Separata da Revista Arqueologia
Número 24
Porto 1999

HUMAN BIOLOGICAL VARIABILITY IN THE PORTUGUESE MESOLITHIC*

by

Mary Jackes & David Lubell**

Summary: What we have, then, is an indication that the Arruda people, and especially the Arruda females, were doing something different from those at Moita. The Arruda females were engaged in some activity which put particular pressure on their tibiae, different from that of both Moita females and Arruda males. Furthermore, it is very likely that stresses on the lower limb in Arruda females were actually lowered in comparison with Moita females, considering the evidence of reduced bone density and cortical thickness in Arruda female femora (Figures 1c & 2c). While we have not demonstrated a statistically significant difference in external size and shape between Moita and Arruda female femora, there is evidence that Moita and Arruda males differed in mid-femoral shaft form, suggesting that Arruda femora were probably subject to reduced bending stress. Furthermore, Arruda males were significantly more varied than Moita males in femoral mid-shaft morphology.

Key-words: Portuguese Mesolithic; Moita do Sebastião; Cabeço da Arruda.

Moita do Sebastião and Cabeço da Arruda (hereafter, Moita and Arruda) are the classic Mesolithic shell middens on the Muge tributary of the Tagus River in central Portugal. They lie on the same terrace, only 3 km apart, and overlap in the radiocarbon dates indicates at least partial contemporaneity (Lubell, *et al.* 1994). Human skeletal collections indicate the minimum number of individuals present is 79 for Moita and 97 for Arruda.

Our analyses provide no indication that these two skeletal samples represent different gene pools (Jackes, *et al.* 1997a, 1997b; Jackes & Lubell, 1999). Furthermore, given documented similarities in burial patterns as well as faunal and artifact assemblages, we

---

* This paper was originally prepared for the symposium "Beyond The Lithics: Mesolithic People in Europe", Society for American Archaeology, Annual Meeting, Seattle, March 1998. Funding for our research in Portugal was provided by the Social Sciences and Humanities Research Council of Canada and the University of Alberta. We are grateful to Dr. M. M. Ramalho, formerly Director of the Serviços Geológicos de Portugal, Lisboa, for permission to study the materials in his care, and to Dr. Eugénia Cunha, Instituto de Antropologia, Universidade de Coimbra, for facilitating the publication of this paper in Portugal.

** Department of Anthropology, University of Alberta, Edmonton, Alberta T6G 2H4, Canada.

were predisposed to expect congruity in the biological characteristics of the human remains from Moita and Arruda, at least in so far as these are observable in the materials available for study. This is not the case.

Initially, the bones gave us a superficial impression that the Moita individuals were smaller (more females?), that the burial modes were a little different with a very much more complicated mixing of individuals at Arruda (poorer control during excavation?), and that there were many more infants, even neonates, at Arruda (better control during excavation?).

As our analyses progressed, we realized that there were differences in patterns of dental pathology and attrition (Lubell, *et al.*, 1994, Figures 6, 9) as well as tooth size (Jackes, *et al.*, 1997a, Figure 4). Some craniometric studies indicated differences (Jackes, *et al.* 1997a, and see data provided at ***http://intarch.ac.uk/antiquity/jackes/craniometry.html***). Several aspects of these results are summarized in Jackes & Lubell (1999).

Can we confirm these impressions of differences with additional data? Here we will choose just one set of comparisons – for the lower limbs.

COMPARISON OF MOITA AND ARRUDA FEMORA

Internal features

As part of our study, samples were taken from many adult left femora in order to count osteons as a means of obtaining more accurate estimates of age at death. This proved impossible because of extensive microbial destruction of bone microstructure and chemical diagenesis of periosteal portions of bone cortex (see Jackes, 1992; Jackes, *et al.* 2000; Palmer, 1987). Nonetheless, we were able to use these samples to measure directly both thickness of the cortical bone at the mid-point of the anterior femoral diaphysis, and bone density (weight over volume with volume determined by displacement).

Figure 1 shows there is very little overlap between Moita and Arruda, whether sexes are pooled or examined separately. In Figure 1a (pooled sexes), however, two Moita individuals (8 & 9) fall within the Arruda distribution. One of these (Moita 8, a male) is the most extreme of the Moita femora. These arthritic femora, badly cleaned by scraping and then lacquered (in the 19th century?), had unusual nodular lipping of many joint margins, but without joint surface destruction. There appeared to have been pathological changes to the femora and fragmentary right ischium, such that periostotic plaque lay over the cortex, though now damaged by the cleaning.

Figures 1b and 1c show the results of analyses by sex (based on the data in Tables 1 and 2). The extremely narrow cortex displayed by four Arruda females are individuals we recorded as: "osteoporotic and arthritic, with extremely worn cheek teeth and dental pathology", "post menopausal, with severe attrition and periodontal disease", "possible pathology of innominate" and "teeth reduced to roots, edentulous mandibular symphysis".

The male:female ratio for these tests is about 0.5. Was determination of sex done differently for Moita and Arruda? Arruda was a much more complex and confusing analytical problem, due in part to the presence of many more mixed and 'stray' femora in the sample. Therefore, we have used two extra measures: one – the maximum shaft dimension (MacLaughlin and Bruce, 1985) – has proven to be extremely valuable in differentiating males from females; the other – the mid-shaft circumference (Black, 1978) – is slightly less highly correlated with sex. We have therefore concentrated on the maximum shaft diameter (DML) and used it in conjunction with the mass of the femoral mid-shaft (DAP), to check that our sex discrimination for Moita and Arruda femora is equivalent. A few Arruda femora have been classified as 'sex unknown' in the analysis.

With the exception of male cortical thickness, the differences between Moita and Arruda in the density and thickness of mid-shaft cortical femoral bone are significant (Tables 1 and 2).

