Equid use and provision during the Early Iron Age in Can Roqueta (NE Iberian Peninsula). Zooarchaeological study and first strontium isotope results ($^{87}Sr/^{86}Sr$).

Albizuri, S.[1*]; Valenzuela-Lamas, S.[2]; Bosch, D.[3]; Fernandez[4], M.; López-Cachero, F. J.[5]

[1] Universitat de Barcelona, Departament d'Història i Arqueologia– SERP, C/ Montalegre 6-8, 08001 Barcelona (Spain). E-mail: silvia.albizuri@upc.edu

[2] Consejo Superior de Investigaciones Científicas - Institució Milà i Fontanals, C/ Egipcíaques 15, 08001 Barcelona (Spain). E-mail: svalenzuela@imf.csic.es

[3] Laboratoire Géosciences, CNRS- Université Montpellier, UMR-5243, 34095 Montpellier. E-mail : Delphine.Bosch@gm.univ-montp2.fr

[4] 608 Farm And Equine Veterinary Surgeons, Quarry Farm, Rowington Green, Rowington, Warwick, (Warwickshire, UK). E-mail: matvet608@icloud.com

[5] Universitat de Barcelona, Departament d'Història i Arqueologia– SERP, C/ Montalegre 6-8, 08001 Barcelona (Spain). E-mail: xavierlopez@ub.edu

[*] Corresponding author. Silvia Albizuri
E-mail address: silvia.albizuri@upc.edu

Highlights

- New data about the use of equids in the NE of the Iberian Peninsula during the Early Iron Age
- Mortality profiles indicated a selection of adult animals
- Withers height estimations revealed a notable diversity in equid sizes
- The pathological features coincide with natural ageing processes, and are thought to be linked with draught, riding and load-carrying
- Strontium isotopes ($^{87}Sr/^{86}Sr$) from tooth enamel provide direct evidence of diverse geographical origins

Declarations of interest: none.

Abstract

This article reports the results of a zooarchaeological study (including, mortality profiles, and anatomical and pathological descriptions) of the Early Iron Age (8th-6th c. BC) equid remains at the Can Roqueta site (Sabadell, Barcelona), together with the first strontium isotope results to determine their geographical origin. The zooarchaeological study reveals a remarkable number of equid remains at the site, the bone pathologies of which suggest their use for riding, drafting and load-carrying. The mortality and sex profiles point to the presence of adult animals, while the absence of neonatal and juvenile remains raises the question as to whether these individuals may have originated from other sites specialised in equid breeding. The strontium values obtained from six individuals suggest that some equids were reared in a geological area with a similar strontium signature to that of the Vallès area, where the site is located. However, three equids present a different strontium signature, pointing to a possibly different geographical origin.

Keywords: Equids, mobility, Early Iron Age, Iberian Peninsula, Strontium Isotopes.

1. Introduction

Horses differ from other domesticates in terms of both their symbolic and economic value. This may be related to their care, feeding or training requirements, all of which are usually much more complex than those of other domesticates (e.g. cattle, sheep, pigs and dogs). Their work force value, slow growth, and low meat weight compared to that of other domesticates means horses have not usually been exploited for food (meat or milk) in the Iberian Peninsula.

In the northern half of the Iberian Peninsula, horse remains in domestic waste contexts have appeared sporadically in some 3rd and 2nd millennium BC settlements (for details, see Alcalde et al*.,* 1997; Alonso et al*.,* 2002; Legge, 1994; Nieto et al*.,* 2016), but their presence does not become widespread until the 12th century BC (i.e. Late Bronze Age) (Albizuri, 2014; Albizuri, 2018; Albizuri et al*.*, 2011). However, it is not until the Early Iron Age (8th-6th c. BC), that the first archaeological evidence of horse remains and iron bits are documented in funerary zones and ritual structures, as in Can Roqueta (Albizuri, 2014; López-Cachero et al*.,* in press).

Horse taming and breeding require specialised knowledge and considerable economic investment before the animals can be put to use. Given the difficulties of equid breeding and training, as well as their value for light transport, the existence of specialised horse breeding sites in Europe during Late Prehistory has been suggested (Bendrey et al*.*, 2009; Bendrey, 2010; Grant, 1984; Harcourt, 1979). Only two sites in NE Iberia present signs of local breeding, as evidenced by foetal remains – that is, Vilars d'Arbeca and Tossal del Molinet (see Gómez, 2003; Nieto et al*.*, 2010 for details) –. This evidence raises important questions about specialisation in horse breeding in this area from the Early Iron Age. At this time, the mobility of both human and animal populations in Europe is clearly visible in the isotope evidence recovered from certain areas (Bendrey et al*.*, 2017; Bendrey et al*.*, 2009; Gerling, 2015; Makarewicz et al*.*, 2018; Nuviala et al*.*, 2014). Concurrent with this, there was a growth in commercial networks and territoriality as well as an increasing social differentiation, something that was especially evident in tombs associated with horse remains (Albizuri et al*.,* 2016a; Gerling, 2015; Kmeťová, 2017; López-Cachero, 2007). All this raises important questions about the economic specialisation of certain settlements, about mobility and trade in this period, and about the growing importance of the horse at a time when social differentiation, militarisation and territoriality were increasing (Beylier 2012; Dedet and Marchand 2016; Gruat and Garcia 2016; López-Cachero 2014).

2. Aims of study

The zooarchaeological study conducted at Can Roqueta revealed an unusual number of equid remains dated to the Early Iron Age. In all, 46 individuals were identified in a period covering c. 200 years. Evidence of bone pathologies and iron bits suggest the use of horses for riding, drafting and carrying loads. The adult age of most of the remains raises the question as to whether these animals were the result of local breeding and taming or, on the contrary, whether they originated from other settlements that specialised in horse breeding. For this reason, and to assess the geographic range of horse provisioning, we performed a pilot strontium isotope study on six individuals.

3. Materials and archaeological context

3.1. The site of Can Roqueta

The archaeological site of Can Roqueta is located in Sabadell, about 25 km to the north of Barcelona. The site lies in the north-east margin of the Catalan Coastal Depression (Vallès-Penedès Depression), a valley forming a natural corridor parallel to the Catalan coast (Fig. 1).

Figure 1

The geology of the Vallès-Penedès Depression is characterised by fragmented outcrops of mainly Mesozoic and Tertiary sedimentary formations overlying infra-Silurian and Varingian batholith and other Palaeozoic metamorphic rocks (Santanach et al., 2011). The site occupies an area of about 2.5 km^2 of distinct geological formations: thus, the sectors of 'Can Revella' (CRV), 'Diasa' (CR) and 'Can Roqueta II' (CRII) lie on Pleistocene alluvial fan sediments, while the sector of 'Torre Romeu' (CRTR) lies on sandstones, clays and limestones dated from the Lower Miocene (Fig. 2). In the vicinity of the site, within 10-15 km, other sedimentary (Triassic sandstones, dolomites, limestones and marls) and metamorphic (Cambro-Ordovician Micacitic slates) formations outcrop. Finally, to the north-east, an extensive outcrop of Late Hercynian biotitic granodiorite is also present (Fig. 2).

The settlement was first excavated at the end of the 1980s, with the site's most relevant areas being associated with the large incineration necropolis of 'Can Piteu' (Carlús et al., 2007) (Fig. 1). Since then, more than 2,700 structures have been excavated, dating from the ancient Neolithic to present times, although most date from the Late Bronze Age (1300-750 cal BC) and the Early Iron Age (750-550 cal BC) (Fig. 1). In general, the best preserved structures are those found in the sediment, among which we find both incineration tombs and silos.

Figure 2

Evidence of equid remains are first attested to in different sectors of the archaeological site of Can Roqueta during the Late Bronze Age (1200 BC). At this time, equids represent 5% of domesticates (NISP counts). In the Early Iron Age layers, there is a considerable increase in horse remains, representing up to 10% of all domesticates (Albizuri et al., 2011; Albizuri, 2014).

