Muge Mesolithic heterogeneity: comparing Moita do Sebastião and Cabeço da Arruda

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Abstract Two Portuguese Mesolithic sites, Moita do Sebastião and Cabeço da Arruda, show osteological differences. Stable isotopes and radiocarbon dates suggest that each site may have two levels (as seems clear also for a third neighbouring site, Cabeço da Amoreira), but the individuals analyzed for this paper are in each case from the lower level. While it is possible that the Arruda sample is slightly later in time than the Moita sample, this cannot be proved on present evidence. Evidence for genetic differentiation is slight, but there is clear evidence of fertility, dietary and activity differences, based on age structure of the samples, on adult dentitions, on stable isotopes, on femoral shaft morphology and on bone cortex characteristics.

Keywords Muge, Mesolithic, stable isotopes, Arruda, Moita, cortical bone, dental pathology.

In 1984, I examined material from Moita do Sebastião held in the Museu Geológico, Lisbon and in 1985 and 1986, I looked at the Cabeço da Arruda burials also in the Museu Geológico. There were early indications that the two sites might show osteological differences, and heterogeneity in Mesolithic Portugal has been a fairly consistent finding in my work. One might expect the two sites to be almost identical, since they are closely situated on two sides of a minor tributary of the Tagus River, but in the small sample of bones that have been analyzed for stable isotopes, there is a clear differentiation (Figure 1; see also Lubell *et al.* 1994, Meiklejohn *et al.* 2009). Five Moita samples cluster tightly within the 40 to 50% marine dietary component range (calculated for a $\delta^{13}C$ range of -21.7 to -10.1). In contrast, the Arruda sample is spread over a range from just under 25% to close to 40%, significantly different from Moita. One individual from Moita (Moita CT: 6810±70 BP, TO-135) and one from Arruda (Arruda N: 6360±80, TO-356), both later in time by several hundred years (Figure 1), have a 55% marine component. In each of these two cases, the matrix adhering to the skeletons is different – a muddy black sediment rather than the usual pale, more cemented, sand and shell breccia. Since it is clear that there may be subsamples within the burials from the two sites, it is important to demonstrate that the samples used in our comparisons of the sites are in fact representative of comparable situations. It must be established that neither sample is mixed in terms of time and sediment.

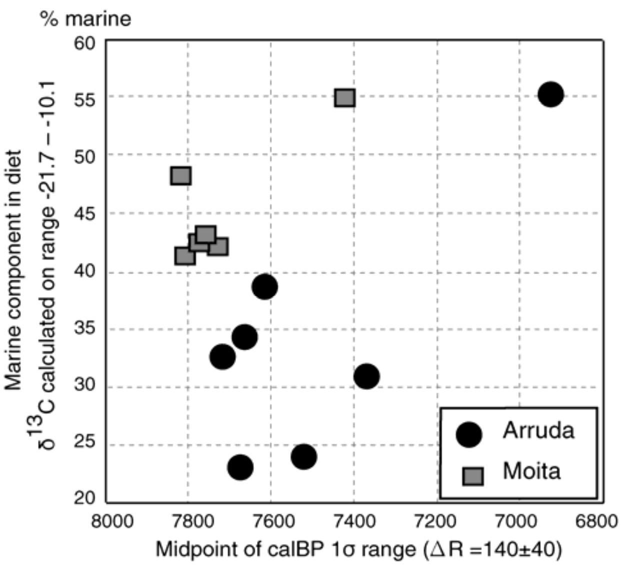

Figure 1: Estimated marine component of diets for dated Moita and Arruda burials.

I will not include in the analyses discussed below a third site from the same valley: the sample is smaller, only three have been dated (Meiklejohn et al. 2009), and many of the excavated pieces have been lost or are mislaid (Roksandic and Jackes n.d.; Jackes *et al*. n.d.a). However, it is important to make a particular point about the Cabeço da Amoreira human material. Many of the Amoreira skeletons have a muddy black sediment adhering and were described by the excavators as being from "the black layer". A few of the Amoreira skeletons are from deep burials into the underlying sands, with the breccia characteristic of the burials at Moita and Arruda. Thus, although the burial practices may be similar throughout, the Amoreira skeletons appear to be from two different levels, the basal level dating to around 7800-7900 cal BP and the darker higher level dating to around 7400-7500 cal BP. Since we seem to have two slightly different Amoreira subsamples, we must be aware that there could be differences through time in each Muge site, perhaps dietary differences, as suggested above for Moita and Arruda, both of which have later skeletons with higher marine components as indicated by $\delta^{13}C$ values. The picture at Amoreira is not yet clearly delineated. It appears that the later period has very variable dietary regimes, since one individual, at ~20% marine, is the most terrestrial of any Muge dietary estimates so far (6550±70, TO-10225 $\delta^{13}C$ = -19.3; see Jackes *et al.* n.d.a), compared to ~45% for the others.