When the anterior cortical thickness is expressed as a percentage of the femoral mid-shaft, the male difference between the two sites is less significant, while the female difference remains significant at the 0.02 level.

Can these results be ascribed to differences in the methods of collecting the samples and analysing them (Moita femora were cored in 1984 and the preparation work was done in Canada; Arruda femora were sampled, not cored, in 1986 and initial work was done in Lisboa by José Severino Rodrigues)?

To control for this, all left femora were radiographed before being sampled, and the images analysed for Nordin's Index (the percent of cortical bone present at the mid-shaft of the femur using AP radiographs: Nordin, *et al.*, 1966). There is the possibility of observer error, especially with archaeological bone, but multiple observers and some control multiple radiographs have been used.

The results (Table 3) indicate highly significant differences between Moita and Arruda in the percent cortical area at the mid-shaft. Can we really believe this? Figure 2, using these data, shows that, regardless of whether sexes are pooled or analysed separately, Moita and Arruda are completely different with regard to the internal geometry of the mid-diaphyseal adult left femur.

External features

The external dimensions – size and shape – must also be considered.

The form of the proximal femur is expressed as the platymeric index based on measurements taken immediately below the lesser trochanter (see e.g. measurements 64 and 65 in Buikstra and Ubelaker, 1994) allowing us to correlate our external measurements with data from radiographs, in which the base of the lesser trochanter can be clearly identified. The platymeric index does not differ significantly between Moita and Arruda (Jackes & Lubell, 1999). Neck-shaft angles, as well as further proximal measurements, derived from standardized photographs, are still being analysed. We will not discuss proximal femora further since work continues using digital calibration on the standardized photographs, as well as on radiographic records of trabecular patterns and cortical width of the lower calcar femorale (Jackes, 1992).

For now, we are concentrating our analysis on the mid-shaft, and we will first control for size by examining the mid-femoral mass as AP diameter in mm (DAP) x ML diameter in mm (DML) based on full data files for adult left femora (Table 4).

The overall size of the mid-diaphyseal area of the femur seems to be irrelevant (note, however, the interesting differences between males and females regarding which site has the higher mean value for this variable).

Next we can examine the pilastric index of the femoral mid-shaft – (100 x DAP)/DML – which may occasionally be expressed as the inverse, but this makes no real difference to the probability values reported in Table 5. The index expresses the form of the bony section and the height of the *linea aspera* (thus being influenced by sex to some extent?).

The difference between the means using full data files, not just radiographed femora, (Figure 3) is very marked: Moita 107.6 vs Arruda 102.6, P = .018, 2 tailed, equal variance. An examination of the variable by sex (Table 5) reveals a significant difference between males but not females.

We have controlled for sex, but we must now control for adult age (we have used no femora here below ca. age 20).

AGE

Our palaeodemographic work has been based on dental features, and in Figure 4 we see that when age is controlled by reference to attritional levels (Jackes & Lubell, 1996: Fig. 5), Nordin's Index does indeed still differ between the two sites. Attrition is reduced at Arruda, which might affect the trajectory of the curves in Figure 4, but not the overall co-variation of attrition and percent cortical bone with age. One could visualize the attrition levels shifted to the right for Moita, which would give a clearer picture of comparable chronological age (as against 'attritional age'). Such a procedure would only augment the tendency towards a higher percentage of cortical bone at the femoral mid-shaft in Moita than in Arruda individuals.

It would certainly be preferable to control for age using features of the lower limb, since we cannot be certain that there has been no mixing of skeletal elements, especially at Arruda. It proved impossible to use osteon counting with the Muge material (Jackes, 1992; Jackes, *et al.,* 2000). We have done detailed work on cortical porosity of Moita femora (Palmer, 1987), but not Arruda. Femoral shaft expansion with age (Heaney, *et al.*, 1997) might be significant, but since the variances in external femoral metrical variables are equal, we might assume that we have roughly equivalent samples in terms of adult ages over the two sites. However, femoral cortical thickness may change (Heaney, *et al.*, 1997) and medullary width may increase with age, especially in females (Feik, *et al.*, 1997), so there will be an age x sex interaction in Nordin's Index. We need then to discover whether the age distribution of the adults is equivalent between the two sites based on internal femoral information.

In order to do this we have analysed the differences on the basis of a number of techniques for summarizing age changes in the trabecular patterning of the proximal femur as seen on radiographs (Bergot & Bouquet 1976; Nemeskéri, *et al.,* 1960; Singh, 1972; Walker & Lovejoy, 1985). We find no significant differences in the levels of trabecular change. For example, in one test of the Bergot-Bouquet method, two researchers independently assessed radiographs of proximal femora of adults over 20 years of age (23 for Moita and 39 for Arruda). They then worked over the interobserver differences and found that P = .291 (equal variances, 2 tailed significance), an indication of a lack of significant difference between the two sites in adult age distributions.

This is a preliminary analysis, but it does appear that we have something to explain. We have found no evidence of bias in the age and sex of the femoral samples, yet the internal geometry and the external shape of the femoral mid-shafts differs between the Moita and Arruda skeletal collections. What could be responsible for these differences? Did these two groups have distinct diets?

DIET

Our stable isotope data (Figure 5), suggest there might be a difference. Unfortunately, our sample sizes are too small for this to be more than a suggestion. The $\delta^{13}C$ means for Moita and Arruda are -16.4 and -17.6 respectively. If our question is whether Arruda is lighter in $\delta^{13}C$ than Moita, then the P is .063 at 8 df (t = -1.70676, equal variances). In other words, the difference approaches significance despite the inadequate sample size.[1]

We might be justified in excluding Arruda N, the outlier, because this individual is exceptional (with spinal changes including osteoporotic collapse of T.10 and collapse and fusion of L.1/L.2). If we do that, the results are very different (means of -18.2 and -16.4, t = -3.5529, P = .00465, 1-tailed, equal variances). Limitation of mobility may be the explanation for the unusual stable isotope values of Arruda N, as is also possible for Samouqueira 2 (Lubell & Jackes 1988).

