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Markers of Activity Patterns in some Populations of the Iberian Peninsula[1]

I. al-OUMAOUI,* S. JIMÉNEZ-BROBEIL AND **P. du SOUICH**
Laboratorio de Antropología, Facultad de Medicina, Universidad de Granada, Spain

ABSTRACT A study was undertaken of musculoskeletal stress markers in the human remains of several ancient populations of the Iberian Peninsula. Frequencies by age group, sex, and side were recorded and compared among the different populations. Results of the study coincide with the available historical and archeological data. The differences observed among these populations are probably due to ecological and socio-cultural factors. Copyright © 2004 John Wiley & Sons, Ltd.

Key words: activity patterns; enthesophytes; muscle development; sexual dimorphism

Introduction

Study of the socioeconomic activities and life conditions of ancient populations is a field of major interest in palaeoecology and palaeopathology. Numerous methods based on the observation and quantification of different skeletal variables can be used for this purpose (Larsen, 1997). The analysis of musculoskeletal stress markers is a widely adopted approach that has been used by Dutour (1986), Kennedy (1989), Stirland (1991), and Palfi (1992), among others.

Since the culture and environment of some samples of populations are known through archaeological and historical data, our initial hypothesis was that musculoskeletal markers may reflect the activities carried out by these populations according to their sex, environment, and culture. If historical sources show that there was a clear sexual division of work, the skeletons of men and women would be expected to differ in the development of markers related to physical activity. Likewise, individuals of a settlement in mountainous areas would be expected to show a greater development of musculoskeletal markers in the lower limbs compared with populations in flat lands, where locomotion would be less demanding. The environment influences the economic foundation of populations, so that it would be reasonable to expect differences between agriculturalists in flat lands and herdsmen in mountainous areas. Kennedy (1998) and Robb (1998) recommend that all these data be studied together.

To test this hypothesis, we designed a study of musculoskeletal markers with the following objectives: first, to investigate the physical activity of these populations of the Iberian Peninsula from distinct chronological, cultural, and geographical settings; second, to examine whether the results of our analysis are related to the environment, economic activities, and cultural setting of these populations; third, to explore differences between the sexes in each culture; and finally, to create a knowledge base for further studies of this type.

Because we could not determine a specific labour activity from individual skeletons, we focused on differences in physical activity among populations and between the sexes in skeletal series.

The aim of the present study was to explore the relationship between these archaeological and historical data and the musculoskeletal stress markers.

* Correspondence to: Anthropology Laboratory, Medical Faculty, Avenida de Madrid II, 18012 Granada, Spain.
e-mail: OUMAOUI@yahoo.es
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Materials and their historical outline

The study included 342 skeletons from five populations, three from the south and two from the north of Spain (Figure 1). These collections are deposited in the Anthropology Laboratory of the University of Granada (Spain). They are in an acceptable state of preservation and contain between 29 and 98 individuals, adequate for the statistical analysis. Two of the present authors (S.J.-B. and P.S.) participated in the archeological excavations. Various methods (Ferembach *et al.*, 1979; Krogman & Iscan, 1986) were used to determine the age and sex of each skeleton. The five collections are described below.

La Carada (Province of Granada): The bones derive from the collective burial site of a small farming village dated to the Early Copper Age (2800–2300 BC). The site is on a flat-land environment near the River Huéscar and the economy of its inhabitants was based on agriculture. The grave goods are relatively opulent for the period, with pottery, stone vases, flint arrowheads, bone needles, idols, and numerous beads of various materials (Jiménez-Brobeil, 1987). The sample used in the present study contained 75 individuals. The bones were disordered and in a variable state of preservation. Because it was a collective grave and the bones and grave goods were mixed together, no indications of social or gender differences could be established for individuals.