We can judge that the Moita skeletons generally date to around 7800 cal BP, with a very few later burials at 7400 cal BP. The Arruda range appears to be a little later, just under 7000 cal BP for the younger level, with the older level ending about 7400 cal BP. We now have a good well-provenanced earliest date for the older Arruda level (7070±40, Beta – 152956, 7826-7971 cal BP). This date derives from a dog buried at the deepest level of the 1880 excavations within the concentration of human skeletons (i.e., not the location reported by Detry and Cardoso 2010).

Moita bones were apparently excavated from one level (Jackes and Alvim 2006), according to a plot from the 1880s showing the location of the skeletons. A derived Moita diagram from the 1950s suggests that the skeletons found in 20th century excavations were in the same level as those excavated in the 19th century (the higher levels having been bulldozed away). We have a firm date (7120±40, Beta-127449) of just under 7800 cal BP (adjusted ΔR =140± 40, $\delta^{13}C$ = -16.8) for the Moita burial level from which virtually the entire sample derives. A posthumous paper of Paula e Oliveira (1889, 67) mentions "*une terre noire*" at Moita, but notes that this is an exceptional deposit, similar to the surface zone, and furthermore containing pottery fragments at just over 50cm depth. Pottery also appeared at Amoreira, but "black earth" was not an exceptional deposit at Amoreira, at least not in that portion of the site dug in the 1930s and 1960s.

It is very difficult to recreate the Arruda excavations: most excavations were along the side of the mound that was washed by seven severe floods in the first half of the 20th century alone (Azevêdo *et al.* 2004). The 1880 excavation can be pinpointed as being to the southeast (see Jackes and Meiklejohn 2004, 96) of those from the 1930s and the 1960s. Perhaps the 1863 excavation was in the region of the 20th century trenches (Jackes *et al.* n.d.b). "Almost all" 1863 burials lay within the deepest level (Pereira da Costa 1865, 13). All indications are that the 1880s burials, those from the 1930s, and those from the earlier Roche excavation were at that same deep level. However, the last Roche excavation was of burials from **four** metres higher. While photographs and transects from the 1880 excavation show one or two burials apparently at a higher level, the maximum difference between the highest and lowest is under 70cm: both are at least three metres below the surface (regarding archival material on Arruda, see Jackes and Meiklejohn 2004:96). Very few 1880s skeletons would be from the higher level dark sediment.

Samples for dating in the 1980s analyses were chosen to represent the entire range of enveloping sediments, particular attention being paid to variations at Moita (Lubell *et al.* 1994, 203) where no differences were found except in the date of the individual we called Moita CT (see above) which had a matrix of dark sediment with pebbles, little shell, no cementing and no calcium carbonate coating. Similarly, Arruda N (see above) was exceptional in having muddy black sediment inside the long bones. While Roche did find skeletons in Arruda upper level 5, material from his excavations is not included in the dental and bone analyses summarized below. Roche stated that the upper level skeletons were always in much worse condition than the lower burials (Roche 1974, 31), and since the 19th century literature states that fragmentary material was discarded (Paula e Oliviera 1889, 71), we can assume that the Lisbon collection retains very few upper level elements.

A preliminary study of dental morphology (Jackes *et al*. 2001) showed a surprising difference between Moita and Arruda based on non-metrical traits, but earlier studies had certainly not demonstrated genetic differentiation: these analyses were based on dental features alone and on dental and post-cranial non-metrical characters combined (Jackes *et al*. 1997a, 646; Jackes and Lubell 1999a, 63). Much more work needs to be done on this, since the number and character of traits analyzed, sample sizes, and especially the other samples used in such studies, have a strong effect on the results (our work on this is stalled by the disappearance of a number of dentitions from a comparative Neolithic collection). Similarly, studies of cranial metrics (Jackes and Lubell 1999a, 63; cf. Jackes et al. 1997b, 843) can suggest differing levels of similarity depending on the samples included within a study. A simple analysis provided a clearer result: we showed that lower second molar breadth was reducing in the Arruda sample compared with Moita (Jackes *et al.* 1997a, 648). We can confirm this with a test of 60 Moita and 69 Arruda molars ($Pt = 0.003$). We should note that it is the left molar which provides the significant difference ($Pt\ df\ 65 = 0.001$; equal variances), an asymmetry probably indicating environmental influences. Our explanation (Jackes *et al.* 1997a, 653) related to changing fertility rates, since a rise in the fertility level "might elicit non-genetic change" (*ibid.* 652) in tooth size.