The zooarchaeological analysis of this Early Iron Age phase facilitated the identification of a minimum number of 46 individuals, most with caballine characteristics. Of this set, 39 individuals (MNI) were deposited in 28 structures mixed with singular bone groups (ABGs following Pigot, 1962; Morris 2008, 2011). Certain patterns in the disposition of the bones and their anatomical selection suggest the intentionality of the deposits, possibly in relation to cultic practices (López Cachero et al., in press). The deposits are mainly located in silos and pits, and in some cases in association with funerary structures. At Can Roqueta, the horse remains are often non-fractured and never found in association with domestic waste.

The taphonomy of the remains reveals several types of intentional accumulations of horse bones. The anatomical selection includes skulls and jaws, pelvis, scapulae, distal limb bones and, in some cases, bone segments appear in anatomical connection. On occasion, isolated bones (teeth, vertebrae, carpal/tarsal bones, metapodials and phalanges) were deposited. Finally, two complete skeletons (CR6 and CRII811, see Table 1) were found fully or partially articulated, with clear signs of anthropic manipulation. In addition, two human burials were accompanied by horse bones (Albizuri et al. 2016a).

3.2. Materials

We have selected the best-preserved equids remains available. Twenty-two dated in Early Iron Age samples for osteometric study (Table 1) and six equid's teeth and two present-day evergreen oak leaves (*Quercus cerrioides*) for isotopic analysis (Table 2).

Table 1

Table 2

4. Methods of analysis

4.1 Osteoarchaeological analysis

The osteological similarity between horses and donkeys, as well as the diversity of characters among their hybrids, makes it difficult to differentiate Early Iron Age equids, especially as the archaeological evidence suggests that domestic horses (*Equus caballus*) and domestic asses (*Equus asinus*) were already present in the Iberian Peninsula. Traditionally, the introduction of the domestic ass is associated with the arrival of the Phoenicians and dated to around the 8th c. BC in the eastern and southern Iberian Peninsula (Nadal et al., 2010). At present, we have no clear evidence of the production of hybrids in the Iberian Peninsula, although they have been recorded from the end of the 2nd millennium BC in the Near East (Michel, 2004). Additionally, in present-day Catalonia there are cases of deposits bearing a clear Phoenician influence – including, for example, the small equids of Hort d'en Grimau and Aldovesta – that raise doubts about their classification as either donkeys or horses (Albizuri and Nadal, 1990; Albizuri et al., 2016b; Nadal et al., 2010).

Given the considerable likelihood of finding different equid species among the sample analysed, the zooarchaeological study focused specifically on distinguishing between them. Morphological and osteometric studies were conducted on the tooth remains, scapulae, humerii, radii, metacarpals, femurs, tibias, metatarsals, taluses and proximal phalanges, in accordance with the various criteria and methods described in the literature (Barone, 1976; Davis, 1980; Eisenmann, 1979, 1980, 1981, 1984; Eisenmann and Beckouche, 1986; Johnstone, 2004). The biometric study was conducted in line with the protocols devised by Von den Driesch (1976) and Eisenmann (2009). Withers heights were calculated according to the greatest length (GL) of all bones in accordance with the factors proposed by May (1985) (in Johnstone, 2004). The shape index (SD x 100/GL) was calculated using the smallest midshaft width (SD) and the greatest length of metacarpals, metatarsals, tibias, phalanxes and radii in order to estimate the slenderness or robustness of differentiated equids (Johnstone, 2004).

Age estimation of individuals was undertaken based on stages of dental eruption and tooth wear (Guadelli, 1998), as well as on average ages of epiphyseal closure (Barone, 1976). Sex identification was based on morphology study of the pubis bone (Barone, 1976) and the presence/absence of canines. If canines were not present, we considered the individual to be female; when canines were well developed, we identified the individual as male. In intermediate cases (rudimentary canines), sexual attribution was not made, as both sexes can develop rudimentary canines. When there is no anatomical connection, sex is defined in accordance with cranial criteria (see Table 1).

The MNI was estimated in each structure by combining the best represented anatomical element and the age of the individuals and their general morphology (Poplin, 1976). Bone and teeth pathologies were determined by equine veterinarian specialists (MF) at 608 Farm and Equine Veterinary Surgeons (UK) and by reference to specific scholars (Bendrey, 2007b; Brown and Anthony, 1998; Cook and Strasser, 2003).

To guarantee the accurate chronological assignment of the equids, most individuals were radiocarbon dated. This was particularly the case for those in which the associated archaeological material was not chronologically characteristic (see Table 1, 2).

4.2 Strontium isotope analysis

Strontium isotopes ($^{87}Sr/^{86}Sr$) from tooth enamel provide direct evidence of geographical origins and, hence, of patterns of human and animal mobility. Consequently, they enable us to determine whether the animals were raised locally or rather they were 'imported' from other areas (e.g. Balasse et al., 2002; Bendrey et al., 2009; Evans et al., 2007; Minniti et al., 2014; Viner et al., 2010). Sr isotope ratio ($^{87}Sr/^{86}Sr$) varies from one geological formation to another depending on the age, the lithology of the considered rocks (schematically basic or felsic) and the original rubidium (Rb) content of the bedrock (Bentley, 2006): the older a rock formation and the higher proportion of ^{87}Sr compared to that of ^{86}Sr. This is because ^{87}Rb decays into ^{87}Sr over time (Faure and Mensing, 2005). Similarly independently of the age of the rock, the more felsic a rock is the higher the $^{87}Sr/^{86}Sr$ ratio.

The $^{87}Sr/^{86}Sr$ isotope composition of skeletal material derives from the food and drink ingested by the animal, with strontium substituting calcium in the minerals of the skeletal tissue (Comar et al., 1957;

Toots and Voorhies, 1965). Here, teeth are particularly valuable, as the isotopic signature of enamel bioapatite persists with few subsequent changes, thus preserving the isotopic signature of the area in which the animal was raised during tooth formation. Dentine is more susceptible to diagenetic alteration, and its strontium isotope values usually reflect those of the burial environment (Budd et al., 2000; Evans et al., 2007; Price et al., 2002). It can therefore be used as a baseline to determine the local strontium values of the archaeological site (e.g. Minniti et al., 2014; Viner et al., 2010).

Six equid teeth were sampled to assess place of rearing during the period of tooth formation (see Table 2). A transversal slice from the protoconid of each tooth was taken for strontium isotope analysis using a diamond cutter disc coupled to a dentist drill. Only fully formed teeth (i.e. in terms of wear and presenting largely closed roots) were chosen for analysis. Wherever possible, the sample was located just above the enamel root junction (ERJ) to facilitate data comparison. The results obtained thus reflect the final period of mineralisation of the sampled tooth (see Table 2 for details).

In addition, three dentine samples and two present-day evergreen oak leaves (*Quercus cerrioides*) taken from two different sectors of the site (namely, Can Revella and Torre Romeu) were analysed to obtain the strontium signature and the bioavailable strontium of different areas of the site.