Argar Culture (Province of Granada): The Argar Culture was one of the most important Bronze Age phenomena in the Western Mediterranean (1700–1200 BC). Populations lived in small

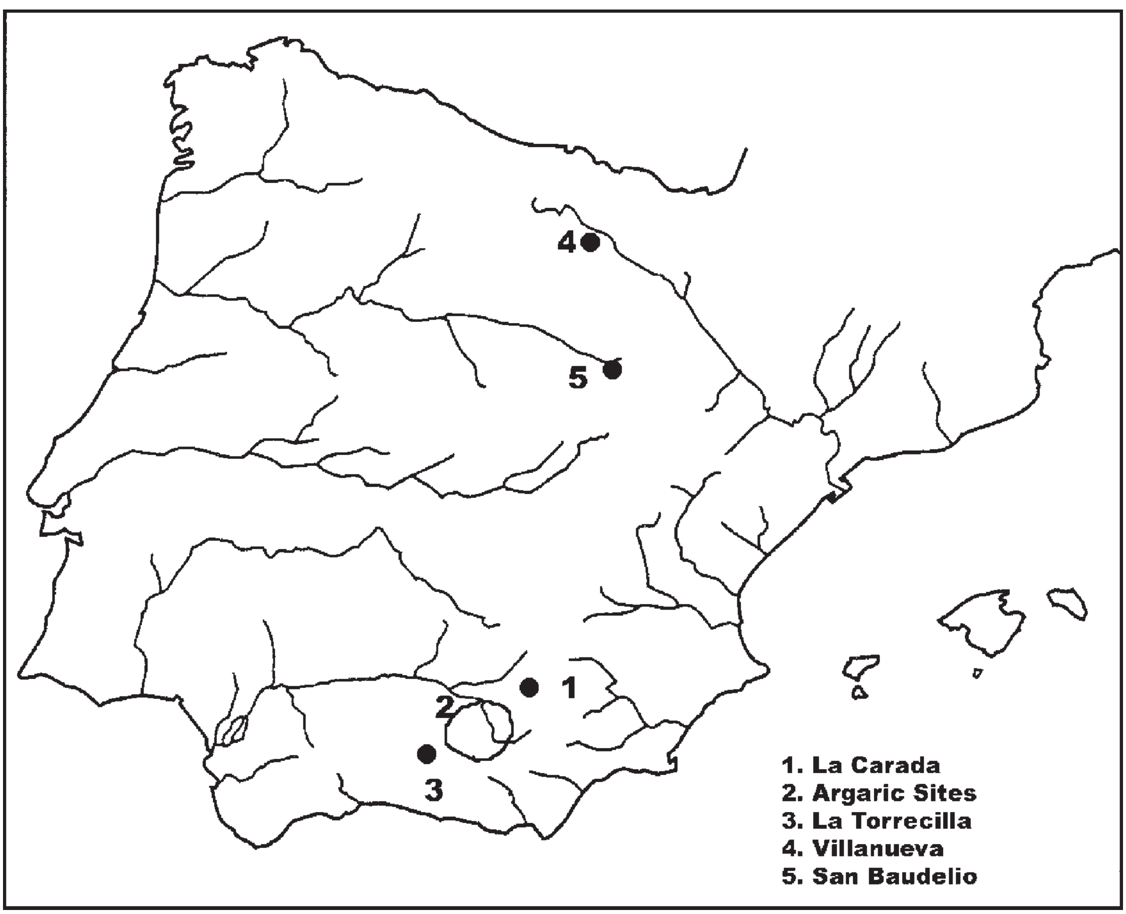

Figure 1. Distribution of sites.

villages on top of steep hills (rugged terrain) dominating fertile valleys, and were located near mineral resources. The economy was based on livestock raising and herding, agriculture, and mining (mixed economy). The tombs were single or double, and were situated below the dwellings. The presence of grave goods denoted a class-structured society, and the goods varied according to the sex of the individual (Lull, 1983). The sample contained 83 individuals from six sites in the Granada province: Cuesta del Negro, Cerro de la Encina, Cerro de la Virgen, Terrera del Reloj, Fuente Amarga and Castellón Alto.

