clays, limestones and/or gypsums
37	Conglomerates, sandstones, clays, limestones and gypsums
36	Conglomerates, limestones and marls
35	Conglomerates, sandstones, arkosic sands, clays, limestones and gypsums
34	Reef limestones, calcarenites and conglomerates
33	Limestones, biocalcarenites and marls. White marls and marlstones with radiolarians.
32	Siliceous Limestones and sandy marls
31	Calcareous turbidites, limestones, marls, conglomerates, sandstones and clays. Lacustrine limestones
30	Calcareous turbidites. Limestones, sandy limestones, sandstones and sandy marls.
29	Siliceous sandstones and clays
28	Conglomerates, sandstones, limestones, marls, clays, gypsum and/or sodium potassium salts
27	Marls and clays with turbiditic levels. Marl limestones and marly limestones. Red layers
26	Gravels, sands, sandstones and clays. Coal
25	Silicic turbidites, marls with turbidites and marl limestones. Bioclastic limestones, calcarenites, sands, marls, dolomites and limestones.
24	Conglomerates, sandstones, sands and marls
23	Limestones, marls, nodular limestones and radiolarites. Volcanic rocks
22	Dolomites, limestones and nodular limestones
21	Versicolor clays and gypsums
20	Conglomerates, sandstones, clays, dolomites, limestones and marls

Fig. 4 (continued)

to others, we have incorporated these two levels of analyses, considering both the distinction between local and non-local, based upon a calculated local range, and using statistical tests to examine the variation between sampled groups according to biological sex and burial time period. Due to the presence of outliers in the datasets, nonparametric tests were used including Kruskal–Wallis one-way ANOVA (with'Levene's equal variance test) and Mann Whitney *U T*-tests (Supplementary Material 2). All these calculations were done using the NCSS 11 Software package.

In addition to statistical tests on the continuous data provided by the $^{87}Sr/^{86}Sr$ values, chi-squared and Fisher's exact tests were employed to analyze possible differences in the data sets by time period — including number and biological sex of locals and non-locals in each surveyed time period. These calculated were done using the PAST — Paleontological Statistics 4.02 Software package.

Results

The results of the $^{87}Sr/^{86}Sr$ analyses are presented in Tables 4 and 5. Using the calculated local range, we have identified the minimum number of non-locals (MNM) at the sampled burials as seven out of the 44 sampled humans (15.9%).

Diachronic Differences

If we examine the three periods (i) PBCA, (ii) BCA-NBCA, and (iii) EBA-MBA), the PBCA time period contains the largest number of non-locals (Fig. 5). Of the 19 individuals which belong to this first period, five are identified as non-local (26.3%). This contrasts to what we find in BCA-NBCA, and in EBA-MBA periods. In BCA-NBCA of the 14 individuals analyzed, only 1 (7.1%) presents Sr ratios falling above or below that of the local baseline. Interestingly, this individual (individual 19,643) is the most extreme outlier found in any of the time periods. For the 11 individuals from EBA-MBA, only one (9.1%) individual falls outside of the local range, but unlike in the BCA-NBCA, this individual is just slightly outside of the upper boundary.

The non-local $^{87}Sr/^{86}Sr$ signatures found for people inhumed in Humanejos during PBCA reveal that the enamel from the sampled teeth formed from ingested food and water from locations with different underlying geological features than the burial environment. The non-local values fall above and below the calculated local range depicting perhaps a more heterogeneous population in terms of childhood homelands. Moreover, values within the calculated local range are also more diverse than in the later time periods strengthening the claim that childhood diets may have been drawn from more diverse locations in this earlier period.

If we focus on the sampled individuals which share the same burial, we find that there is variation in the strontium-based markers of mobility (Fig. 5). Although in most cases people that were inhumed in the same tomb are all defined as local to the burial site (1, 5, 15, 20, 34, 38, and 48), burials 34, 38, and, especially, burial 48 held individuals with larger variations in $^{87}Sr/^{86}Sr$ values which may imply some differences in childhood diets (geographic locations from which food and water is obtained). There is only one burial, structure 66 from the PBCA (with one female and one male) where the differences in the $^{87}Sr/^{86}Sr$ values between the two individuals sharing this grave mark one as local

Table 4 Strontium results human individuals. PBCA: Pre-Beaker Copper Age; BCA: Beaker Copper Age; NBCE: Non Beaker Copper Age; EBA: Early Bronze Age; MBA: Middle Bronze Age. M2L: second molar lower; M2U: second molar upper; PML: premolar lower