Nutritional differences have long been considered the determining factor in the shape of femoral and tibial diaphyses (Buxton 1938; Bisel 1988). While we would question this interpretation, there is some possibility that Moita 35, with small and extremely curved femora, may have suffered pathological changes related to nutrition, causing abnormal femoral dimensions (Janssens *et al.* 1991), and this individual has therefore been excluded from the analyses.

ACTIVITY

Extensive research on biomechanics and femoral form indicates that the most likely explanation for the differences is based on activity. Larsen (1997: 199) has summarized the matter with regard to long bones: "the cross-sectional area and the manner in which bone is distributed about an axis reflect mechanical/functional behaviour".

The femoral mid-shaft is primarily subject to AP bending stress. Meiklejohn *et al.* (1999) have shown, in a fascinating paper by which an 'Iron Man' athlete was identified forensically from a femoral shaft alone, that a high pilastric index indicates great bending stress.

Figure 3 demonstrates that there is a very considerable difference between Moita and Arruda. Note that we are not just examining crude size here: the correlation between the mid-shaft circumference and the pilastric index for the adult left femora from Arruda is insignificant: r = .1538, P = .337).

How does all this information fit together? Moita femora have a higher percentage of cortical bone at the mid-femur, the bone is denser and the pilastric index is higher. All of this implies that Moita femora were subject to greater bending and torsional stresses than those from Arruda.

A test of this might be by reference to the cnemic index (DML x 100/DAP), taken at the nutrient foramen of the tibia. Figure 6 gives a fair indication that tibiae from Arruda are narrower (more platycnemic) than Moita: the Moita mean is 65.5 while Arruda is 63.

---

[1] Recent analyses of material from the Oporto collections, to be published separately by Cunha, corroborate our results. The differences in $\delta^{13}C$ for Moita and Arruda are again highly significant if Arruda N and a new outlier are removed, but there would have to be evidence that the new outlier could reasonably be considered unusual by reason of pathology or trauma.

It is to be expected that females are more platycnemic than males (e.g. Olivier 1969), but this is not true for Moita, where sex differences for the cnemic flattening and shape of the mid-shaft area are not significant for either side.

An analysis by sex, and by discriminant analysis sex ascription, indicates a very interesting difference between Moita and Arruda. Moita and Arruda adult male tibial indices and Moita female indices are not significantly different from the Moita male mean index. The mean left cnemic index for Arruda adult females is 59.8 (n = 13), however, and significantly different from the mean index for Arruda males of 65.6 (n = 15) at the .001 level (2 tailed, equal variances).

Flattening of the tibia has been less extensively studied than flattening of the femoral shaft, but again, the modern interpretation would generally be in terms of function rather than nutrition (genetic differentiation is not the primary determinant of lower limb long bone cross-sectional morphology: see e.g. Meiklejohn *et al.* 1999). The interpretation of platycnemia as related to squatting (Cameron 1934) seems quite outmoded.

Note that the cnemic index (ML/AP) is the reverse of the pilastric index (AP/ML). Since the strength of the bone is greater as the AP breadth increases over the ML dimension, a high pilastric index indicates strength and a low cnemic index might also indicate strength. Lovejoy *et al.* (1976) point out that platycnemic bones could be regarded as actually weaker, however, than other tibiae, and suggest that the best interpretation is of substantially different stresses being placed on platycnemic tibiae from eurycnemic bones.

Certainly, the geometry of the tibia is not necessarily correlated with that of the femur in any particular direction. We have attempted, as well as is possible, to pair femorae and tibiae in a full data file, by side and by individual. The relationship of the geometry of the femoral mid-shaft and the tibial proximal shaft differs somewhat between the two sites.

SUMMARY

What we have, then, is an indication that the Arruda people, and especially the Arruda females, were doing something different from those at Moita. The Arruda females were engaged in some activity which put particular pressure on their tibiae, different from that of both Moita females and Arruda males. Furthermore, it is very likely that stresses on the lower limb in Arruda females were actually lowered in comparison with Moita females, considering the evidence of reduced bone density and cortical thickness in Arruda female femora (Figures 1c & 2c). While we have not demonstrated a statistically significant difference in external size and shape between Moita and Arruda female femora, there is evidence that Moita and Arruda males differed in mid-femoral shaft form, suggesting that Arruda femora were probably subject to reduced bending stress. Furthermore, Arruda males were significantly more varied than Moita males in femoral mid-shaft morphology.

DISCUSSION

Our initial hypothesis was that there is a difference between Moita and Arruda, that the Arruda group was more sedentary, that Arruda should be interpreted as a base camp, and that there may have been a greater emphasis on small mammals in the diet (see also Lubell & Jackes, 1988).

Arruda juveniles are difficult to analyse because of their extreme fragmentation. We have done the formal palaeodemographic studies using mandibles, so as to be sure that we are not counting individuals more than once. We will not report on that here, because it has been discussed in the literature several times (e.g. Jackes, *et al.,* 1997a). We have reported slight differences in demographic estimates between Moita and Arruda, but do not consider them particularly significant, and we plan to do more detailed work on the juvenile dentitions, based on radiographs, because of the unusual aspects of the eruption sequences.

If analysis is restricted to the Arruda mandibles, there are only one or two infants under 6 months (170e and a), but when right femora are included, the total increases to at least nine individuals under 6 months (femoral mid-diaphyseal maximum diameters of 6-7 mm), confirmed by the lengths of the innominate elements. Of these, three or four appear to be preterm (49, 51, 52, 54; 6-9 months gestational age), one or two perhaps at term (170e, 55a), with 170a, M32 and the fragmentary 170b, 68a and 68b perhaps a little older.