La Torrecilla (Province of Granada): The sample contained 98 individuals from the cemetery of a small rural nucleus, which has been dated to 900–1300 AD. They were Muslims and lived in a flat-land environment by the River Cacín. Their economy was based on agriculture. The tombs provide no data on the social class of these individuals because in the Muslim religion there are no differences among individuals at the time of death. However, the site was located far from large urban centres or major routes, suggesting that the population was composed of peasants with scant economic resources (Souich, 1979).

Villanueva de Soportilla (Province of Burgos): The sample came from the cemetery of a small rural nucleus of Christian peasants dated between 850–1100 AD. It is in a flat-land environment beside the River Ebro. The economy was based on agriculture, using land received from King Alfonso III in exchange for defence of the area. The males can be considered peasant-soldiers, who alternated the plough and the sword in a frontier area frequently attacked by armies of the Muslim monarchs from the south of the Peninsula (Souich *et al.*, 1991).

San Baudelio de Berlanga (Province of Soria): This population had lived in a livestock farm, with considerable herding, at the service of the small monastery of San Baudelio. They worked for their own sustenance and that of the monks. The monastery, located in a low mountainous environment (rugged terrain), was in use from 1100 to 1200 AD and was then abandoned. The bones came from the farm cemetery and represent 29 individuals (Andrío & Loyola, 1992).

The above information is summarized in Table 1.

Table 1. Summary of the cultural information about the populations

Population	Dating	Economy	Terrain	Religion
La Carada	Early Copper	Agriculture	Flat	Unknown
Argar	Bronze Age	Mixed	Rugged	Unknown
La Torrecilla	Medieval	Agriculture	Flat	Islamic
Villanueva	Medieval	Agriculture	Flat	Christian
S. Baudelio	Medieval	Mainly herding	Rugged	Christian

Methods

The musculoskeletal stress markers studied are listed in Table 2. They were selected from among the markers proposed by Mann & Murphy (1990) for the following reasons: they can be easily observed; they are found on bones that are usually well preserved; they express the activity of certain muscles; and they include the main articulations (Peterson & Hawkey, 1998). To avoid subjectivity, the stress markers were determined by consensus of the three present authors. Although specific methods (Hawkey & Merbs, 1995) have been designed to record the development of some of these markers, they have several drawbacks (Robb, 1998; Wilczak, 1998)

Table 2. Musculoskeletal stress markers

Bone	Markers
1 Humerus	Cortical defect in attachment of pectoralis major muscle
2 Humerus	Cortical defect in attachment of teres major muscle
3 Humerus	Roughened and raised area in attachment of deltoid muscle
4 Radius	Radial tuberosity (biceps muscle attachment)
5 Ulna	Olecranon (triceps muscle insertion)
6 Ulna	Supinator crest (attachment of supinator muscle)
7 Femur	Enthesophytes on greater trochanter
8 Femur	Enthesophytes on lesser trochanter
9 Femur	Enthesophytes on *linea aspera*
10 Patella	Supero-anterior face (quadriceps tendon attachment)
11 Tibia	Popliteal line (soleal muscle attachment)
12 Tibia	Tibial tuberosity (patellar ligament)
13 Calcaneus	Achilles tendon attachment
14 Calcaneus	Attachment of *abductor hallucis* and *flexor digitorum brevis* tendons (spur)

and no standards have met general acceptance (Kennedy, 1998). Furthermore, methods were developed in non-Iberian populations that were genetically different from those under study here. We considered the presence or absence of the markers as the only criterion, despite the limitation that this had consequences for our ability to compare muscle development among populations. Figures 2–5 illustrate bone surfaces regarded as unaffected and those with the minimal marker development considered to indicate presence of the feature.