Period	Sample	SR#	UEX	Burial	UE/Individual	Tooth	Sex	Age	Sr	DNA
PBCA	6	HU6	194	20	194.1 (ind 1)	M2U	M?	Adult	0.709312	
PBCA	7	HU7	194	20	194.1 (ind 2)	M2L	M	Adult	0.709286	
PBCA	8	HU8	194	20	194.1(ind 3)	M2U	M?	Adult	0.709492	
PBCA	11	HU11	1638	68	1638.2	M2L	M	Adult	0.708153	
PBCA	13	HU13	1097	53	1097.2	M2U	M	Adult	0.714375	
PBCA	14	HU14	1166	49	1166.4	M2U	F?	Adult	0.713058	
PBCA	15	HU15	1169	51	1169.2	M2L	M	Adult	0.710293	
PBCA	16	HU16	1309	48	1309.2	M2L	M	Adult	0.712275	
PBCA	17	HU17	1309	48	1309.4	M2U	F	Adult	0.709641	
PBCA	18	HU18	1355	44	1355.4	M2L	F	Adult	0.709253	
PBCA	19	HU19	1356	45	1356.2	M2U	F	Adult	0.709448	
PBCA	22	HU22	1701	65	1701.2	M2U	F?	Adult	0.710793	
PBCA	24	HU24	1778	21	1778.2	M2U	M	Adult	0.708807	
PBCA	26	HU26	2226	60	2226.4	M2U	M	Adult	0.708202	
PBCA	27	HU27	1706	66	1709.2	M2L	M	Adult	0.714061	
PBCA	28	HU28.1	1709	66	1709.4	M2U	F	Adult	0.711994	
		HU28.2							0.712241	
PBCA	29	HU29	2002	33	2002.2	M2L	M	Adult	0.710772	
PBCA	9	HU9	422	34	422.4	M2U	F	Adult	0.710158	
PBCA	10	HU10	422	34	422.5	M2L	F	Adult	0.708836	
NBCA	30	HU30	638	39	638.2	M2	M	Adult	0.711214	
NBCA	31	HU31	537	76	537.2	M2U	F	Adult	0.710649	
BCA	32	HU32	455	7	455.9	M2L	M	Adult	0.711114	X
NBCA	34	HU34	1461	38	1461.4	M2U	F	Adult	0.710352	X
NBCA	35	HU35	1461	38	1461.8	M2L	F	YA 15 y ± 36	0.710278	X

Table 4 (continued)

Period	Sample	SR#	UEX	Burial	UE/Individual	Tooth	Sex	Age	Sr	DNA
NBCA	36	MES-227, MES-85, MES-86	1461	38	1461.5	M2L	M	Inf 11 y ± 30	0.7096369	X
NBCA	37	MES-228, MES-85, MES-86	1461	38	1461.6	M2L	M	Inf 12 y ± 30	0.7105844	X
NBCA	39	MES-226, MES-81, MES-82	1461	38	1461.1	M2U	M	Adult	0.7086296	X
NBCA	12	HU12	770	61	770.2	M2U	F?	Adult	0.710007	
BCA	41	MES-37, MES-38	1853	1	18,534	M2L	M	Adult	0.7113197	
BCA	42	MES-213, MES-39, MES-40	1853	1	18,535	M2U	F	Adult	0.7103179	X
BCA	44	MES-216, MES-45, MES-46	1964	4	19,643	M2U	F	Adult	0.7170807	X
BCA	45	MES-215, MES-43, MES-44	2014	5	20,143	PML	M	Adult	0.7090539	X
BCA	46	MES-214, MES-41, MES-42	2014	5	20,144	M1L	M	Adult	0.709582	
MBA	1	HU1	39	15	39.2	M2L	M	Adult	0.711045	
MBA	2	HU2	39	15	39.3	M2L	F	Adult	0.710348	
EBA	3	HU3	44	18	44.3	M2L	M	Adult	0.710483	X
MBA	4	HU4	187	17	187.2	M2L	M	Adult	0.71216	
MBA	20	HU20.1	1816	24	1816.2	M2U	M	Adult	0.710737	
		HU 20.2							0.710726	
EBA	21	HU21	1750	14	1750.2	M2L	F	Adult	0.710323	
MBA	23	HU23	1725	10	1725.5	M2L	M?	Adult	0.710334	
EBA	25	HU25	1961	30	1961.2	M2U	M	Adult	0.709473	
MBA	33	HU33	129	82	129.2	M2L	M	Adult	0.713012	
EBA	38	MES-217, MES,47, MES-48	327	31	3274	M2U	M	YA 15–18 y	0.7107689	
EBA	5	HU5	193	22	193.1	M2U	M?	Adult	0.712412	