The enamel samples were first cleaned mechanically using a rotating drill to remove the tartar, dentine and dirt, and then transferred to the Laboratoire de Géosciences–CNRS in Montpellier (France) to complete the process. This involved ultrasonic cleaning to remove any adhering material and immersion in 60 °C ultrapure water for 1 h for further cleaning. After each cleaning phase, the sample was rinsed three times in MilliQ high purity de-ionised water. In a final cleaning step, the sample was immersed in an ultrasonic bath containing 5% acetic acid for half an hour, and rinsed three or four times with pure water, to ensure that all potential remaining diagenetic effects had been removed. Once cleaned and dried in a laminar flow hood, the samples were weighed in pre-cleaned Teflon beakers. The samples were then dissolved in closed Teflon beakers with 1cc of tridistilled nitric acid (8 M HNO_3) using sonication to help digestion during 15minutes and subsequently put on a hotplate at 70°C during 12h followed evaporation to dryness. Samples was then diluted in nitric acid 2M and uploaded into Teflon columns filled with Eichrom Sr-Spec ion-exchange in order to isolate Sr using standard procedure (e.g. Pin et al., 1994). The strontium was purified following four steps of elution using various concentration of nitric acid solutions. The solutions were then evaporated to dryness at 85°C before to be diluted with nitric acid 2% in order to be analysed using a Neptune+ ThermoScientific Multi-Collector Inductively-Coupled-Plasma Mass Spectrometer (MC-ICP-MS) from the AETE-ISO platform (OSU OREME) from the University of Montpellier. Total chemistry blanks were less than 20pg and thus negligible for this study. The samples were alternatively run with international NBS 987 standards using a sample-standard-bracketing measurement protocol wherein standards were run every 3 unknowns. The ^{88}Sr beam intensity for all standards and samples ranges from 8V to 15V.$^{87}Sr/^{86}Sr$ isotopic ratios were internally normalized from the instrumental bias using a value of 0.1194 for the $^{86}Sr/^{88}Sr$ ratio. Then the corrected ratios were normalized to the NBS 987 standards, which gave a mean value of 0.710245 with a reproducibility of ± 0.000004 (2□, n = 8) during the course of this study. Samples of present-day leaves were crushed using a pestle and mortar, and weighed into pre-cleaned pressure vessels in a clean laboratory environment. They were dissolved in Teflon distilled nitric acid (8M HNO_3) overnight at room temperature. Additional nitric acid and a trace of H_2O_2 were then added, before the samples were processed in a microwave oven at 175 °C for 20 min. The samples obtained were dried overnight on a hotplate prior to a secondary oxidation step involving the repetition of the entire process. To convert the samples to chloride, 6M HCl was added, the sample was dried and a further 2M HNO_3 was added prior to strontium separation using the same chemical procedure as that previously described for enamel samples. The strontium isotope composition was determined by MC-ICP-MS using the same equipment as that used with the enamel samples.

5. Results

The zooarchaeological study of equid remains allowed us to identify 310 bones and a minimum number of 46 individuals, most presenting caballine characteristics. The remains are distributed around the whole of the archaeological site, but concentrate especially in the southern sector Can Revella (Fig. 1).

5.1. Osteometric data

Withers height estimations revealed a notable diversity in equid sizes (Table 1) among complete individuals or isolated bones in partial anatomical connection. Most presented a withers height between 125 and 135 cm. Three specimens were between 110-122 cm and a further four specimens represented by isolated bones were around 140 cm. Only a single individual (CRV05-217) was taller than 143.5 cm (Fig. 3).

Figure 3

The shape index, calculated on radii, metacarpals, tibias and metatarsals (Fig. 3), revealed the existence of two groups: a more numerous very slender group (< 13.5) and a slender group (13-14). Only four individuals presented higher values in relation to their metacarpals (14.5-15, medium slender), in accordance with *Brauner's* metacarpal slenderness *index* (Fig. 4). We recorded a diversity of sizes –tall and less tall horses– in the very slender and slender groups. In general, for those individuals for which both metacarpals and metatarsals were present, the index of robustness was higher for metacarpals than for metatarsals (Table 1). In individuals represented by all skeletal elements (e.g. CR6 and CRII-811), we found no correlation between the greatest length and breadth of the different bones, which seems to be indicative of allometric growth differences (Table 1). The variability observed in the withers heights and the robustness of the individuals might reflect specific incidents in the development of the animals, such as castration. In the metacarpals attributed by sex (Fig. 4), both males and females present the same range of variability, and it would seem that there is no sexual differentiation in terms of the morphology.

Figure 4

In general, the morphological characteristics presented by the metacarpus and metatarsus are horse-like. But the classification of one specimen (CRV05-89) is unclear as its metacarpus presents mule-like morphological traits (Fig. 5) (Johnstone, 2004). The correlation between GL and SD of the metacarpus places this individual among the tallest and most robust specimens (Fig. 6). Note that the main group of horses is defined by lengths >200 cm and midshaft widths >28 cm. In contrast, some individuals, most notably CRII-811 and CRII-9, occupy an intermediate position between the group of horses and donkeys in Eisenmann's dataset. Despite their having horse-like osteological characteristics, we cannot rule out a hybrid origin. Only the male CR6 presents values that correspond closely to those of the donkey (Fig. 6) but their skeleton presents morphological caballine characteristics (severe wear of its dentition impedes the analysis of discriminant parameters). These characteristics oblige us to exclude him from the group of hybrids.

Figure 5

Figure 6

The comparative morphometry of the metacarpus (Fig. 7) reinforces the hypothesis of the presence of two clearly differentiated groups of equids at Can Roqueta. Among the smallest, the complete specimens CR6 (male) and CRII-811 (female) and the articulated limb of CRII-9, present measurements more similar to those of the donkey, albeit with different metacarpal dimensions (Fig. 7). The remaining specimens are all larger and more robust.

Figure 7

5.2. Mortality profiles and sex

The age of death of 46 individuals in Early Iron Age are estimate. The mortality profiles define clearly a selection of adult animals between the ages of 5 and 10 years. Only one individual – Torre Romeu CRTR-179 – was aged below this. On the basis of their deciduous dentition their age is between one and two and a half years, and, as such, was still a juvenile (Fig. 8).

Figure 8

Among the adults, about 48% died when they were older than 5 years. This means most of the equids found in Can Roqueta were old enough to have been tamed, saddled and mounted, and to have reached reproductive maturity and adult weight. As such they would have been used for several years before they died. In preserved skulls and mandibles male characteristics, that is, bulky canines are present (see Table 1, 2). All in all, our results point to a shortage of females, at least among the animals deposited as ABGs.

5.3. Pathologies

Several horses present visible wear marks in the second premolars (PM2) of the mandible and maxilla, at the point where the bit impacts in the mouth. According to dental wear studies in archaeological horses the presence of such features is indicative of the use of metal bits (Anthony and Brown, 1989; Brown and Anthony, 1998; Bendrey, 2007a). Individuals CRV16-15, CRV16-18, CRV05-79 (2), CRV16-31 and CRTR-179 show tooth wear in the shape of a step (Fig. 9). The heavy wear shown by individual CRV05-79 (2) (Fig. 10) may be due to poorly fitting bit , with the horse developing the habit of biting down on the bit (Cook and Strasser, 2003). This type of wear has also been recorded in horses of the Early Iron Age Iberian Peninsula (Soto de Medinilla: Liesau, 1998) and at the Buhen site in Egypt, dated from 1675 BC (Clutton-Brock, 1974). Furthermore, four iron snaffles were found inside the tombs at the necropolis of Can Piteu-Can Roqueta, dated from the Early Iron Age (Carlús et al., 2007; López-Cachero, 2014). The measurements of these snaffles correspond anatomically with the horse jaws documented at Can Roqueta (Albizuri, 2014).

Figure 9

Figure 10

A rubbing bit can damage the horse's soft tissue structures, resulting in mandibular periostitis on the surface of the diastema in the free space between the canines and the premolars (Bendrey, 2007a). Damage attributable to the bit includes the bone spurs observed in three Can Roqueta equids (complete mare CRII-811 – Fig. 11 – and individuals CR6 and CRII-223).

Figure 11

Osteophytes have been observed at the ends of the posterior or palmar face of some of the fore 1st phalanxs at the point of insertion of the flexor tendons. These pathological findings are related to trauma and other factors such as age (Bendrey, 2007b; Rooney, 1997; Thomas, 2017). The small lesions can also be attributed to stress of the tendons given the exertions associated with the traction of carts and/or ploughs (Fig. 12).