There is, in fact, a marked difference between the two sites based on estimated total fertility rates (TFR). The method of TFR estimation provides very good results (tested in a number of papers, most recently Jackes 2011), but sample representation is of course an important consideration. While Arruda material from the 1860s is not included here (Jackes *et al*. n.d.b), eight individuals presumed to be from the basal sands 1964 excavation (Jackes and Meiklejohn 2004, 102), and now nine from the deeper levels of the 1937 Arruda excavation (in the Museu de História Natural, Porto), are added to the 1880s material for a new TFR estimation. The addition of the Porto material has increased the total fertility rate (TFR) for Arruda, the 95% CI from both estimators covering 6.2 to 7.9: the wide range arises from discrepancy between the two estimators which indicates an underrepresentation of adults. Nonetheless, previous estimates (Jackes and Meiklejohn 2008, 232) of higher fertility at Arruda (c. 6.5) than at Moita (c. 4.5) continue to be supported. The difference between the two sites is not trivial. The Moita TFR would be standard for a hunter-gatherer population with a very slow growth rate, whereas the Arruda estimate indicates an expanding population.

The dental, cranial and postcranial analyses discussed in this paper include only material from the 1880s excavations and the present condition of these materials dictates that the minimum number of individuals (MNI) for palaeodemographic work is best arrived at through seriation of the mandibles. My work focuses on mandibles for a variety of reasons (outlined most recently in Jackes 2011) to do with biases in terms of preservation and representation in samples, consistency of attrition and how it can be observed, the way in which tooth root morphology determines the teeth likely to be retained in the jaws after death. I focus on mandibular molars for analyses of attrition and pathology because teeth differ in the degree to which they are susceptible to carious lesions, abscessing, premortem and postmortem tooth loss.

This focused approach allows us to demonstrate that Moita attrition is stronger than that at Arruda, for example in M1/M2 relative attrition (Jackes and Lubell 1999a, 60). A more dramatic illustration of this is the fact that at Moita, 87.5% of first lower molars were already at wear stage 4 when M3 came into initial occlusion, whereas the figure is 44.4% at Arruda (Lubell *et al.* 1994, 209). Wear stage 4 is characterized by removal of fissures from the central crown and the presence of large discrete exposures of two or more areas of dentin. A complete adolescent skeleton from Moita shows us clearly that M1 wear can reach level 4 before M3 comes into occlusion. And, in fact, all individuals assessed at age 20-25 had level 4 first lower molar wear, with the three molars attrition levels recorded as 4-2-1. On the other hand, adolescents at Arruda had 2.5 M1 wear and all those aged 20-25 were assessed as 3-2-1 across the three molars. This difference between Moita and Arruda was independently confirmed by Meiklejohn: my collaboration with Meiklejohn involved completely independent analyses of the mandibles in order to control for inter-observer error.

Since the age distribution of the dead is key to any osteological analysis, the derivation of the MNI through seriation of mandibles was vital to our comparisons of dental pathology. Seriation allowed us to demonstrate that molar caries differed between the two sites when those over 15 years of age were distributed across attrition grades (Lubell and Jackes 1988; Jackes and Lubell 1996, 460). Meiklejohn recorded dentitions individually and his results show complete congruence with mine for caries and tooth loss across broad age classes. Moita had more pathology all through the various wear stages and the Moita older adults had very high levels of dental pathology.

I have recently used a different approach, a distribution of seriated mandibular molar sockets across ten groupings, each with a more or less equal number of sockets. This change of approach is to control for the possibility that attrition scoring had altered over time so that there could be intra-observer error. Again, the picture is the same, whether we examine caries, abscessing and pre-mortem tooth loss relative to the number of sockets in each of the ten groupings, or caries alone (see Jackes 2011, 131). The pathology rate is not just higher in Moita dentitions: Moita has pathology from late adolescence and pathology is very common in old age in Moita molars. Arruda does not have pathology within the first attrition groupings and it has less pathology than Moita in the oldest three groupings (for details on the differences see Jackes 2009).