Table 5 Strontium results for faunal, plants, and soil samples from Humanejos

SR#	UE	Type of sample	Taxon	Sr
HUF1	416.1	Tooth	*Bos sp*	0.709728
HUF2	416.1	Bone	Lagomorph	0.711006
HUF3	416.1	Mandible	Lagomorph	0.711128
HUF4	416.1	Mandible	Ovicaprid	0.710953
HUF5	416.1	Tooth	*Sus sp.*	0.705073
HUF6	416.1	Tooth	Ovicaprid	0.711396
HUF7	429.1	Tooth	Und	0.709887
HUF8	435.3	Tooth	*Sus sp.*	0.711509
HUF9	257.2	Mandible	*Canis sp.*	0.710942
HUF10	298.1	Bone	Und	0.710921
Hum P1		Plants		0.711076
Hum P2		Plants		0.710793
Hum P4		Plants		0.710669
Hum P4		Plants		0.710709
Hum P5		Plants		0.710619
Hum S1		Soil		0.710592

and one as non-local to Humanejos. In this case, the male in the burial is designated non-local, while the female is local. Thus, tomb placement, in principle, does not seem to relate to mobility patterns.

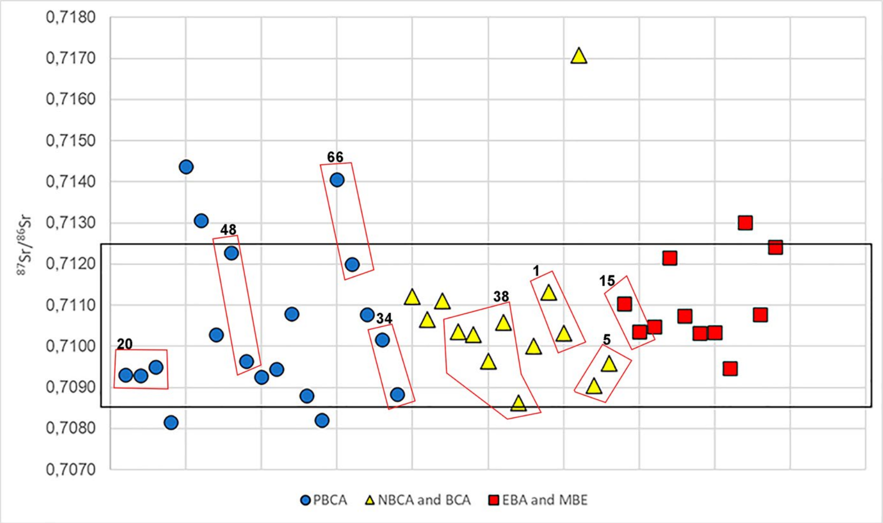

Fig. 5 Scatter plot of 87Sr/86Sr ratios of human individuals distinguishing among PBCA (blue circles, on the left), NBCA-BCA (yellow triangles, in the middle), and EBA-MBE (red squares, on the right). Black rectangle represents the range of the local baseline. Those individuals who share a grave appear grouped within a red polygon, with the indication of the number of the burial

Biological Sex and Mobility

If we consider the relationship between biological sex and mobility, we see that 5/28 individuals identified as males (or likely males) exhibit values that exceed the calculated ^{87}Sr/^{86}Sr local range, in comparison to two females (or likely females) non-locals out of 16 (Fig. 6). Thus, the percentage of outliers in each sex is quite similar: 17.9% of the males and 12.5% of the females.

During PBCA, we find four males (36.4%) *versus* one likely female (12.5%) exhibiting non-local ^{87}Sr/^{86}Sr values, which could suggest a higher male mobility. For individuals whose values fit into the local baseline, both males or likely males and female or likely females' ratios are dispersed across the local range, pointing to possibly more variability in the food and water sources (Fig. 6, left; Table 6, columns "PBCA"). Next, among individuals inhumed in NBCA-BCA, the only outlier is a female, with an ^{87}Sr/^{86}Sr value (0.7170) that clearly exceeds that of the rest of the group and marks her as on outlier in this analysis. If we exclude this female, the range of male's values is much more variable than that of female values that are tightly clustered together (Fig. 6, middle; Table 6, columns "NBCA and BCA"). Something similar can be seen in the EBA-MBE values (Fig. 6, right; Table 6, columns "EBA and MBE"). Here, there is only one non-local, in this case a male, with a value that falls just outside the upper local range. Overall, the distribution of male or likely male values during this time is again more variable, while the only two females have very similar ratios (0.710348 and 0.710323).