Figure 12

During load dragging, the horse's fore limbs are subjected to a greater force and pressure than the hind limbs. This was more so before the appearance of the plough head collar in the Middle Ages (Lignereux et al., 1998). However, the study of an isolated pathology can be misleading, since, for example, the exostoses may have an infectious or traumatic origin or may be associated with ageing. It is, therefore, important to have the complete skeletons from which a comprehensive study provides an accurate diagnosis. Indeed, the complete mare of Can Roqueta (CRII-811) presents a set of pathologies that can be related to dragging and carrying loads on the loins (Albizuri et al., 2010). The lesions observed include significant exostosis on the right scapular girdle and an obvious exostosis on the margin of the glenoid cavity (right proximal humerus is broken and so possible alterations in this area are not observable). This exostosis invades the path of the *circumflexa scapolae* artery on the neck of the scapula, near the shoulder joint surface (Fig. 13A). These pathological changes might be related to continuous effort. An example of similar pathologies was recorded on the scapulo-humeral joints of a 3rd century AD Roman horse, excavated in a pit of Bois Harlé (Oise) (Lepetz, 1990). These lesions were interpreted as resulting from the animal having been used for draught purposes, as they are characteristic and well documented in draught horses of the 19th and 20th centuries AD.

Figure 13

Individual CRII-811 also presents exostoses over the vertebral bodies and transverse process from the 11th thoracic to the 2nd lumbar vertebrae (Fig. 13B,C). In some cases, impingement of the supraspinous processes are observed with partial fusion of one process to the next ("kissing spines") (Albizuri et al., 2010). This pathology is related to the animal having been ridden bareback or with a soft saddle, according to the studies of Levine (Levine, 2005; Levine et al., 2000) on Scytho-Siberian horses dated from the 5th to the 3rd centuries BC. They might also be linked to the strain caused by the carrying of loads in saddle-bags, given the higher pathological incidence between the 10th thoracic and the 2nd lumbar vertebrae. These pathological features coincide with natural ageing processes, and are thought to be linked with draught, riding and load-carrying.

5.4. Geographic origin of equids at Can Roqueta

Table 2 summarizes the strontium isotope results obtained on both the archaeological samples and the present-day leaves. The strontium isotope ratios of the local baseline samples (dentine and leaves) range between 0.7093 and 0.7107. These values are in close agreement with those recorded in other samples of Pleistocene and Miocene sediments from other places (e.g. Evans et al., 2010; Scheeres et al., 2013; Valenzuela-Lamas et al., 2018; Voerkelius et al., 2010).

The archaeological enamel samples display a greater variability and range from 0.7103 to 0.7126 (Table 2 and Fig. 14). Three enamel samples – CR6, CRV09-285 (1) and CRII-223 (nd) – are consistent with the local strontium signature, whereas the other three (CRV09-294, CRV05-79 (2), CRV05-103) probably originate from another location. The only study mapping the bioavailable strontium in the central Catalan area (Valenzuela-Lamas et al., 2018) has registered values higher than 0.71101 on Middle Upper Palaeozoic sediments and Mesozoic metamorphic rocks, which occur about 15 km from the site, in both the Littoral mountain range and the pre-Littoral mountain range, which marks the limit of the Vallès-Penedès valley in which Can Roqueta lies. Sediments of this kind are also present in other areas of Catalonia, including Cap de Creus and the Pyrenees (180 km range), and further afield in the mountains near Béziers (Montagne Noire), in France (Fig. 2). Studies conducted in other geographical areas of Western Europe have also reported ranges between 0.71101 and 0.71300 on Middle Upper Palaeozoic sediments and Mesozoic metamorphic rocks (e.g. Evans et al., 2010; Scheeres et al., 2013; Voerkelius et al., 2010; Waterman et al., 2014).

Figure 14

6. Discussion

The results of the zooarchaeological study – age at death, predominance of males based on the skulls and mandibles recovered and the pathologies registered – suggest the selection of adult male equids for the purposes of riding and work, at least as far as the remains deposited in the silos and other excavated structures indicate. The pathologies recorded on mandibles and maxilla suggests that the equids were bitted and, probably, ridden. In the case of the complete mare specimen, CRII-811, there is the highly suggestive physical evidence on its back of her having been used for dragging loads.

The variability in the shape index values and the withers heights may reflect sexual dimorphism or even the presence of hybrids of different morphology. In the case of individuals whose gender could be determined, both males and females presented a similar range of withers height variability, although the tallest animals correspond to three males. However, some individuals (e.g. CRV05-89, Fig. 5) present hybrid morphological traits, suggesting that the size variability observed at Can Roqueta may reflect the presence of hybrids or notable diversity in its equine population. Alternatively, the differences might be attributed to the effects of castration and to the age at which this was performed, since if bone growth was complete (over the age of 4), castration would not influence any increase in bone robustness. This fact is critical in work animals (Johnstone, 2004). Castration is widely documented in Greco-Latin writings, and was used for the more effective management of animals, since it reduces aggression. However, the effects of castration on mules have not been extensively studied, though it seems that in young castrated animals today their bones maintain their graceful characteristics (Chuang, 2016). A further factor to consider in the osteometric variability present is the influence of putting the animals to work, since this is likely to have affected the development of certain skeletal areas in the working horses (Hanot et al., 2018).

The range of withers heights of the Can Roqueta equids (110-143.5 cm) agrees with that reported for the Iron Age Celtic horses (c. 110 cm to 140 cm) of the Iberian Peninsula and Western Europe (e.g. horses of Manching) (Altuna and Mariezkurrena, 2010; Liesau, 2005; Quesada, 2004). Specimens from France dated from the Bronze Age and the Early La Tène have an average withers height of around 130 cm, and evidence of a wider range is only found from the 3rd c. BC onwards (Arbogast et al., 2002). The variability in the withers heights at Can Roqueta may reflect the diversity of geographical origin of the equids, especially if we consider that Chalcolithic and Bronze Age equids in the Iberian Peninsula had withers heights around 130-145 cm (Legge, 1994; Liesau, 2005; Morales, 1992). However, the presence of hybrids and donkeys among the remains identified as horses cannot be fully ruled out given the difficulties involved in equid species identification. Indeed, from the Early Iron Age onwards, small equids appear in the archaeological record of the Iberian Peninsula, which coincides in time with the presence of Phoenician materials from the Mediterranean (Albizuri et al., 2016b). This is also the case at Can Roqueta, where Phoenician materials have been recovered from silos and from two incineration tombs in the Can Piteu sector (Carlús et al., 2007).

The low incidence of females and juveniles seems to be inconsistent with on-site equid breeding, but it might equally reflect an archaeological bias due to the nature of the deposits or poor taphonomic preservation. The individuals that we could sex correspond to six adult males and two adult females, but not to any juveniles, figures that do not coincide with what we would expect from a typical stud farm, even if the males had been castrated. In the Iberian Peninsula at present, a proportion of one stallion for every 5 to 10 mares (without counting the offspring) is the norm in semi-feral herds (Spanish Ministry of Agriculture of Spain, 2003).

The results of the strontium isotope analysis suggest the presence of two distinct geographical origins for the six individuals sampled, although seasonal movements cannot be ruled out here. Three of the individuals present strontium signatures that are compatible with the geological layer on which the site is located – 0.7102-0.7103: individuals CR6, CRV09-285 (1) and CRII-223 (nd). However, the wide extension of Cenozoic sediments in the Iberian Peninsula and neighbouring areas does not allow us to determine, on the sole basis of the strontium values, whether these three samples were raised on the site or somewhere else with similar strontium ratios. Conversely, three individuals (CRV09-294, CRV05-79 (2) and CRV05-103) present higher strontium values (0.7111-0.7126). Based on the local bioavailable strontium sampling as well as on other values drawn from the literature (Scheeres et al*.,* 2013; Valenzuela-Lamas et al*.,* 2018; Voerkelius et al*.,* 2010), these strontium ratios correspond with those detected in relation to Triassic sediments. Within a 200-km radius of the site, Triassic sediments are present in the nearby Collserola mountain as well as in the Montseny, Albera-Serra de Rodes, and the Montagne Noire in France (Fig. 2).