The presence of markers depends on the physical activity of the individual but is also influenced by the sex, age, hormonal levels, and genetic differences (Wilczak, 1998). According to Wilczak, it may not be possible to compare results among populations that show large differences in skeleton size or degree of sexual dimorphism. This was not the case in the present study, because all of the Iberian Peninsula samples were morphologically gracile. The skeletal size was similar for individuals of the same sex from the different samples, with mean male stature ranging from 166.9 cm (Villanueva) to 169.1 cm (San Baudelio), and sexual dimorphism was low. On the other hand, relative differences were found between the population with greatest dimorphism (La Torrecilla) and that with least (El Argar) in some upper member measurements, calculated following Relethford & Hodges (1985).

Because the development of muscle markers increases with age, they are considered indicators of skeletal maturation (Mann & Murphy, 1990). Therefore, a population with a long life expectancy and a large number of elderly individuals may give a misleading appearance of strong muscular development. For this reason, elderly and juvenile (not fully developed) individuals were excluded from the study. Therefore, the final study population comprised the skeletons of young adults (ya: 20–35 yrs) and mature adults (ma: 36–50 yrs). Also excluded from the study, after meticulous examination of the vertebrae, were individuals who presented signs of diffuse idiopathic skeletal hyperostosis (DISH) because these individuals are more prone to develop osteophytes (Aufderheide & Rodríguez Martin, 1998).

A chi-square (χ^2) test was performed to determine whether the samples were comparable in terms of the percentages of each sex and age category. The chi-squared test is the best-known and most widely used test when we deal with frequencies of occurrences or events (Madrigal, 1998). Although there were no mature adult females in San Baudelio and few subjects of mature age in La Carada, the results showed no statistically significant differences overall (♂young adults $p = 0.43$; ♂mature adults $p = 0.08$; ♀young adults $p = 0.54$ and ♀ mature adults $p = 0.13$).

In the first stage of the study, the different results were analysed according to the sex, side and age of the individuals by means of the chi-square test.

In the second stage, cluster analyses were performed on all the male and female series of the five populations. 'In statistics, the search for relatively homogenous groups of objects is called *cluster analysis*' (Norusis, 1986). The goal of cluster analysis is to identify similar groups of series or populations that will form agglomerations. In a sample of populations that are each associated with a series of variables, cluster analysis serves to classify them into the most homogeneous possible groups, based on the similarity or dissimilarity of these variables (Norusis, 1986; Bisquerra, 1989; Peña, 2002). Both cluster and discriminant analyses classify individuals into categories. The main difference between them is that in discriminant analysis the groups are known *a priori*, whereas an unpredictable number of homogeneous groups are formed during the cluster analysis process (Norusis, 1986; Bisquerra, 1989). A search of the literature indicated that in case of doubt, the most recommended method is the average linkage between groups, with the squared Euclidean distance as a measure of proximity (Wilminck & Uytterschaut, 1984; Norusis, 1986; Bisquerra, 1989; Peña, 2002). Moreover, this method can be used with distance measures (Norusis, 1986) and is widely used in physical anthropology, above all in studies based on the observation of discrete variables (Finnegan & Cooprider, 1978; Prowse & Lowell, 1996; Rao, 1984; Souich *et al.*, 2000; Turner, 1987; among others). In order to transform the discrete values (presence-absence) into quantitative values, our analysis was preceded by angular transformation of the percentages into radians, using the

Figure 2. 1: Absence of deltoid marker; 2: Presence of deltoid marker; 3: Absence of *pectoralis* and *teres* markers; 4: Presence of *pectoralis* marker. 5: Presence of *teres* marker.

Figure 3. 1: Absence of radial tuberosity marker; 2: Presence of radial tuberosity marker; 3: Absence of enthesophyte on olecranon; 4: Presence of enthesophyte on olecranon; 5: Absence of supinator marker; 6: Presence of supinator marker.