These results suggests that with the exception of female 19,643, in the three periods, males or likely males seem to have had a higher mobility than females or likely females, especially during NBCA-BCA and EBA-MBE, where ^{87}Sr/^{86}Sr values of the latter seem to be very homogeneous. In fact, if we consider the narrow local

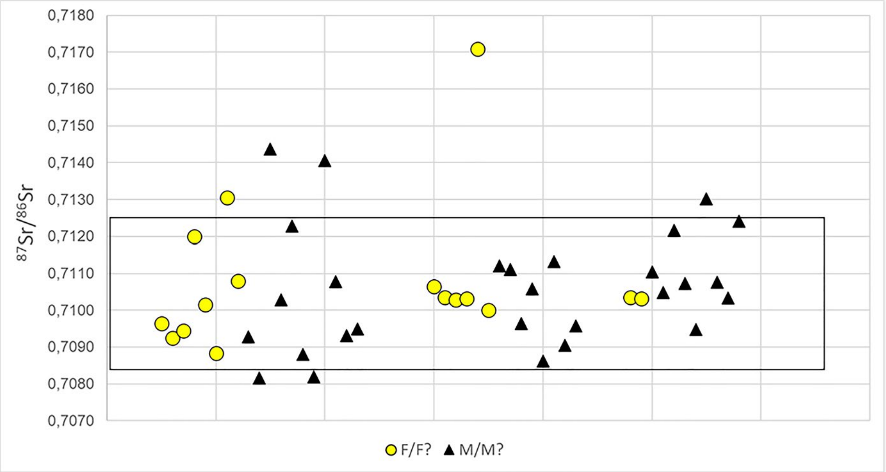

Fig. 6 Scatter plot of ^{87}Sr/^{86}Sr ratios of human individuals distinguishing between F/F? (yellow circles) and M/M? (black triangles) in each of the periods: on the left, PBCA, in the middle NBCA-BCA, on the right, EBA-MBE^{87}Sr/^{86}Sr values by sex. Black rectangle represents the range of the local baseline

Table 6 Mean, standard deviation, range, and variance considering sex and period

	ALL		PBCA		NBCA and BCA		EBA and MBE	
	M/M?	F/F?	M/M?	F/F?	M/M?	F/F?	M/M?	F/F?
Mean	0.7106	0.7108	0.7105	0.7104	0.7101	0,7114	0,7112	0,7103
SD	0.0016	0.0020	0.0022	0.0015	0.0010	0,0028	0,0011	0,0000
Range	0.0062	0.0082	0.0062	0.0042	0.0027	0,0071	0,0035	0,0000
Variance	2.63904E−06	3.83937E−06	4.85002E−06	2.15184E−06	1.10239E−06	7,65796E−06	1,29113E−06	3,125E−10
					Without individual 19,643			
				Mean	0.7101	0,7103		
				SD	0.0010	0,0002		
				Range	0.0027	0,0006		
				Variance	1.10239E−06	5,22498E−08		

baseline (0.7100–0.7200) calculated just using the plant, animal, and soil values from Humanejos, all females or likely females (with the exception of the extreme outlier) would still be considered local, even as many of the males would not. This implies that males more often consumed food produced in a more diverse geological region than females or that they migrated to Humanejos from geological distinct regions after their second molars were formed. Females, in the later time periods, conversely, consumed foods produced from very similar landscapes during the time their second molars were formed and the values from these foods closely matches that of Humanejos where they were later buried.

Statistics Tests

Despite the larger number of non-locals found in the PBCA burials, the results of the chi-squared and Fisher's exact tests which compared non-locals across time periods found no statistically significant differences in mobility (2.7245 and 0.32918; Supplementary Material, contingency Table S1). Similarly, the results of chi-squared test and Fisher's exact test show no difference in the statistical distribution of this data by sex (χ^2: 0.21842, $p = 0.64024$.). This means that despite the appearance of higher mobility in the earlier time periods, the hypothesis that mobility was higher PBCA and declined in later periods is not supported.

When the $^{87}Sr/^{86}Sr$ values were considered as a continuous dataset, rather than in a "local"/"non-local" dichotomy, statistical tests continued to find no significant differences between the males and females for each time period, or for each time period when males and females were pooled together, or for males and females across the entire considered time span (Kruskal–Wallis one-way ANOVA (including Levene's test) and Mann Whitney *U T*-tests (Supplementary Material 2). Thus, it is not possible, based upon the data in this study, to suggest a male-centered residential pattern (patrilocality), or a female-centered one (matrilocality).

Type of Grave and Grave Goods

There are no significant differences concerning type of burial structure across time periods (Tables 7 and 8). Simple pit burials are the most common structure in all periods, containing both males (or likely males) and female (or likely females) individuals. Some people during PBCA, NBCA-BCA, and EBA-MBA were inhumed in other types of structures, such as stone structures or pit with post holes, but there are no associations between the type of burial and strontium values.