The teeth were all sampled close to the enamel-root junction, so the strontium values reflect the latest period of enamel mineralisation (at around age 3, see Table 2). This means that three of the animals would have been grazing somewhere with Triassic sediments when they were about 3 years old. As stated above, seasonal movement between different geological areas during the period of enamel mineralisation cannot be fully ruled out, as we only have one sample per tooth. However, a more plausible explanation is that (at least some of) the equids of Can Roqueta were acquired as a final product, i.e. older than 3 years old and when they were old enough to be trained for riding and work.

The archaeological evidence suggests that the territory comprising the whole of the Vallés area as well as the immediate coastal zone were integrated within the same cultural entity (López-Cachero, 2014; López-Cachero & Rovira, 2012). These communities would have exploited the rich variety of resources in the surrounding mountains, suggesting that the equids may have originated from the local area and its surroundings. However, other more distant origins (e.g. the Pyrenees or the Béziers area) cannot be ruled out. Contact with the Pyrenees is not well documented, there being evidence only of temporary cave occupations and the presence of some incineration necropolises. Within the Pyrenees, the most likely areas of origin would be the plain of La Cerdanya or the mountainous area between the Albera range and the Serra de Rodes (Fig. 2). The latter, moreover, lies very close to the Empordà, which was an active trading area during Protohistory a time when the Greek colony of *Emporion* – and earlier settlements on this site – was one of the main trading points during the Iron Age in this area (Fig. 2). The similarity of the metallic objects recovered at the necropolis of Vilanera (Empordà) and those of the necropolis of Can Piteu-Can Roqueta (Fig. 1) suggest the existence of trade –or at least of some influence– between these two areas. The specific elements that support this claim are the similarities between the iron knives and certain types of fibulae found at both sites, in particular those with a *serpentiform* (López-Cachero and Rovira, 2012; Rovira and López-Cachero, 2016). Some morphotypes of metal objects (i.e. knives, horse bits, fibulas and needles) similar to those found in Can Piteu-Can Roqueta have also been recovered in some incineration necropolises in south-eastern France, especially in those lying close to the Montagne Noire. This is the specific case of the necropolis of Grand Bassin in Mailhac, and of the three necropolises of Castres and Le Peyrou in Agde (Rovira and López-Cachero, 2016). Additionally, the lead isotope analyses performed on some bronze objects from the necropolis of Can Piteu-Can Roqueta (i.e. a Mialhacian arrowhead, and a double-spring fibula) (Rovira et al., 2008, Rovira and López-Cachero, 2016) show the probable use of copper ores from the area of Les Cévennes – located in the area adjacent to the Montagne Noire –.

Consequently, the ensemble of information – archaeology, zooarchaeology, Sr geochemical data – points to the complex management of Can Roqueta's horse population. The combination of isotope data from six individuals and the archaeological finds suggests that (at least) some of the equids from Can Roqueta could have been introduced to the site having already been tamed and trained, perhaps from the Empordà or south-eastern France. Local breeding in neighbouring mountain areas cannot completely be ruled out, but the lack of juvenile and foetal remains and the low percentage of females greatly weaken this hypothesis. Indeed, there is evidence of the exchange of horses in Europe during the Iron Age (Bendrey et al. 2009; Gerling, 2015; Nuviala et al., 2014). Regardless of the role or roles attributed to horses in Early Iron Age societies in Iberia and Europe, equid deposits documented at the site and snaffle bits documented in the necropolis of Can Piteu-Can Roqueta suggest the emergence of people of differentiated status associated with the use of horses (Albizuri et al., 2016a). From the late 7th c. BC, and especially during the 6th c. BC, the progressive appearance of weapons in the necropolises of the north-eastern Iberian Peninsula and southern France suggests that the material related to equid riding, as well as the greater presence of horses in the faunal record, reflects the consolidation of a warrior elite in these societies (Gailledrat, 2015; Graells, 2013; López Cachero and Rovira, 2012). Further studies will be able to expand the number of samples so that we can address the question of the provisioning and mobility of horses in greater depth. Moreover, studies examining the diet together with DNA analyses are currently underway.

7. Conclusion

Can Roqueta (Barcelona) has an unusual concentration of equid remains dated from the Late Bronze and the Early Iron Ages. The results of the zooarchaeological study conducted here reveal that most of the equids recovered were horses; however, the classification of one specimen (CRV05-89) is unclear since the morphology of the metacarpus presents mule-like characteristics. The equids were mainly adult males, and most individuals presented pathologies related to the use of metal bits and of having been put to work. The lack of foetal and juvenile remains, together with the low percentage of female remains, suggests that the animals may have been brought to the site, rather than that Can Roqueta acted as a centre for horse production. The pilot study reported here in which the strontium isotopes of six equids were analysed indicates that some of them (at least) could have been brought to the site once tamed and trained (i.e. after they were 3 years old). Previous studies on the site's metallic items (iron knives and fibulae) have attested to the existence of contacts between the Vallès area, the Empordà, and south-eastern France (Béziers area). Indeed, an analysis of the lead isotopes of these items from Can Roqueta confirmed that copper ores from south-eastern France were used in their fabrication. Likewise, animals may also have originated from the Empordà or from south-eastern France, although local breeding in the neighbouring hinterland cannot be completely ruled out.

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Figure-Table captions

FIGURES:

Figure 1. Location of the site. Archaeological sectors of Can Roqueta.

Figure 2. Site location (star) and sampling locations of modern tree leaves and archaeological bones used to assess the bioavailable strontium of the geological formations surrounding the site. The site is on a Miocene plateau surrounded by Pliocene and Pleistocene sediments.

Figure 3. Shoulder height ratio expressed as shape index: radii (red), metatarsal (blue), tibia (green). SH and SI average is calculated for individuals with more than two data (yellow).

Figure 4. Shoulder height ratio expressed as shape index: metacarpal.

Figure 5. CRV05-89: metacarpal. Details of distal morphology (palmar view).

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Figure 7. Logarithmic differences of the metacarpal measurements in horses and asses (Onager – *Equus Hemionus* – is used as a standard, where shoulder height is calculated at a metacarpal of 115.8 cm). The shoulder heights for each specimen were calculated in the metacarpals. Data of Onager, donkeys – *E. asinus*, Przewalskii, Island pony and Steblev's horse K6 (Kiev, 5th century BC) are extracted from Eisenmann's dataset.

GL: maximum length, SD: smallest midshaft width, D SD: thickness of the midshaft, Bp: maximum width of the proximal joint surface, Dp: maximum thickness of the proximal joint surface, Bd-10: maximum width of the surface distal joint on the trochlea, Bd-11: maximum width of the distal joint surface in the trochlea.

Figure 8. Mortality profiles.

Figure 9. CRV16-31: concave abrasion in anterior surface of both upper PM2. Occlusal view (left), labial surface (right).