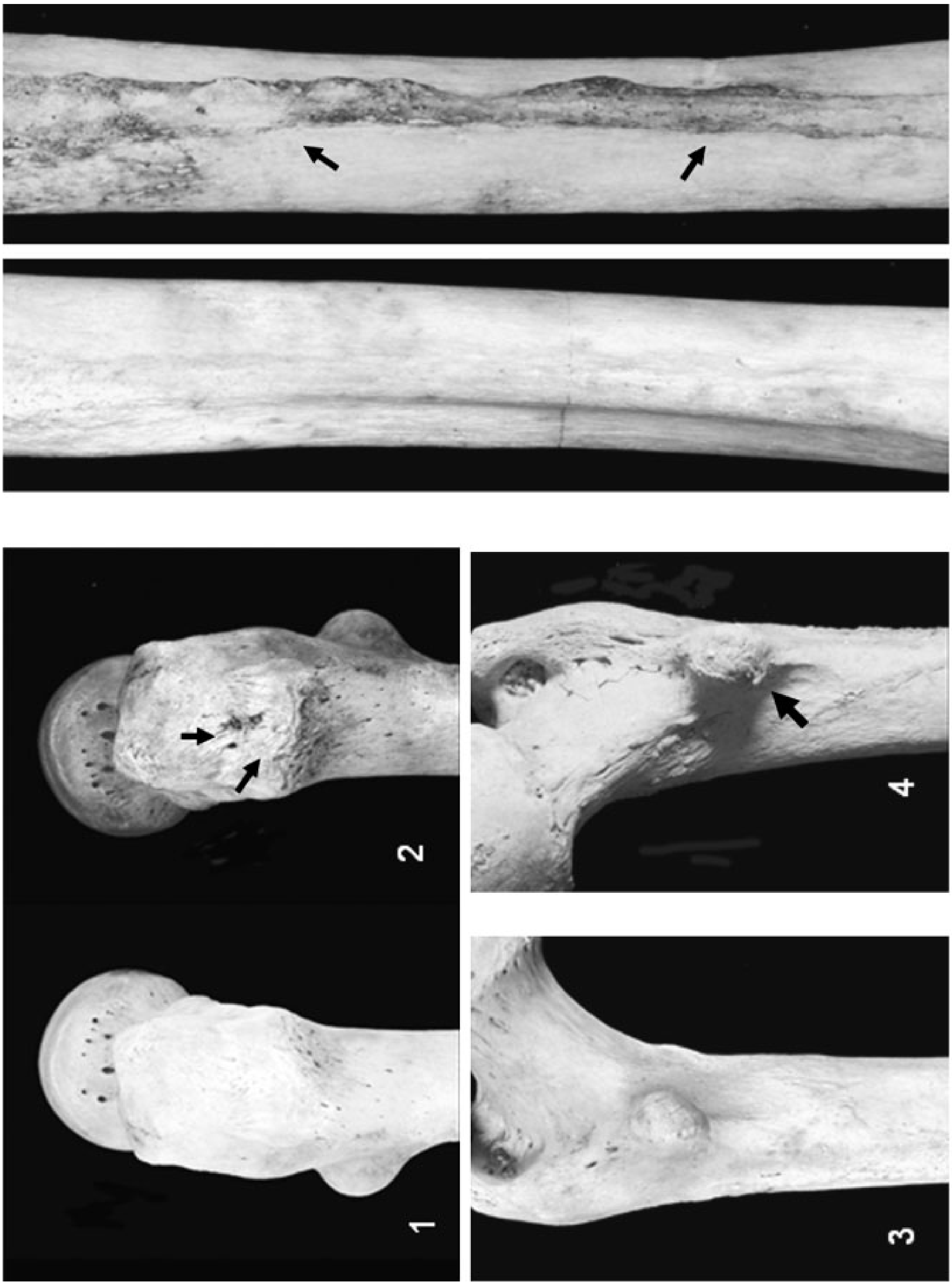

Figure 4. 1: Absence of enthesophytes on greater trochanter; 2: Presence of enthesophytes on greater trochanter; 3: Absence of enthesophytes on lesser trochanter; 4: Presence of enthesophytes on lesser trochanter; 5: Absence of enthesophytes on *linea aspera*; 6: Presence of enthesophytes on *linea aspera*.