Concerning grave goods, for which we have considered ten categories: (i) pottery, (ii) bell-beaker pottery, (iii) copper, (iv) gold, (v) ivory, (vi) cinnabar, (vii) lithics, (viii) variscite, (ix) bone, and (x) faunal deposits (Tables 7, 8, and 9), there are some interesting associations between individuals, time period, and biological sex. During PBCA, the most common grave good element was pottery ($n = 8$), followed by lithics ($n = 5$), and copper, cinnabar, and faunal deposits ($n = 4$ in each case). All lithic artefacts were tied to males (or likely males), while copper and red pigments were more frequently deposited with females (or likely females) (3F/F? *versus* 1 M/M?

Table 7 Type of container and grave goods associated to each of the individuals sampled. In bold, the presence of grave goods and non-local individuals

Period	Burial	MNI	Type of burial	UE/Individual	Sex	Age	Pottery	Beaker pottery	Copper	Gold	Ivory	Cinnabar	Lithics	Variscite	Bone	Faunal deposit
PBCA	20	3	Simple pit	194.1 (ind 1)	M?	Adult							x			x
	20	3	Simple pit	194.1 (ind 2)	M	Adult							x			
	20	3	Simple pit	194.1(ind 3)	M?	Adult										
	68	1	Simple pit	**1638.2**	M	Adult							x			
	53	1	Simple pit	**1097.2**	M	Adult	x									x
	49	4	Simple pit	**1166.4**	F?	Adult	x		x			x				
	51	1	Simple pit	1169.2	M	Adult	x									
	48	2	Simple pit	1309.2	M	Adult	x									
	48	2	Simple pit	1309.4	F	Adult	x									
	44	2	Simple pit	1355.4	F	Adult										
	45	1	Simple pit	1356.2	F	Adult	x									
	65	2	Simple pit	1701.2	F?	Adult			x			x		x		
	21	1	Simple pit	1778.2	M	Adult	x						x			
	60	1	Simple pit	**2226.4**	M	Adult									x	x
	66	2	Pit with post holes	**1709.2**	M	Adult			x			x	x			
	66	2	Pit with post holes	1709.4	F	Adult	x		x			x				x
	33	2	Simple pit	2002.2	M	Adult										
	34	2	Simple pit	422.4	F	Adult										
	34	2	Simple pit	422.5	F	Adult										

Table 7 (continued)

Period	Burial	MNI	Type of burial	UE/Individual	Sex	Age	Pottery	Beaker pottery	Copper	Gold	Ivory	Cinnabar	Lithics	Variscite	Bone	Faunal deposit
NBCA-BCA	39	1	Simple pit	638.2	M	Adult										
	76	1	Simple pit	537.2	F	Adult										
	7	5	Pit with post holes and corridor	455.9	M	Adult		x				x				
	38	6	Simple pit	1461.4	F	Adult										
	38	6	Simple pit	1461.8	F	YA, 15 ± 36										
	38	6	Simple pit	1461.5	M	Inf 11 ± 30										
	38	6	Simple pit	1461.6	M	Inf 12 ± 30										
	38	6	Simple pit	1461.1	M	Adult										
	61	2	Simple pit	770.2	F?	adult	x		x							
	1	2	Stone structure	1853.4	M	Adult		x	x			x	x		x	
	1	2	Stone structure	1853.5	F	Adult		x			x					
	4	1	Pit with post holes	**1964.3**	F	Adult		x	x	x	x	x				
	5	2	Hypogeum	2014.3	M	Adult		x				x				
	5	2	Hypogeum	2014.4	M	Adult		x	x			x				

Table 7 (continued)

Period	Burial	MNI	Type of burial	UE/Individual	Sex	Age	Pottery	Beaker pottery	Copper	Gold	Ivory	Cinnabar	Lithics	Variscite	Bone	Faunal deposit
EBA-MBE	15	3	Simple pit	39.2	M	Adult										
	15	3	Simple pit	39.3	F	Adult										
	18	1	Simple pit	44.3	M	Adult										
	17	1	Simple pit	187.2	M	Adult										
	24	1	Complex pit	1816.2	M	Adult										
	14	1	Simple pit	1750.2	F	Adult										
	10	1	Simple pit	1725.5	M?	Adult										
	30	1	Simple pit	1961.2	M	Adult										
	82	1	Simple pit	**129.2**	M	Adult										
	31	1	Simple pit	3274	M	YA 15–18 y							**x**			
	22	1	Simple pit	193.1	M?	adult										

In bold, presence of grave goods and non-local individuals

Table 8 Type of container in relation to sex and distinguishing among periods

Type of container		Simple pit	Pit with post holes	Pit with post holes and corridor	Complex pit	Hypogeum	Stone structure
PBCA	M/M?	10	1	0	0	0	0
	F/F?	7	1	0	0	0	0
	Total	17	2	0	0	0	0
NBCA-BCA	M/M?	4	0	1	0	2	1
	F/F?	4	1	0	0	0	1
	Total	8	1	1	0	2	2
EBA-MBE	M/M?	8	0	0	1	0	0
	F/F?	2	0	0	0	0	0
	Total	10	0	0	1	0	0

for both copper and red pigment). There are no differences among local or non-local individuals (as ascribed by the strontium analysis) in any of the categories of grave goods, nor are they associated with a higher quantity or quality of material culture. This contrasts clearly with what we find in the NBCA-BCA. In this period, all types of burials, other than simple pits burials, yielded richer grave goods.