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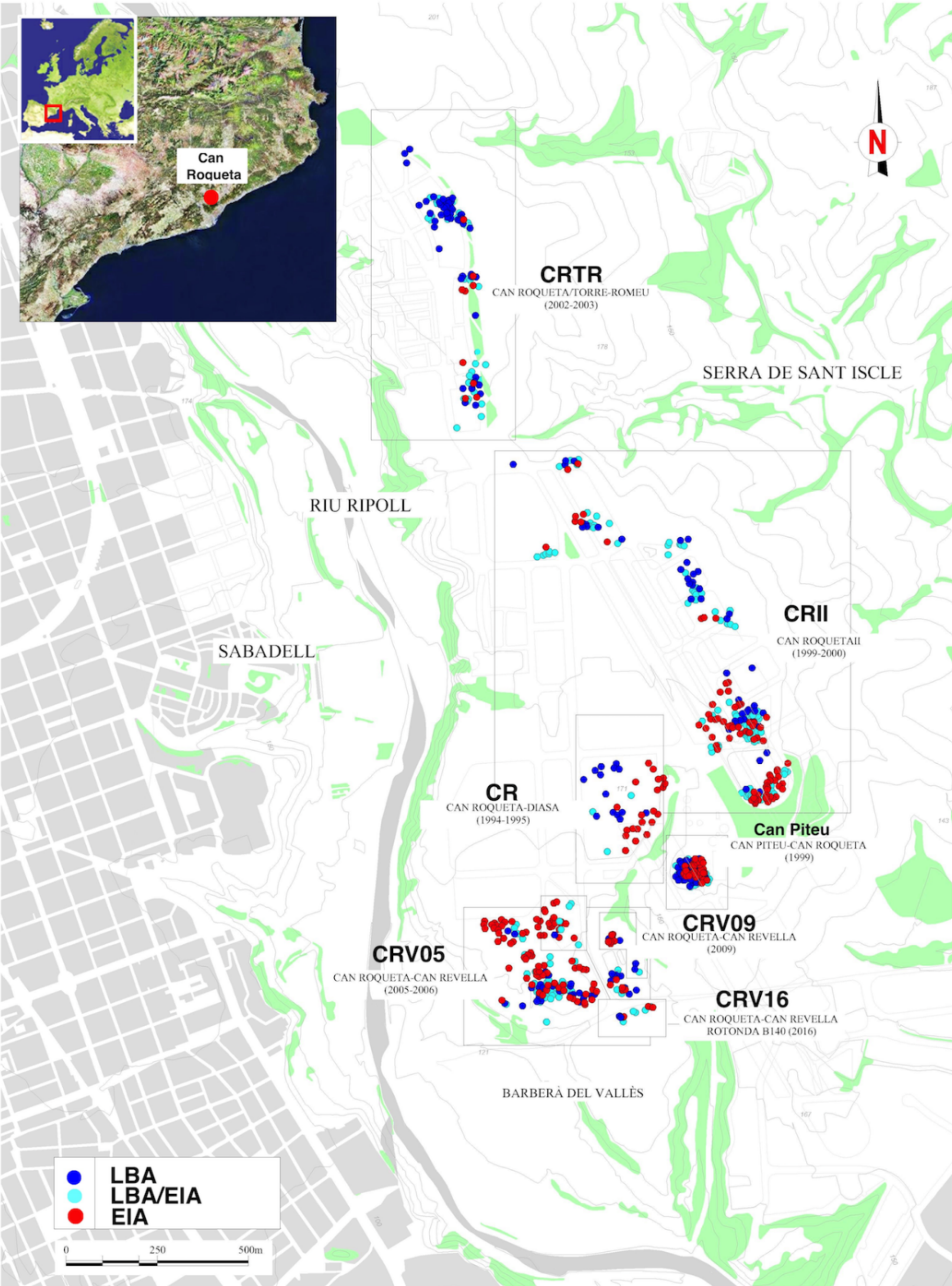

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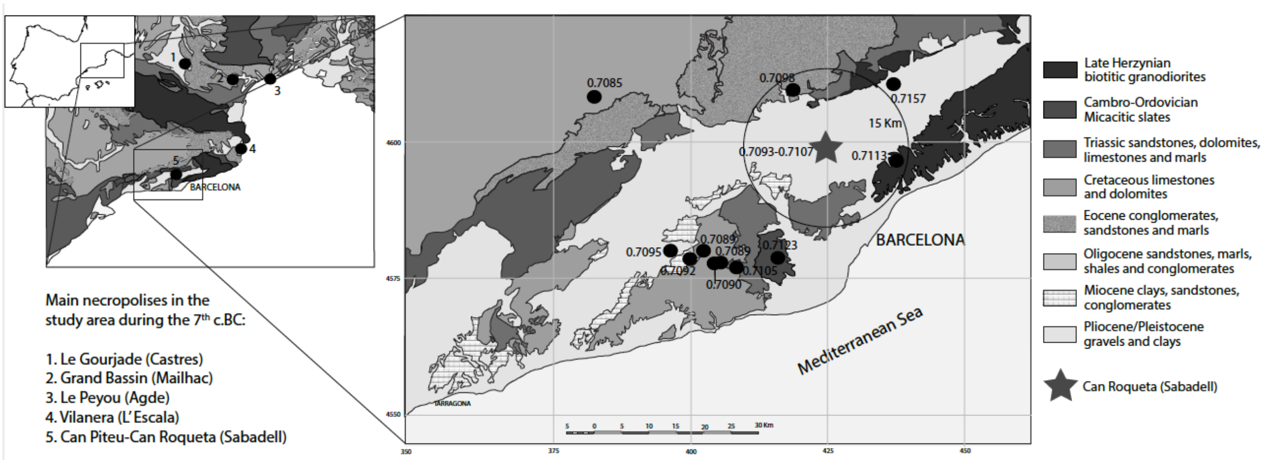

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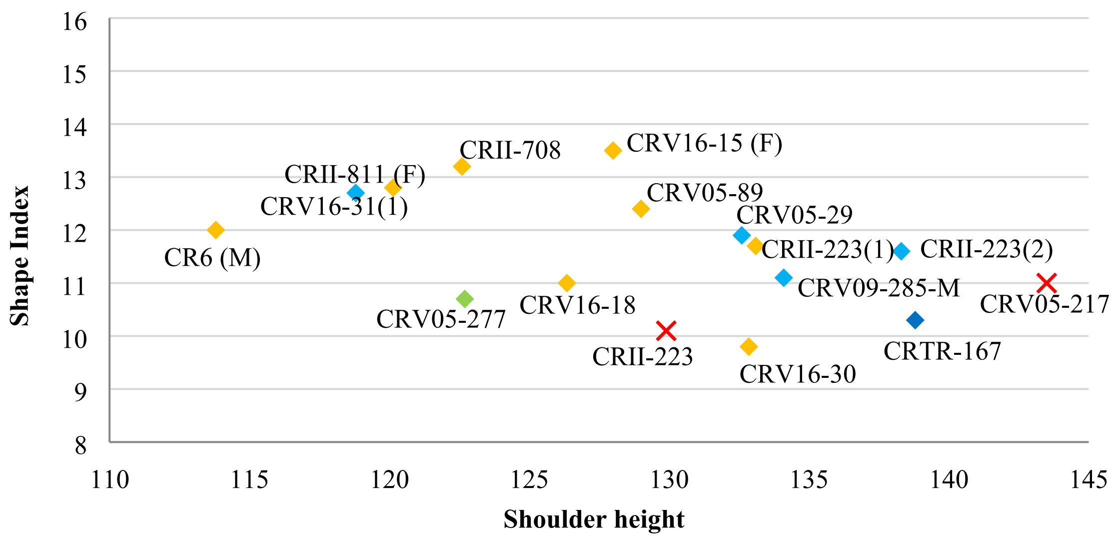