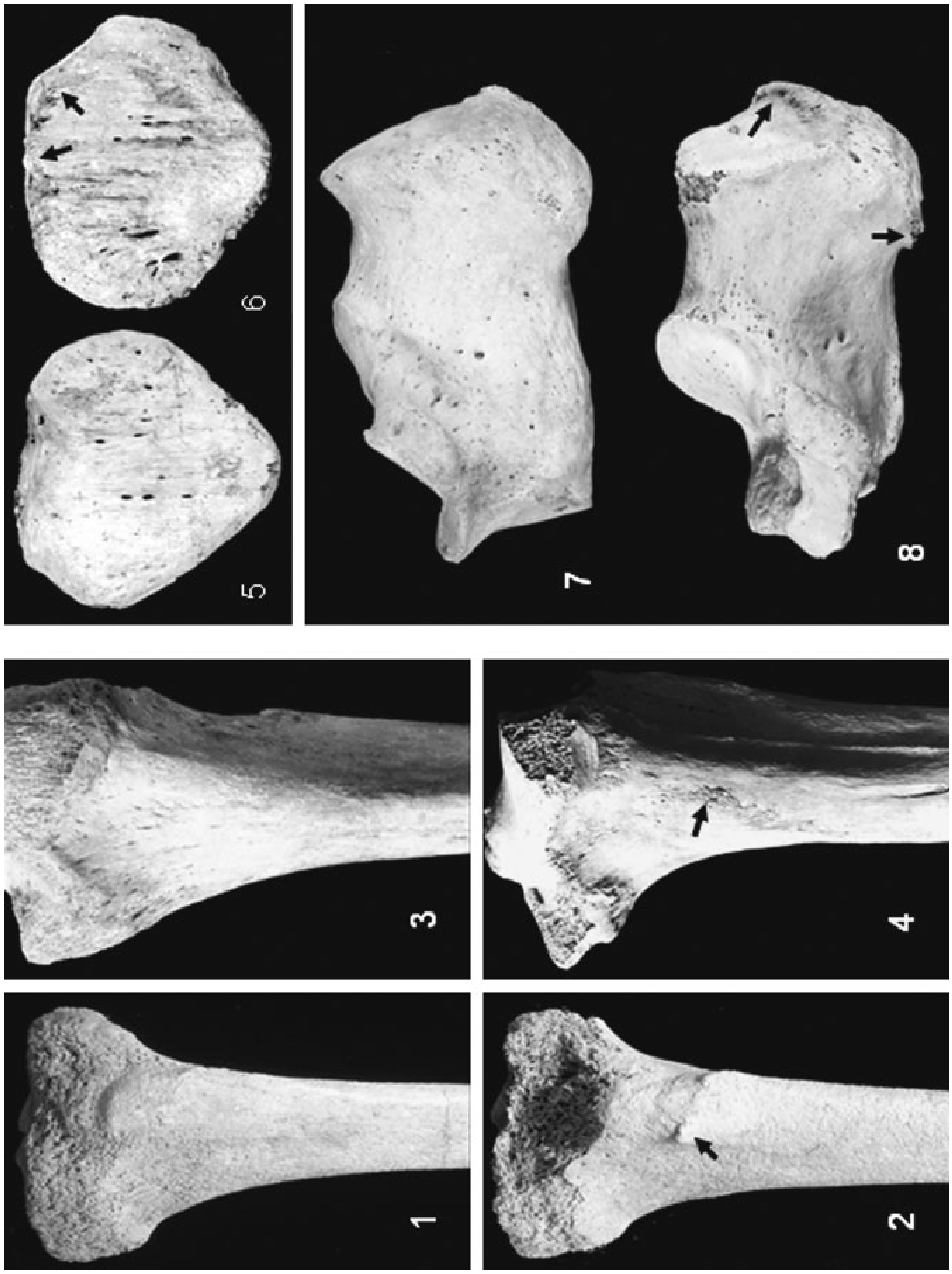

Figure 5. 1: Absence of tibial tuberosity marker; 2: Presence of tibial tuberosity marker; 3: Absence of popliteal line marker; 4: Presence of popliteal line marker; 5: *Patella* without enthesophytes; 6: *Patella* with enthesophytes; 7: Absence of Achilles tendon and spur markers; 8: Presence of Achilles tendon and spur markers.