However, one burial (number 4) stands out from the rest, as this burial has a great quantity of artefacts made of copper, gold, and ivory, together with bell beaker pottery and cinnabar (for a full description of the grave goods see Garrido Pena et al., 2019: 66–87). These grave goods were deposited with a female (individual 1964.3) who died at the age of 25–35 years (Fig. 7). This female is also the individual whose strontium values clearly exceed the local baseline and was the only non-local found in our study for the PBCA-BCA. Lastly, during EBA-MBA, none of the individuals were deposited with any grave goods.

Discussion

Regional and Extra-regional Comparisons

As presented earlier, out of 44 individuals, seven (15.9%) show $^{87}Sr/^{86}Sr$ signatures which exceed calculated local baselines. This percentage of outliers is three times higher than data published by Díaz-del-Río et al. (2017), which is currently the only published paper examining mobility in late prehistoric central Iberia through the analysis of strontium isotopes. In Díaz-del-Río et al. (2017), one analyzed site, Los Berrocales, is comparable to Humanejos in terms of its chronology (Bronze Age) and the number of individuals sampled. At Los Berrocales, 35 individuals were analyzed, of which three (8.6%) exhibited $^{87}Sr/^{86}Sr$ ratios that fell outside of the calculated local range for that site.

While the number of outliers at Humanejos is higher than Los Berrocales, if we consider late prehistoric burials throughout the Iberian Peninsula, we find the

Table 9 Presence of each category of grave goods in relation to sex and distinguishing among periods

Grave goods		Pottery	Beaker pottery	Copper	Gold	Ivory	Cinnabar	Lithics	Variscite	Bone	Faunal deposit
PBCA	M/M?	4	0	1	0	0	1	5	0	1	3
	F/F?	4	0	3	0	0	3	0	1	0	1
	Total	8	0	4	0	0	4	5	1	1	4
NBCA-BCA	M/M?	0	4	2	0	0	4	1	0	1	0
	F/F?	1	2	2	1	2	1	0	0	0	0
	Total	1	6	4	1	2	5	1	0	1	0
EBA-MBE	M/M?	0	0	0	0	0	0	1	0	0	0
	F/F?	0	0	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	1	0	0	0

number of non-locals is highly variable. For example, a recent review of published data for the Chalcolithic period in Portugal and Spain (Cintas-Peña and García Sanjuán, 2022) found that while ^{87}Sr/^{86}Sr analyses at some burial sites reveal no non-locals (Bolores, Cueva de los Cristales, El Rebollosillo and Los Husos), at others nonlocals account for 75% of individuals. The mean for the whole Iberia is currently 22.6% (Cintas-Peña and García Sanjuán, 2022). The highest numbers of nonlocal humans may be linked to the particularities of certain large settlements, like Perdigões (75% outliers) (Valera et al., 2020), but other sites also exhibit moderately high numbers of nonlocals including Valencina (33%) (Díaz-Zorita Bonilla, 2017) and La Pijotilla (29.4%) (Díaz-Zorita Bonilla, 2017). However, this general synopsis must be viewed with caution as different researchers may apply different methodologies to distinguish between locals and nonlocals, with some using strontium data from animals to calculate local baselines, while other may use only environmental samples or, alternatively, employ statistical analyses of the variations in strontium values between individuals in the burial population. Furthermore, the size of these burials also varies dramatically, which also may complicate these comparisons.

The number of non-locals in the pre-Beaker period of Humanejos could be explained by this being a burial site that drew people from disparate settlements for interment activities. If this hypothesis were true, it could imply that the burials in the area preceded the activity in the adjacent settlements, as is found for some other Copper Age sites, such as Los Millares, where radiocarbon dates suggest the cemetery was established *c.* 230 years before the settlement foundation (Aranda Jiménez et al., 2020). However, at Humanejos, both domestic and funerary deposits seem to be coetaneous. At other Copper Age sites, such as Perdigões (Valera et al., 2020), the high number of non-locals has been explained by the existence of some kind of aggregation process, linking the higher mobility to the unstable character of the settlement, although some authors argue that the highly variable local geology could be behind the pattern (Díaz-del-Río, 2021: 178). At Humanejos, the archaeological record currently does not support this explanation either.