We would expect an inverse relationship of caries with dental attrition, but at Moita caries is established very early, despite the attrition. The abscesses and tooth loss cannot be attributed to attrition alone – caries is obviously an important contributing factor. And there is a further paradoxical situation: Moita has a higher rate of occlusal caries than Arruda, whereas heavy attrition might be expected to reduce occlusal caries rates (see also Meiklejohn *et al.* 1992). Yet Moita has almost double the occlusal caries (Lubell *et al.* 1994, 212), a significant difference (P = 0.019).

The Moita pathology rate is not higher simply because there are more old people in the sample. In fact, it is likely that Arruda had relatively more older people: despite the heavy Moita attrition, Moita had more deaths at early wear stages (Lubell and Jackes 1988).

Examination of other characteristics of individuals seriated by mandibular molar wear can support the contention that the Arruda sample had more older people and for this we focused on bone cortex. The first test was based on Nordin's index of cortical bone thickness using femoral neck radiographs (for details see Jackes 1992). With sample sizes of 29 adult left femora for Moita and 39 for Arruda, the difference is significant at P*t* = 0.000 (equal variances). The difference between the two sites increases across the mandibular wear stages (Jackes and Lubell 1999b) and within the last five of 11 original attrition stages, the Nordin's index values for Arruda are lower than those of Moita for all but one exceptional specimen not included in Jackes and Lubell 1999b Figure 4: the excluded individual was Moita C for whom not all variables are available and because skull and post-cranial association can be uncertain (Jackes and Meiklejohn 2008, 223). Seriating mandibles, though only an approximation, does allow us to distribute age-related trends along an axis (age) for which accurate values could never be determined and the examination of femoral neck bone cortex demonstrates that at Arruda, femoral cortical bone is thinner, with the difference between the two sites increasing across adult ages. The site difference in cortical bone holds when male and female data are tested separately. The suggestion here is that Arruda individuals with severe attrition grades are older than Moita individuals, but the cortical bone difference is so extreme that it is very possible age alone does not explain it.

We can look also at midshaft cortical thickness in 38 Moita and 43 Arruda left femora, this time based on actual anterior shaft bone samples, rather than on radiographs. Note that the direct measurement is relative to the midshaft outer dimension. Adult midshaft cortical thickness (CT/DAP) is different between the two sites: P*t* = 0.000 (equal variances). Again it appears that Arruda cortex in general is thinner, increasingly into old age, in comparison with Moita (apart from the exceptional Moita C femur). Bone samples also allowed us to test anterior femoral midshaft cortical bone density. Bone density for archaeological material presents many problems (Jackes 1992:205), but we can note that cortical bone density displays a dramatic difference between the sites (Jackes and Lubell 1999b), indicating the greater density and mineralization of bone at Arruda. Within the Moita sample, studied also for cortical porosity, the youngest had low density and few resorption spaces and the individuals with the highest density had many resorption spaces and radiographic alteration of the femoral trabeculae indicating greater age (Palmer 1987, 77; Moita C not studiable). From this we can deduce that the Arruda sample contains many more older adults than Moita.

Could the differences in bone cortex relate to age distribution alone? The shape of adult mid-shaft femora is independent of age (based on Arruda wear levels), and we can test site differences for this by calculating the pilastric index of left femora (DAP*100/DML). This expresses the robusticity of the linea aspera. A rounded bone with a weak pilaster will have a low index value while a stronger triangular shape with a robust pilaster will be present as the index increases. While neither site is marked by strong robusticity, Arruda femora have a significantly lower pilastric index (n = 33, mean = 107.7 for Moita; n = 41, mean = 102.6 for Arruda: P*t* = 0.017; equal variances). This is a convincing difference indicating that there may have been different activity levels involved. It holds across the sexes – for adult left femora (equal variances) the male P*t* = 0.029 and for females P*t* = 0.038. It seems that Arruda femora were less strong under bending stress, suggesting lower activity levels. The suggestion was made that there might be a greater reliance on small mammals in the diet at Arruda than at Moita based on faunal evidence (Jackes and Lubell 1999b). However, this cannot be sustained on the basis of the limited samples we have for the deep layers in the two sites (Detry 2007): the conditions of recovery may make it impossible to interpret these data.