Moita is very different, with only a few young infants being mentioned by Ferembach (1974). Our analyses indicate that one of these (one of several individuals included in Ossada 7) would be very slightly older than Arruda 170b, probably under 6 months, but that the innominate fragment mentioned by Ferembach seems to be no longer present (the one included with Ossada 7 is that of an 18 month old). Ferembach also describes the fragmentary cranium of a newborn (?) Moita 38 (in Lisboa), and we agree that this individual was aged from birth to 3 months. There is also a scapula fragment of a very young infant in Ossada 45.

Of the Moita material in Oporto, Ferembach describes only one individual as "a few months old" (part of Oporto 7). We agree that there is a left ulna of an infant present, but we did not undertake analyses of the Oporto collections because the material has not been prepared for study.

In sum, the Arruda collections provide very good indications of the presence of foetal, neonatal and very young infant material – at least eight to ten individuals altogether. The Moita material is minimal, but indicates no more than two or three early postnatal individuals.

Excavation history and techniques

The history of the excavation of Moita and Arruda may well be relevant to this discussion.

In the 1860's, Da Costa excavated 45 skeletons from Arruda. Roche (1972:23) states that 120 skeletons, some from Moita and some Arruda, were excavated in the early 1880s by Ribeiro, and implies that there was possible mixing of skeletons. In 1884-1885, De Paula e Oliveira excavated 52 skeletons, which could have been from both Moita and Arruda (Roche 1972:25). In 1937, a large part of Arruda was excavated. In 1964-5, Roche excavated 13 more skeletons – all in a basal layer.

In 1880, Ribeiro carried out the first excavations at Moita. In 1892, De Paula e Oliveira excavated an unspecified number of skeletons. In 1951, part of Moita was bulldozed away, and beginning in 1952, Roche (1972) excavated the remaining material – 34 graves, with about 40 individuals, all from the brecciated basal layer. Material from Roche's excavations was for many years stored in Oporto, and has never been fully cleaned or studied: our preliminary examination indicated that a fire which occurred in 1974 had led to some mixing and loss of skeletons, with possible transfer of labels. The collection has now been moved to Coimbra where Cunha and her team have begun to clean and analyse the collection.

We assume that most of the individuals labelled Arruda at the Serviços Geológicos in Lisboa, are actually from Arruda (there are also a few Arruda skeletons in the Oporto collection). We were doubtful about the Muge origin of only one or two Arruda skeletons in Lisboa, because of obvious differences of morphology or preservation.

Roche's excavation map indicates that only a small area of Moita was excavated before destruction. But this means, of course, that although it is unlikely that much mixing of Moita and Arruda material occurred, the Moita skeletons represent an incomplete sample, possibly biassed, and since Arruda was not excavated entirely, the Arruda sample may also be biassed.

Do excavation techniques explain the apparent difference between Moita and Arruda in the frequency of perinatal infants? So far as we can determine from records available to us, only Roche used screens. Thus, there could be parallels in the differences in frequency of small mammal remains.

Lentacker (1991) has analysed the faunal remains from Moita, Arruda, and Cabeço da Amoreira (the third Muge site from which there are almost no human remains that can be studied) and used these data to reconstruct the local ecology at the time the sites were in use. The area must have been fairly swampy, and the Muge river brackish. Forest cover was extensive and dense, alternating with more open woodland. Food resources were rich. Mammalian remains are smaller in size than elsewhere but abundant, and include red deer, rabbit, wild boar, aurochs and even wild horse. Shellfish, fish and bird remains are also common, and analyses strongly suggest year-round occupation.

Figure 7 shows that despite the vagaries of excavation methods and post-excavation curation, the three Muge sites bear a basic resemblance to each other in comparison with the faunal assemblages from two contemporaneous Mesolithic sites further to the south, both excavated with modern methods: Cabeço do Pez along the Sado River and Fiais near Odemira (data for the former from Rowley-Conwy, personal communication; for the latter *ibid.* as well as our own analyses; see also Gonzales Morales & Morais Arnaud, 1990).

Nonetheless, Moita is certainly lacking in lagomorphs compared to Arruda and Amoreira. It may well be that the lower frequency of small mammals and infant skeletal remains reflects the excavation history, rather than a firm difference between Moita and Arruda.

Burial patterns

At the moment it does not appear that the posture at burial and mode of burial (generally supine and tightly flexed with feet crossed and hands in one of three positions) differs between Moita and Arruda (*contra* Lubell & Jackes, 1988). Photographs of the 19th century excavations at Arruda in the archives of the Serviços Geológicos suggest that skeletons were originally quite neatly buried as individuals and that the mixing may have occurred during and after excavation. Thus, some of the differences between Moita and Arruda may be an artifact of methods of excavation and storage.

CONCLUSION

In sum, the differences between the human skeletal samples from Moita and Arruda are not necessarily the obvious ones, but subtle and complex. The fascination (and frustration) of human osteology lies in the fact that we are working with samples, not simply of unknown age and sex and of unknown health and lifestyle, but biassed in unknown ways. Constant reassessment of methods, techniques, assumptions and data is essential, and when bias may be compounded by excavation and storage history, it is especially important that we resist the temptation to be doctrinaire about our conclusions.

Analyses of our data are continuing. Despite all the questions, and despite the fact that many of the initial impressions of differences may have been based on weak evidence, it is clear that there *are* differences in the two samples which appear to indicate that the late Mesolithic in central Portugal was not a static period, but one of change. Work on the Moita collections originally stored at Oporto and now moved to Coimbra will be of great importance, and it is to be hoped that analyses of the Sado human material currently in Lisboa will be undertaken and published in detail, in order to expand understanding of these important collections of skeletons.

REFERENCES CITED

BERGOT, C. & J. P. BOCQUET (1976) – Étude systématique de l'os spongieux et de l'os cortical du femur et de l'humerus en fonction de l'âge. *Bull. Mém. Soc. d'Anthropol. (Paris)*: (Série XIII) 3: 215-42.