When we consider the geology for the surrounding area, we can propose that variations in ^{87}Sr/^{86}Sr signatures from the Madrid region are related to limestones

Fig. 7 Female individual 1964.3. Author: Raúl Flores Fernández and Sara Genicio

(lower range values 0.707 and 0.708), granitic areas (higher range values 0.714 up), and to the sedimentary depositional environments (intermediate values) (Díaz-del-Río et al., 2022). If we apply this mapping strategy to the nonlocals found in the data presented here, then we could suggest that PBCA individuals 1638.2, 1778.2, 2226.4, and 422.4 could be individuals born in limestone areas, and 1097.2 and 1709.2 from granitic areas. For the NBCA-BCA, individual 18,535 must hale from a significantly more radiogenic strontium landscape than all the others in this study which could be composed of granites and other older rock formations, while EBA-MBE individual 187.2 moved from granitic areas similar to 1097.2 and 1709.2. All the rest of the sampled people could be assigned to sedimentary depositional environments. As all of these types of geologic landscapes can be found in the region around Madrid (Díaz-del-Río et al., 2022), we see no real evidence of long-distance migration at Humanejos.

Iberia in the European Context

Recently published research focused on prehistoric human strontium isotopes and aDNA data have led to a major transformation of our view of European prehistoric mobility. As genetic and strontium data suggest major demographic movements between the Neolithic and Bronze Age, debates about the relationships between cultural diffusion and migration in the development of societies during the third millennium BC have become more complex (Allentof et al., 2015; Narasimhan et al., 2019; Olalde et al., 2018, 2019; Patterson et al., 2022).

Based on genomics data, Haak et al. (2015) reveal important demographic movements linked with the expansion of the Corded Ware peoples from the steppes of Eastern Europe (Yamnaya groups) into Northern and Central Europe. Later populations using Bell Beakers, presumably derived from these steppe populations, were responsible (based on genomics data) for the subsequent massive displacements that completely changed the genetic composition of the population in the British Isles (Olalde et al., 2018). Finally, during Bell Beaker times, and later in the Bronze Age, another significant movement might have taken place (Olalde et al., 2019). This movement, as documented in the Iberian Peninsula, appears to have involved the arrival of large numbers of male individuals from outside of Spain and Portugal. The genetic signatures of these men are seen in patrilineal lineages which prevailed during the second millennium BC at the expense of the local patrilines (Olalde et al., 2019). Similar observations on patrilineality are found in other recent studies, based on Southern Iberian data (Villalba-Mouco et al., 2021) including the Bronze Age El Argar culture in the Southeast of Spain (Villalba-Mouco et al., 2022).

The recent DNA evidence has been interpreted in nuanced ways. However, between the Neolithic and Bronze Age, both in Iberia and in a wider European context, the most widespread interpretation is male-centered patterns of residence and kinship, which infers female exogamy, patrilocality, and perhaps patrilineality (Fowler et al., 2022; Mittnik et al., 2019; Sjögren et al., 2020). Some researchers using strontium isotopic data have also reached these same conclusions for specific regions of Europe based on evidence of higher female mobility and supported by statistical analyses (Bentley et al., 2012; Knipper et al., 2017) — but see Bentley et al. (2022) for an exploration of the role matrilocality and matrilineality could have in selected areas. However, others contend that the current datasets are not robust enough to support such interpretations and suggest a better understanding of descent and kinship systems in a cross-cultural perspective is warranted (*cf.* Furholt, 2018, 2019, 2021; Frieman & Hofmann, 2019; Frieman et al., 2019; Hofman et al., 2021: 527–529; Brück, 2021; Ensor, 2021a, 2021b).

The Humanejos data presented here does not fit a pattern of female exogamy and patrilocality. First, the results of strontium isotopic analyses do not show a higher mobility for women in general. In fact, across all three considered time periods only 2 females were found to have non-local values in contrast to five males. Moreover, with the exception of one woman (NBCA-BCA, individual 19,643 of tomb 4), the distribution of male strontium values in relation to female ones is more variable in both the NBCA-BCA and EBA-MBE. Furthermore, in this study, there were no statistically significant differences in Sr values between males and females in general or across different time periods. Thus, we suggest that bilocality would be the most parsimonious way to view residence patterns in this site with the movements of men and women in and out roughly equal.