equation $\theta = \sin^{-1}(1 - 2p)$ (Berry & Berry, 1967). The dendrogram is the graphical representation of the cluster analysis result.

Results

Laterality

No population showed any significant differences between the left and right side. However, greater asymmetry was observed in the upper limbs (see Table 3).

Age

As expected (Mann & Murphy, 1990), we observed higher frequencies of markers among mature adults, although statistical significance was reached in only a few cases (see Tables 4–6). In San Baudelio, individuals of more advanced age tended to present more markers, although without significant differences, possibly due to the small sample size. The absence of significant differences between young adults and mature adults of either sex in La Carada may also have been influenced by the small number of individuals over 40 years old. In La Torrecilla, significant age differences were only found for two markers in males and two in females. In Villanueva, some markers showed higher frequencies in young adults, and only four markers were found with a clearly greater frequency among the mature adults. The mature females in Villanueva always presented higher values, although statistical significance was only reached for one marker. Finally, the Argar population showed

Table 3. Frequency of markers by side

Features	Carada		Argar		Torrecilla		Villanueva		Baudelio	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)
Pectoralis major	25/20	27/10	72/31	64/16	91/20	87/11	54/32	47/24	21/6	22/3
	80.0	**37.0**	**43.0**	**25.0**	**22.0**	**12.6**	**59.2**	**51.1**	**28.6**	**13.6**
Teres major	25/12	23/11	72/23	63/8	91/20	87/9	55/22	47/14	21/6	22/3
	48.0	**47.8**	**31.9**	**12.7**	**22.0**	**10.3**	**40.0**	**29.8**	**28.6**	**13.6**
Deltoid	33/9	27/3	71/14	66/11	90/31	89/25	55/26	49/18	21/5	22/3
	27.3	**11.1**	**19.7**	**16.7**	**34.4**	**28.1**	**47.2**	**36.7**	**23.8**	**13.6**
Olecranon	53/12	55/4	60/13	63/12	59/13	65/8	40/7	38/12	23/11	26/10
	22.6	**7.3**	**21.7**	**19.0**	**22.0**	**12.3**	**17.5**	**31.6**	**47.8**	**38.5**
Supinator	74/28	70/15	62/24	71/17	86/23	84/13	52/10	46/11	23/9	26/7
	37.8	**21.4**	**38.7**	**23.9**	**26.7**	**15.5**	**19.2**	**23.9**	**39.1**	**26.9**
Radius	71/25	64/26	64/21	69/18	90/26	82/17	47/20	47/20	23/12	25/12
	35.2	**40.6**	**32.8**	**26.1**	**28.9**	**20.7**	**42.5**	**42.5**	**52.5**	**48.0**
Great. trochanter	20/1	9/0	53/10	54/9	55/7	8/4	38/16	39/18	26/6	23/7
	5.0	**0.0**	**18.9**	**16.7**	**12.7**	**6.9**	**42.1**	**46.1**	**23.1**	**30.4**
Les. trochanter	19/1	11/2	53/10	52/10	63/12	66/11	44/16	45/13	27/6	24/6
	5.3	**18.2**	**18.9**	**19.2**	**19.0**	**16.7**	**36.4**	**28.9**	**22.2**	**25.0**
Linea aspera	20/9	25/16	68/12	67/12	88/26	91/24	53/25	63/24	26/6	23/5
	45.0	**64.0**	**17.6**	**17.9**	**29.5**	**26.4**	**47.2**	**38.1**	**23.1**	**21.7**
Patella	50/5	43/6	46/18	43/17	24/4	21/4	22/6	14/6	7/4	4/3
	10.0	**14.0**	**39.1**	**39.5**	**16.7**	**19.0**	**27.3**	**42.8**	**57.1**	**75.0**
Tibial tuberos.	18/0	24/0	60/13	59/13	71/13	70/12	38/6	36/9	26/3	22/4
	0.0	**0.0**	**21.7**	**22.0**	**18.3**	**17.1**	**15.8**	**25.0**	**11.5**	**18.2**
Popliteal line	30/15	27/9	60/15	59/14	88/16	89/15	47/18	43/17	25/8	22/6
	50.0	**33.3**	**25.0**	**23.7**	**18.2**	**16.8**	**38.3**	**39.5**	**32.0**	**27.3**
Achilles tendon	46/22	36/18	62/30	59/32	43/8	38/6	31/15	31/18	17/11	19/3
	47.8	**50.0**	**50.0**	**54.2**	**18.6**	**15.8**	**48.4**	**58.1**	**64.7**	**68.4**
Spur	41/8	36/5	61/11	58/12	47/5	46/3	30/1	31/4	17/1	19/0
	19.5	**13.9**	**18.0**	**20.7**	**10.6**	**6.5**	**3.3**	**12.9**	**5.9**	**0.0**