BISEL, S. C. (1988) – Nutrition in first century Herculaneum. *Anthropologie (Brno)* 26(1): 61-6.

BLACK, T. K. (1978) – A new method for assessing the sex of fragmentary skeletal remains: femoral shaft circumference. *American Journal of Physical Anthropology* 48: 227-32.

BUIKSTRA, J. E. & D. H. UBELAKER (1994) – *Standards for Data Collection from Skeletal Remains*. Arkansas Archeological Survey Research Series No. 44, Fayetteville: Arkansas.

BUXTON, L. H. D. (1938) – Platymeria & platycnemia. *Journal of Anatomy (London)* 73: 31-6.

CAMERON, J. (1934) – *The Skeleton of British Neolithic Man*. London.

FEIK, S. A., C. D. L. THOMAS & J. G. CLEMENT (1997) – Age-related changes in cortical porosity of the midshaft of the human femur. *Journal of Anatomy* 191: 407-16.

FEREMBACH, D. (1974) – *Le Gisement Mésolithique de Moita do Sebastião, Muge, Portugal II: Anthropologie.* Lisboa: Instituto de Alta Cultura.

GONZALES MORALES, M. R. & J. E. MORAIS ARNAUD (1990) – Recent research on the Mesolithic in the Iberian Peninsula: problems and perspectives. In, P.M. Vermeersch & P. Van Peer (eds.), *Contributions to the Mesolithic in Europe*, pp. 451-461. Leuven: Leuven University Press.

HEANEY, R. P., M. J. BARGER-LUX, K. M. DAVIES, R. A. RYAN, M. L. JOHNSON & G. GONG (1997) – Bone dimensional change with age: interactions of genetic, hormonal, and body size variables. *Osteoporos Int.* 7(5): 426-31.

JACKES, M. (1992) – Paleodemography: problems and techniques. In, S.R. Saunders & M.A. Katzenberg (eds.), *Skeletal Biology of Past Peoples: Research Methods*, pp. 189-224. New York: Wiley-Liss.

JACKES, M. & D. LUBELL (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, pp. 457-80.

JACKES, M. & D. LUBELL (1999) – 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., D. LUBELL & C. MEIKLEJOHN (1997a) – Healthy but mortal: human biology and the first farmers of Western Europe. *Antiquity* 71 (273): 639-58 (supplementary material published electronically at http://intarch.ac.uk/antiquity).

JACKES, M., D. LUBELL & C. MEIKLEJOHN. (1997b) – On physical anthropological aspects of the Mesolithic-Neolithic transition in the Iberian Peninsula. *Current Anthropology* 35(4): 839-46.

JACKES, M., M. WAYMAN, C. BARKER & R. SHERBURNE (2000) – Bacterial effects on human bone from archaeological sites. *Journal of Iberian Archaeology* 2.

JANSSENS, P., A. MARCSIK & C. DE MEYERE (1991) – The influence of rickets on the anthropological measurements of the femur *Journal of Paleopathology* 4:201-10.

LARSEN, C. L. (1997) – *Bioarchaeology: interpreting behavior from the human skeleton.* Cambridge: Cambridge University Press.

LENTACKER, A. (1991) – *Archeozoölogisch onderzoek van laat-prehistorische vindplaatsen uit Portugal.* Unpublished Ph.D. thesis, Laboratorium voor Paleontologie, Rijksuniversiteit Gent.

LOVEJOY, C. O., A. H. BURSTEIN & K. G. HEIPLE (1976) – The biomechanical analysis of bone strength: a method and its application to platycenemia. *American Journal of Physical Anthropology* 44: 489-506.

LUBELL, D. & M. JACKES (1988) – Portuguese Mesolithic-Neolithic subsistence and settlement. *Rivista di Antropologia (Roma)* LXVI (Supp): 231-48.

LUBELL, D., M. JACKES, H. SCHWARCZ, M. KNYF & C. MEIKLEJOHN (1994) – The Mesolithic-Neolithic transition in Portugal: isotopic and dental evidence of diet. *Journal of Archaeological Science* 21: 201-16.

MACLAUGHLIN, S. M. & M. F. BRUCE (1985) – A simple univariate technique for determining sex from fragmentary femora: its application to a Scottish short cist population. *American Journal of Physical Anthropology* 67:413-17.

MEIKLEJOHN, C., B. WADDELL, I. TRUDEL, D. MICHAUD & P. HODGE (1999) – Identification of a missing person using biomechanical and DNA analysis: a case study. In, S. Fairgrieve (ed.), *Forensic Osteological Analysis.* Springfield: C.C. Thomas.

NEMESKÉRI J., L. HARSÁNYI & G. ACSÁDI (1960) – Methoden zur diagnose des Iebensalters von skelettfunden. *Anthropol. Anz.* 24: 70-95.

NORDIN, B. E. C., J. MACGREGOR & D. A. SMITH (1966) – The incidence of osteoporosis in normal women, its relation to age and the menopause. *Q J Med* 35 (137): 25-38.

OLIVIER, G. (1969) – *Practical Anthropology.* Springfield: C.C. Thomas.

PALMER, E. (1987) – *Micromorphology of prehistoric human bone from the Mesolithic site of Moita do Sebastião, Portugal.* Unpublished MA thesis, Department of Anthropology, University of Alberta. (Copy on deposit at the Instituto de Antropologia, Universidade de Coimbra).

ROCHE, ABBÉ J. (1972) – *Le Gisement Mésolithique de Moita do Sebastião, Muge, Portugal I: Archéologie.* Lisboa: Instituto de Alta Cultura.

SINGH, I. J. (1972) – Femoral trabecular pattern of the upper end of the femur as an index of osteoporosis. *J. Bone Joint Surg.* 52-A: 457-67.