Second, the diachronic analysis does not show an arrival or migration of male individuals to Humanejos from other places in comparison to females, as suggested by genetic studies, especially for Beaker period (Olalde et al., 2019) and Bronze Age (Villalba-Mouco et al., 2021). The strontium value of individual 455.9 (burial 7), an adult male that was inhumed with beaker pottery, indicates that he was local, while his genetic analysis shows Steppe-like ancestry (Olalde, 2019b 282–283). However, individual 1964.3 (burial 4), an adult female also deposited together with Beaker pottery and whose strontium ratio clearly shows that she was non-local, most likely had an Iberian genetic origin (Olalde, 2019b: 282–283). Another five individuals (three males and two females) from the contemporary, but non-beaker, burial (burial 38) had the same Iberian ancestry as female 1964.3. Lastly, one male individual (burial 5, individual 2014.3) buried with beaker pottery did not present a "Steppe" signal, according to genetic data, suggesting that there were male individuals with Beaker pottery and Iberian ancestry. While these data could indicate a more frequent relationship between Steppe ancestry, maleness, and Beaker grave goods, as has been already proposed (Olalde et al., 2019a), at Humanejos, we see a divergence between aDNA and strontium values.

Strontium isotopic and genetic data inform us about mobility at different levels. Strontium isotopic values inform us about intra-lifetime mobility, while aDNA can inform us about genetic ancestry and therefore infer ancestral homelands and past migration events. Since our analysis is diachronic, one could expect some degree of correspondence among these two types of information. However, the strontium isotopic data presented here, with no statistically significant differences between males and females — and with no signs of increasing mobility in Bell Beaker period — does not support large-scale male long-distant migration for PBCA, NBCA-BCA, nor MBE-EBA. This contrasts with what is suggested by the genetic data presented in Olalde et al., (2019). In fact, in the group of 44 individuals analyzed here, there is only one individual who clearly arrived to Humanejos from a very different geological area: female 19,643. The high strontium ratio obtained for this individual (0.7170) indicates that she grew up in more radiogenic siliceous lithologies. In Iberia, this geological area comprises lithologies as gneiss, slate, quartzite, or granite, which are present in a vast region in the west of the peninsula, as well as in the Pyrenees or Central System (Díaz-del-Río et al., 2022: Figs. 5a and 5b, in red; James et al., 2022). This means that the closest place for this female to come from would be Central System, with its nearest location (Fig. 4, granitoids represent by numbers 4–7) 40 km away from Humanejos to the northwest. In the 1054 ^{87}Sr/^{86}Sr human values compiled by Díaz-del-Río et al., (2022, Supplementary Material), there are only five individuals from five different sites with equal or higher strontium values: from the Chalcolithic sites of Valencina-Castilleja (Díaz-Zorita Bonilla 2017), Camino del Molino (Merner, 2017), and Cova da Moura (Waterman, 2012); from the Bronze Age site of Los Berrocales (Díaz-del-Río et al., 2017); and a medieval individual whose bones are located in the Evora Museum (MacRoberts et al., 2020). This could be an indication that very few individuals lived in this type of geological area or that strontium data has not yet been collected from settlements that would be located in geologic landscapes with these values. Certainly, humans tend to aggregate in fertile river valleys that are more likely to exhibit less radiogenic strontium values. The quantity and quality of grave goods associated with this individual also greatly differentiate her from the rest of the burials at Humanejos. Indeed, based upon the material culture recovered together with this woman, this may be the most distinguished female Beaker burial in the whole Iberian Peninsula. These two lines of evidence, (i) the absence of settlements in the closest geological area whose ratio would be coherent with the values obtained in this individual, and (ii) the exceptional material culture associated to her, led us to suggest that this woman may be a long-distance non-local, although this hypothesis is currently unfalsifiable.

Conclusion

Data on human mobility can be valuable in reconstructing past residential patterns and kinship systems, which center human social organization and vary across time and space according to cultural and environmental inputs and constraints. In this paper we aim to contribute to our understanding of mobility, residence, and kinship patterns in late Prehistoric Iberia by offering new data from the site of Humanejos.

Our results suggest complexity in residential patterns and kinship systems of pre-Beaker, Bell Beaker, and Bronze Age communities from the Iberian and European context. The data presented in this paper shows no statistically significant differences in the mobility of men and women in pre-Bell Beaker, Bell Beaker or Bronze Age communities of Humanejos. This is in contrast with other archaeological datasets for late prehistoric Europe which suggest higher female mobility, female exogamy, and male-centered residential patterns were common. Our data also contrasts with the diachronic perspective offered by aDNA data which suggests mobility increase through time — especially male mobility during Bell Beaker and Bronze Age. At Humanejos, we find no evidence for this mobility shift. In sum, the data presented here indicates that combining evidence from strontium isotopic analyses, aDNA, biological sex, and grave goods can provide a more nuanced understanding of residential patterns and kinship systems in past societies and highlight changes in them over time.

Competing interests

The authors declare no competing interests.

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Declarations

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