We can say then that greater numbers of people surviving into old age is one of the differences between Moita and Arruda, but that, in addition to more older people, it is likely Arruda individuals also had thinner cortical bone because of reduced activity levels. Vainionpää *et al.* (2007) suggest that the femur is much more altered by impact exercise than the tibia, and we see greater femoral than tibial (cnemic index) differences. They also propose that the greatest morphological differences will be found at the femoral midshaft, which accords with our finding that the pilastric index difference was greater than the platymeric index difference (Jackes and Lubell 1999b and Jackes *et al.* 1997a illustrate these points).

I have suggested in past papers that people were eating chenopods (e.g. Jackes and Meiklejohn 2008, 218) which contain oxalates. When foods have a high oxalic acid content and also a high salt content (as in halophytic chenopods), calcium absorption is reduced. Perhaps the changes in femoral cortex seen in Arruda femora are not just a result of reduced activity (implying increased sedentism), but also because there was a higher dependence on chenopods (as salt marshes spread up the Muge). Were chenopods substituting for something more cariogenic in the Moita diet at Arruda, with the Arruda sample spread over a wider timespan? We are in the process of testing for chenopod presence.

It does not appear that the dental pathology rate at Moita is higher just because it had more old people. In fact, to repeat, it is likely that Arruda had more older people, that the Arruda activity pattern differed somewhat from Moita, and that Arruda bone strength was reduced. I have suggested more sedentism. Sedentism would correlate with a higher fertility level and possibly a difference in diet, a more localized source of plant food and more emphasis on small mammals in the diet. Dietary difference is indicated by the δ^{13}C results, by differential dental attrition, by significantly different dental pathology and – in association with activity patterns – by bone cortex reduction. The suggestion is that the trends discerned here would be mediated by time.

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References

Azevêdo, T. M., Nunes E. and Ramos C. 2004. Some morphological aspects and hydrological characterization of the Tagus floods in the Santarém region, Portugal. *Natural Hazards* 31, 587-601.

Detry, C. 2007 *Paleoecologia e paleoeconomia do Baixo Tejo no Mesolítico final: o contributo do estudo dos mamíferos dos concheiros de Muge*. Unpublished PhD thesis, Universidade Autónoma de Lisboa.