WALKER, R. A. & C. D. LOVEJOY (1985) – Radiographic changes in the clavicle and proximal femur and their use in the determination of skeletal age at death. *American Journal of Physical Anthropology* 68: 67-78.

Table 1 – Density of cortical bone (adult left femora) measured as weight (g) over volume (cc) with volume determined by displacement

Males						
	n	$\bar{x}$	δ	Standard error of $\bar{x}$		
Moite	13	1.2682	.171	.047		
Arruda	24	1.5632	.242	.049		
Levene's Test for Equlity of Variances					F = 1.293	P = .263
t-value	df	2-Tail Sig				
-3.89	35	.000				
Females						
	n	$\bar{x}$	δ	Standard error of $\bar{x}$		
Moita	9	1.1734	.093	.031		
Arruda	20	1.5665	.410	.092		
Levene's Test for Equality of Variances					F = 3.235	P = .083
t-value	df	2-Tail Sig				
-2.82	27	.009				

Table 2 – Cortical thickness, measured in mm directly on adult left femoral cores

Males						
	n	$\bar{x}$	δ	Standard error of $\bar{x}$		
Moite	16	6.4333	.918	.229		
Arruda	24	5.8865	.888	.181		
Levene's Test for Equality of Variances					F = .032	P = .859
t-value	df	2-Tail Sig				
1.88	38	.067				
Females						
	n	$\bar{x}$	δ	Standard error of $\bar{x}$		
Moita	10	6.0500	.781	.247		
Arruda	20	4.7410	1.015	.227		
Levene's Test for Equality of Variances					F = .855	P = .363
t-value	df	2-Tail Sig				
3.57	28	.001				

Table 3 – Nordin's Index calculated from radiographs of Moita and Arruda adult left femora

Males						
	n	x̄	δ	Standard error of x̄		
Moite	18	61.7222	5.131	1.209		
Arruda	21	56.7143	6.076	1.326		
Levene's Test for Equality of Variances					F = .035	P = .852
t-value	df	2-Tail Sig				
-3.89	37	.009				
Females						
	n	x̄	δ	Standard error of x̄		
Moita	9	64.5556	4.693	1.564		
Arruda	17	55.7059	8.168	1.981		
Levene's Test for Equality of Variances					F = 2.613	P = .119
t-value	df	2-Tail Sig				
2.98	24	.006				

Table 4 – Mid femoral mass as AP diameter in mm (D_{AP}) x ML diameter in mm (D_{ML}) based on full data files for adult left femora

Males						
	n	x̄	δ	Standard error of x̄		
Moite	17	699.0	79.093	19.183		
Arruda	21	666.8095	75.444	16.463		
Levene's Test for Equality of Variances					F = .296	P = .590
t-value	df	2-Tail Sig				
1.28	36	.209				
Females						
	n	x̄	δ	Standard error of x̄		
Moita	11	548.1818	55.371	16.695		
Arruda	18	570.7222	59.631	14.055		
Levene's Test for Equality of Variances					F = .1052	P = .314
t-value	df	2-Tail Sig				
-1.01	27	.320				

Table 5 – Pilastric Index for adult left femora only, based on full data files

Males						
	n	x̄	δ	Standard error of x̄		
Moite	17	109.3488	7.094	1.917		
Arruda	21	103.7270	8.648	1.887		
Levene's Test for Equality of Variances					F = .006	P = .937
t-value	df	2-Tail Sig				
2.09	35.4	.044				
Females						
	n	x̄	δ	Standard error of x̄		
Moita	11	104.7377	9.408	2.837		
Arruda	18	101.7778	10.522	2.480		
Levene's Test for Equality of Variances					F = .492	P = .489
t-value	df	2-Tail Sig				
.76	27	.452				

Fig. 1 – Cortical thickness and cortex density in left femora of adults from Moita do Sebastião and Cabeço da Arruda: (A) males and females, (B) males, (C) females.

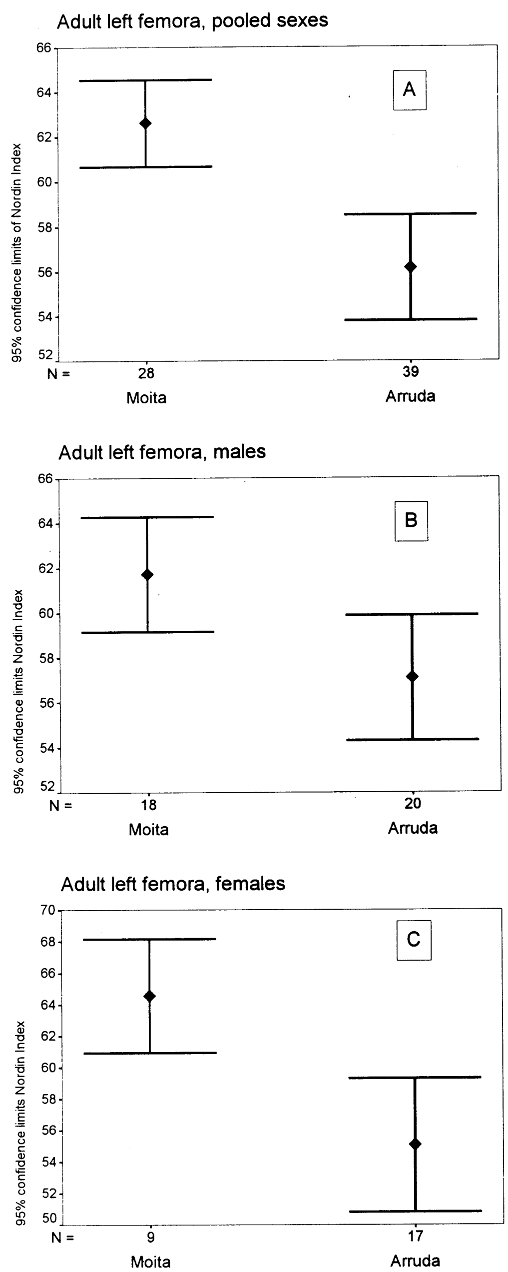

Fig. 2 – Mean and 95% confidence limits of the Nordin Index of adult left femora from Moita do Sebastião and Cabeço da Arruda: (A) males and females, (B) males, (C) females.