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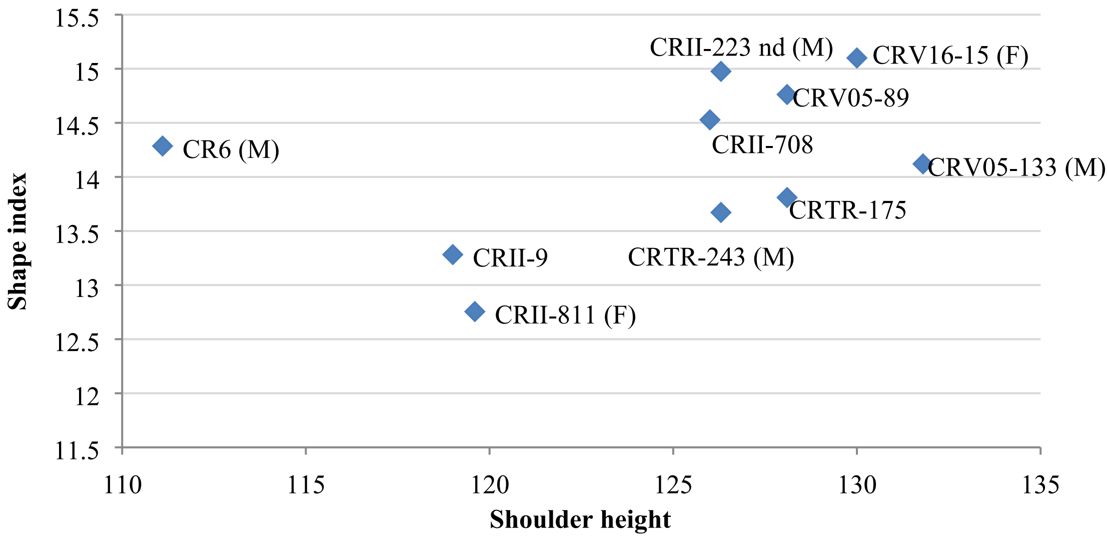

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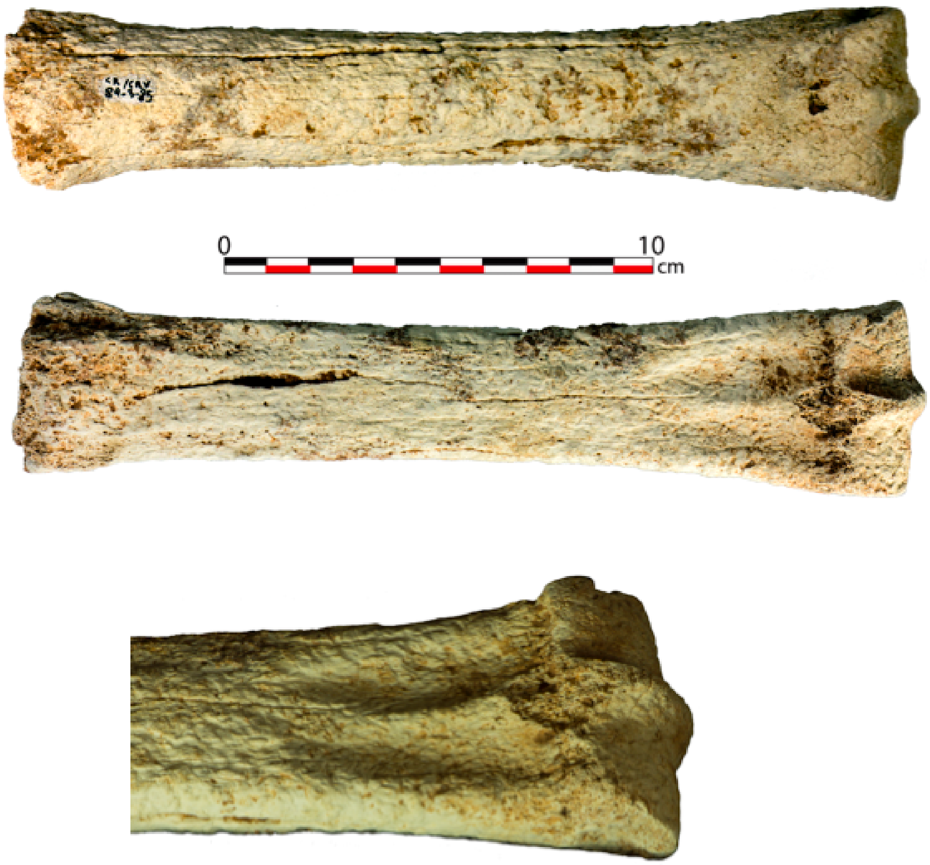

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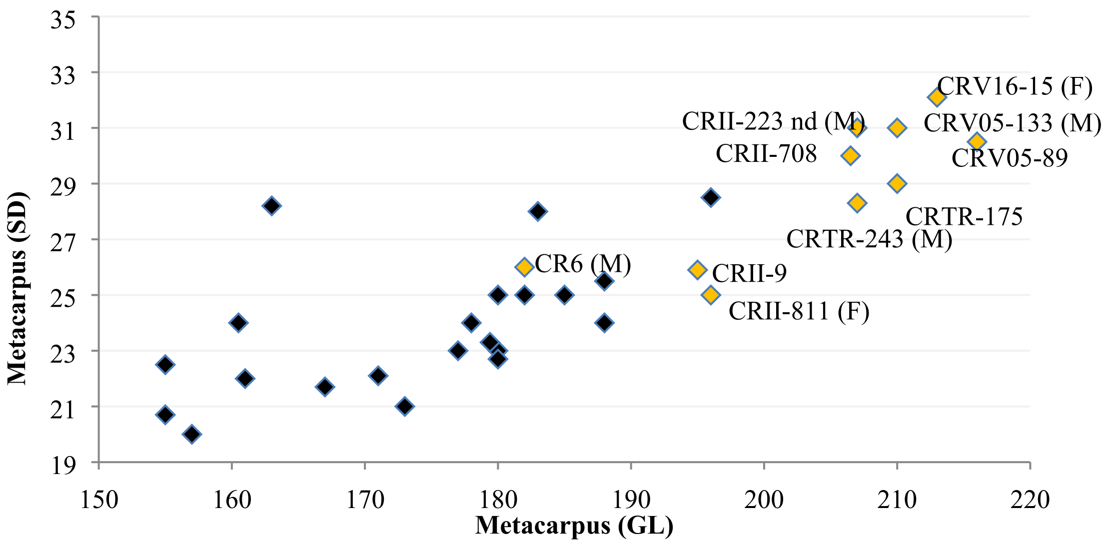

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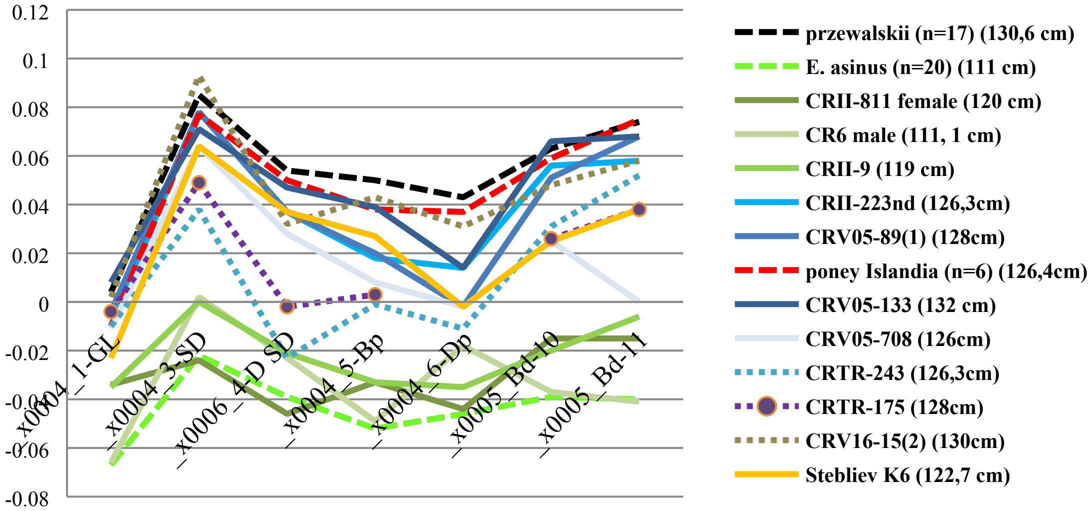