Detry, C. and Cardoso, J.L. 2010. On some remains of dog (*Canis familiaris*) from the Mesolithic shell-middens of Muge, Portugal. *Journal of Archaeological Science* 37, 2762-2774.
Jackes, M. 1992. Paleodemography: problems and techniques, in S.R. Saunders and M.A. Katzenberg (eds.), *Skeletal Biology of Past Peoples: Research Methods*, 189-224. New York, Wiley-Liss.
Jackes, M. 2009. Teeth and the past in Portugal: pathology and the Mesolithic-Neolithic transition, in T. Koppe, G. Meyer and K.W. Alt (eds.), *Comparative Dental Morphology* Frontiers of Oral Biology 13,167-72. Basel, Karger.
Jackes, M. 2011. Representativeness and bias in archaeological skeletal samples, in S.C. Agarwal and B.A. Glencross (eds.), *Social Bioarchaeology,* 107 – 146. Blackwell Studies in Global Archaeology. Wiley-Blackwell.
Jackes, M. and Alvim, P. 2006. Reconstructing Moita do Sebastião, the first step. In J. Rolão (ed.), O Complexo Mesolítico de Muge: Passado, Presente et Futuro, in N. Bicho and N. Veríssimo (eds.), *Do Epipapelolítico ao Calcolítico na Península Ibérica*. Actas do IV Congresso de Arqueologia Peninsular, 13-25. Faro, University of Algarve Press.
Jackes, M. and Lubell, D. 1996. Dental pathology and diet: second thoughts. In M. Otte (ed.), *Nature et Culture: Actes du Colloque International de Liège*, 13-17 decembre 1993. Etudes et Recherches Archéologiques de L'Université de Liège, no 68, 457-480.
Jackes, M. and D. Lubell 1999a. Human skeletal biology and the Mesolithic-Neolithic transition in Portugal. In A. Thévenin (ed.), dir. scientifique P. Bintz, *Europe des derniers chasseurs Épipaléolithique et Mésolithique*: actes du 5e colloque international UISPP, commission XII, Grenoble, 18-23 septembre 1995. Paris: Éditions du CTHS, pp. 59-64
Jackes, M. and D. Lubell 1999b. Human biological variability in the Portuguese Mesolithic. *Arqueologia* 24: 25-42
Jackes, M. and Meiklejohn C. 2004. Building a method for the study of the Mesolithic-Neolithic transition in Portugal. In M. Budja (ed.), Neolithic Studies 11, *Documenta Praehistorica* 31, 89-111.
Jackes, M. and Meiklejohn C. 2008. The Paleodemography of central Portugal and the Mesolithic-Neolithic transition. In J.P. Bocquet-Appel (ed.), *Recent Advances in Paleodemography: Data, Techniques, Patterns*. 209-258. Dordrecht, Springer.
Jackes, M., Lubell, D. and Meiklejohn, C. 1997a. Healthy but mortal: human biology and the first farmers of Western Europe. *Antiquity* 71, 639-658.
Jackes, M., D. Lubell and C. Meiklejohn 1997b. On physical anthropological aspects of the Mesolithic-Neolithic transition in the Iberian Peninsula. *Current Anthropology* 38: 839-846
Jackes, M., Alvim, P. and Cunha, M. J. n.d.a Amoreira 1930 to 1933. This volume
Jackes, M., Lubell. D. and Cardoso, H. n.d.b Description and radiocarbon dating of the surviving human material from the 1860s excavation of Cabeço da Arruda.
Jackes, M., Silva, A.M. and Irish, J. 2001. Dental morphology: a valuable contribution to our understanding of prehistory. *Journal of Iberian Archaeology* 3, 97-119.
Lubell, D. and Jackes, M. 1988. Portuguese Mesolithic-Neolithic subsistence and settlement. *Rivista di Antropologia* (Supplemento) LXVI, 231-248.
Lubell, D., Jackes, M., Schwarcz, H., Knyf, M. and Meiklejohn C.1994. The Mesolithic-Neolithic transition in Portugal: Isotopic and dental evidence of diet. *Journal of Archaeological Science* 21, 201-216
Meiklejohn, C., Wyman J. M. and Schentag C. T. 1992. Caries and attrition: Dependent or independent variables? *International Journal of Anthropology* 7, 17-22.
Meiklejohn , C., Roksandic, M., Jackes, M. and D. Lubell 2009. Radiocarbon dating of Mesolithic human remains in Portugal Mesolithic Miscellany 20(1):4-16.
Palmer, E.M. 1987. *Micromorphology of Prehistoric Human Bone from the Mesolithic Site of Moita do Sebastião*. Unpublished MA thesis, University of Alberta.
Paula e Oliveira, F. de 1889. Nouvelles fouilles faites dans les kjoekkenmoeddings de la Vallée du Tage. *Comunicações da da Comissão do Trabalhos Geológicos* 2, 57-81.
Pereira da Costa, F. A. 1865. *Da Existência do Homem em Epochas Remotas no Valle do Tejo, Primero opusculo. Notícia sobre os esqueletos humanos descobertos no Cabeço da Arruda* Comissão Geológica de Portugal Lisboa, Imprensa Nacional.
Reimer, P.J., Baillie, M.G.L., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Burr, G.S., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Hajdas, I., Heaton, T.J., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., McCormac, F.G., Manning, S.W., Reimer, R.W., Richards, D.A., Southon, J.R., Talamo, S., Turney, C.S.M., van der Plicht, J.and Weyhenmeyer, C.E. 2009. IntCal09 and Marine09 radiocarbon age calibration curves, 0–50,000 years cal BP. *Radiocarbon* 51,1111–1150.
Roche J. 1974. Sépultures de l'amas coquillier mésolithique de Cabeço da Arruda (Muge). In *Actas do 3° Congresso nacional de Arqueologia, Porto 1973*, 25-36. Lisboa, Junta Nacional de Educação.
Roksandic, M. and Jackes, M. n.d. The skeletal assemblage and burial ritual at the site of Cabeço da Amoreira: the 1960s excavations by Veiga Fereira and Roche, in M. Roksandic, S. Mendonça, S. Eggers, M. Burchell and D. Klokler, (eds.), *The Cultural Dynamics of Shell Middens and Shell Mounds: a worldwide perspective*. Albuquerque, University of New Mexico Press.

Vainionpää, A., Korpelainen, R., Sievänen, H., Vihriälä, E., Leppäluoto, J. and Jämsä, T. 2007. Effect of impact exercise and its intensity on bone geometry at weight-bearing tibia and femur *Bone* 40, 604-611.