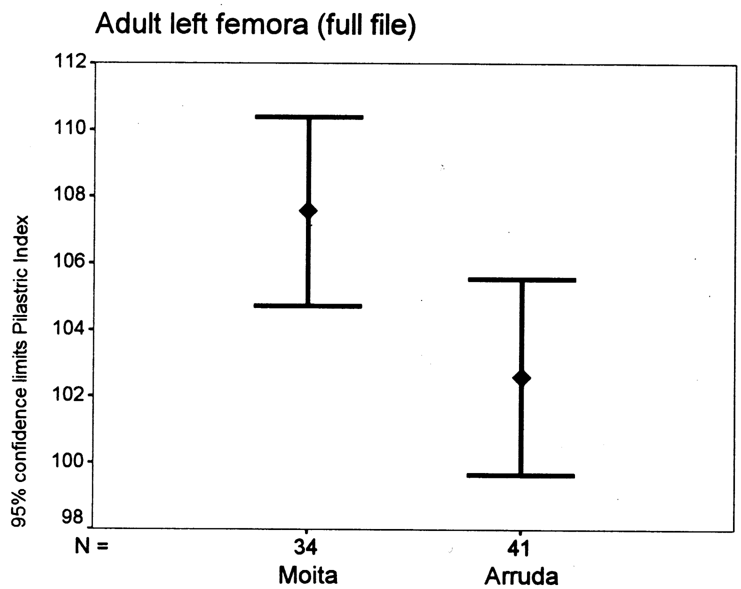

Fig. 3 – Mean and 95% confidence limits of the Pilastric Index in male and female adult left femora.

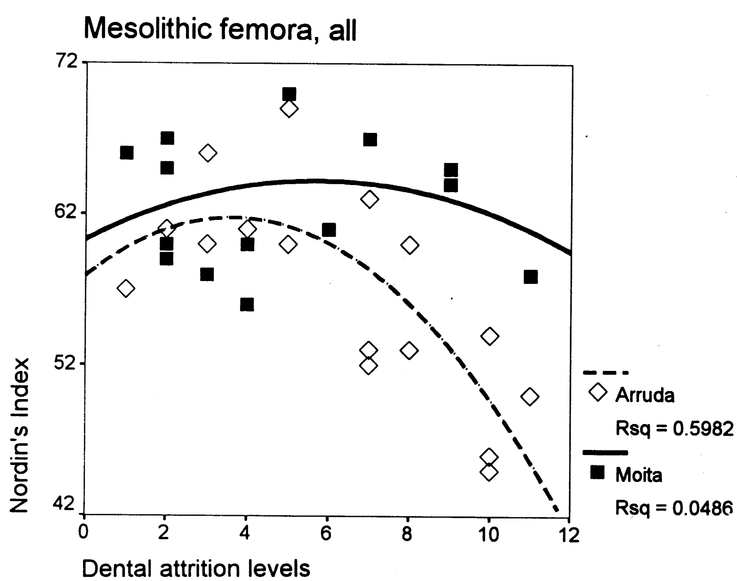

Fig. 4 – Nordin's Index for femora of males and females over age 15 by dental attrition level (derived from seriation of mandibular molars). Exponential curves demonstrate how % cortex at the mid femoral diaphysis increases into adulthood and then decreases. Note that the two instances of apparently paired Arruda data points are from different individuals in each case.

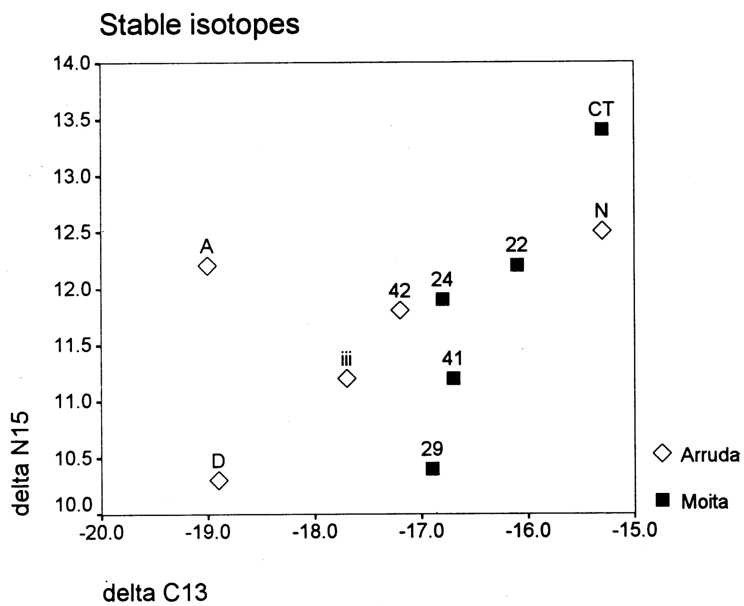

Fig. 5 – Comparison of stable isotopic composition for Moita do Sebastião and Cabeço da Arruda showing almost complete separation of the two samples for $\delta^{13}C$.