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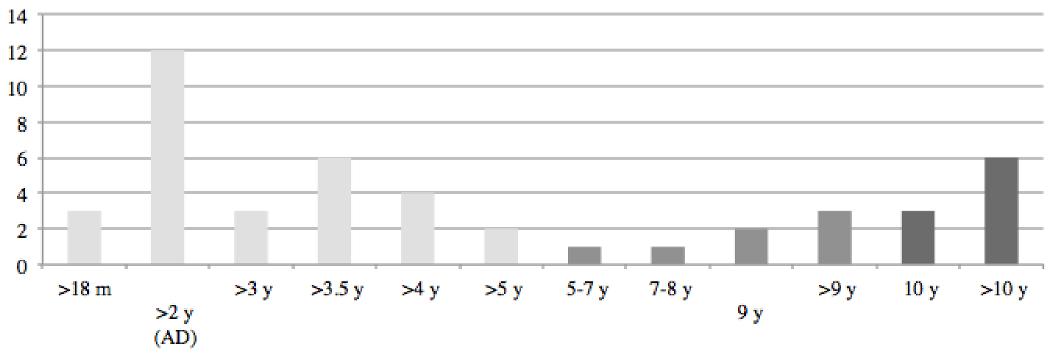

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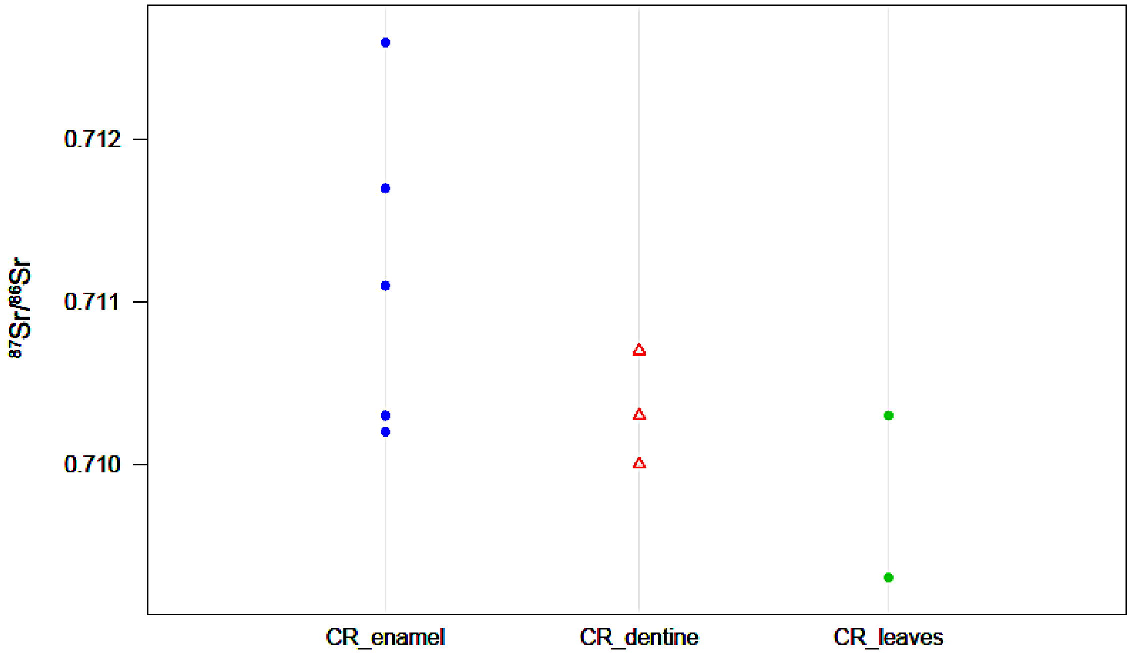

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Individual	Period	Radiocarbon date BP	Sex (skull)	GL/SH Radius	GL/SH Metacarpal	GL/SH Femur	GL/SH Tibia	GL/SH Metatarsal	SH average	SI (Radius)	SI (MC)	SI (Tibia)	SI (MT)
CRV05-217	EIA			(349)143,5					143,5	11			
CRTR-167	LBA/EIA							(265)138,8	138,8				10,3
CRII-223(2)	EIA	2505+40 2540+30						(264)138,3	138,3				11,6
CRV09-285(2)	EIA	2510+/-30	M					(256)134,1	134,1				11,1
CRII-223 nd	EIA	2505+40 2540+30	M				(340)134,2		134,2			11,5	
CRV16-30	EIA	2450+/-30		(315)129,5			(345)136,2		**132,85**	9,8		9,7	
CRV16-29	EIA	2480+/-30						(253)132,6	132,6				11,9
CRII-223(1)	EIA	2505+40 2540+30						(252)132	132				11,8
CRV05-133	EIA		M		(216)131,8				131,8		14,1		
CRII-223 nd	EIA	2505+40 2540+30		(316)129,9					129,9	10,1			
CRV05-89	EIA			(317)130,3	(210)128,1				**129**	10	14,8		
CRTR-175	IB	2390+/-30			(210)128,1				128,1		13,8		
CRV16-15	EIA	2430+/-30	F		(213)130			(240)125,7	**128**		15,1		11,8
CRII-223 nd	EIA	2505+40 2540+30			(207)126,3				126,3		15		
CRTR-243	EIA	2470+/-30	M		(207)126,3				126,3		13,7		
CRV16-18	EIA	2410+/-30	M	(306)125,7			(322)127		**126,35**	11		11,1	
CRV09-277	EIA						(311)122,7		122,7			10,7	
CRII-708	EIA	2500+/-		(290)119,2	(206,5)126				**122,6**	11,9	14,5		
Complete CRII- 811	EIA		F	(294)120,9	(196)119,6	(328)114,8	(310)122,3	(235)123,1	**120,14**	10,5	12,8	10,5	10,6
CRII-9	EIA				(195)119				119		13,3		
CRV16-31(1)	EIA	2530+/-30						(227)118,8	118,8				12,7
Complete CR6	EIA	2470+/-30	M	(281)115,5	(182)111,1	(310)108,5	(300)118,4	(220)115,3	**113,76**	11	14,3		10,8

Table 1. Horse's osteometric data. GL: greatest length in mm, SH: shoulder height in cm and in bold the results obtained from various measures in articulated individuals, SI: shape index.

Period: Late Bronze Age-Early Iron Age (LBA-EIA), Early Iron Age (EIA) and Iberian Culture (IB).

Structure	Radiocarbon date BP	95.4% probability	COD LAB	Sample	Type	87Sr/86Sr	2std dev	Age M	Age D
CR6	2470+/-30	768BC (92.4%) 476BC	Beta 449094	Pm3 inf.	enamel	0.710253	0.000007	14-36 m	10-13 y (male)
CRV09-294	2480+/-30	774BC (94.9%) 482BC	Beta 423328	Pm3 inf.	enamel	0.712636	0.000007	14-36 m	>5 y
CRV09-285(1)	2510+/-30	790BC (27.7%) 701BC & 696BC (67.7%) 540BC	Beta 463865	Pm3 sup.	enamel	0.711099	0.000008	14-36 m	7-8 y (male)
CRV05-79(2)	2590+/-30	820BC (92.7%) 754BC	Beta 423330	Pm3 sup.	enamel	0.710341	0.000005	14-36 m	10 y (male)
CRV05-103	2460+/-30	758BC (29.5%) 678BC & 672BC (65.9%) 428BC	Beta 423329	I2 inf.	enamel	0.711747	0.000005		7 y (male)
CRII-223(0)	2540+/-30	799BC (44.4%) 736BC, 688BC (12.2%), 662BC & 647BC (38.9%), 547BC	Beta 423331	I2 inf.	enamel	0.710218	0.000007		10 y (male)
CR6	2470+/-30		Beta 449094	Pm3 inf.	dentine	0.710049	0.000003		
CRV09-294	2480+/-30		Beta 423328	Pm3 inf.	dentine	0.710735	0.000006		
CRV09-285(1)	2510+/-30		Beta 463865	Pm3 sup.	dentine	0.710295	0.000005		
	2016				oak leaf	*0.709291*	*0.000007*		
	2016				oak leaf	0.710347	0.000003		

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