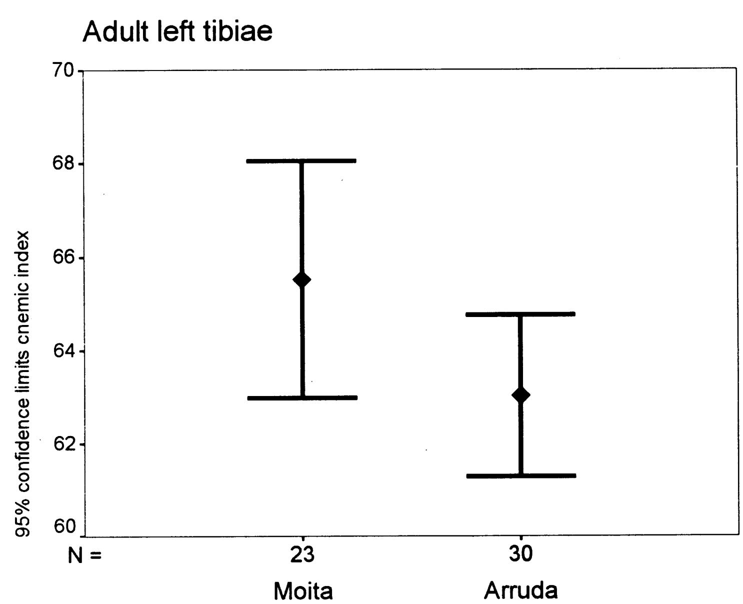

Fig. 6 – Mean and 95% confidence limits of the Cnemic Index in male and female adult left tibiae.

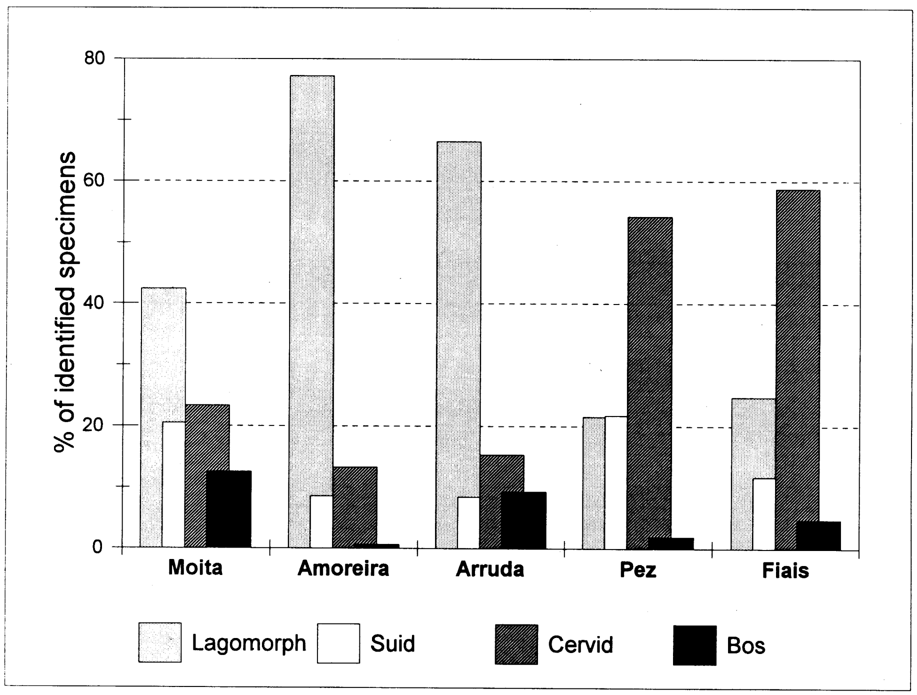

Fig. 7 – Major mammalian fauna from Mesolithic sites in Portugal: Moita do Sebastião, Cabeço da Amoreira and Cabeço da Arruda from Muge, north the of Tagus; Cabeço do Pez from the Sado, and Fiais from the Mira, both south of the Tagus.

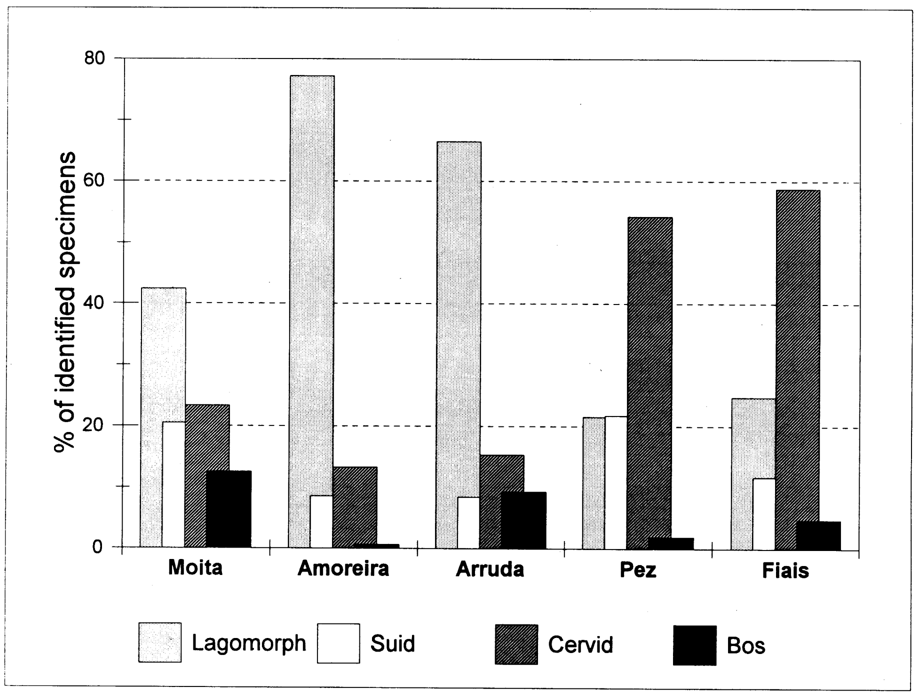

Fig. 7 – Major mammalian fauna from Mesolithic sites in Portugal: Moita do Sebastião, Cabeço da Amoreira and Cabeço da Arruda from Muge, north the of Tagus; Cabeço do Pez from the Sado, and Fiais from the Mira, both south of the Tagus.