N: number of individuals; k: number of individuals with the trait.

Table 4. Differences by age: males

Features	Carada		Argar		Torrecilla		Villanueva		Baudelio	
	Ya	Ma	Ya	Ma	Ya	Ma	Ya	Ma	Ya	Ma
	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)
Pectoralis major	13/11	3/3	25/12	19/13	31/8	19/8	19/14	9/6	9/3	4/2
	84.6	**100**	**48.0**	**68.4**	**25.8**	**42.1**	**73.7**	**66.6**	**33.3**	**50.0**
Teres major	13/6	3/3	26/9	19/9	31/9	19/8	19/12	9/5	9/4	4/1
	46.1	**100**	**34.6**	**47.4**	**29.0**	**42.1**	**63.1**	**55.5**	**44.4**	**25.0**
Deltoid	18/5	3/0	26/3	19/10	31/11	19/10	18/8	9/7	9/2	4/2
	27.8	**0.0**	**11.5**	**52.6**	**35.5**	**52.6**	**44.4**	**77.7**	**22.2**	**50.0**
Olecranon	26/8	4/2	24/6	18/7	30/12	18/7	15/3	9/4	11/6	5/3
	30.8	**50.0**	**25.0**	**38.9**	**40.0**	**38.9**	**20.0**	**44.4**	**54.5**	**60.0**
Supinator	31/11	4/4	25/8	17/8	28/4	17/5	18/1	9/1	11/8	5/2
	35.5	**100**	**32.0**	**47.0**	**14.3**	**29.4**	**5.5**	**11.1**	**72.7**	**40.0**
Radius	35/11	4/3	27/5	17/10	30/10	19/8	20/6	9/8	11/9	4/2
	31.4	**75.0**	**18.5**	**58.5**	**33.3**	**42.1**	**30.0**	**88.9**	**81.8**	**50.0**
Great. trochanter	10/1	0/0	25/6	12/8	24/2	13/3	15/2	7/6	10/4	5/3
	10.0	**0.0**	**24.0**	**66.7**	**8.33**	**23.1**	**13.3**	**85.7**	**40.0**	**60.0**
Les. trochanter	7/1	0/0	22/5	12/9	27/6	12/7	18/3	8/7	10/5	5/2
	14.3	**0.0**	**22.7**	**75.0**	**22.2**	**58.3**	**16.7**	**87.5**	**50.0**	**40.0**
Linea Aspera	8/2	2/1	27/5	17/6	32/9	18/12	20/7	9/9	10/3	5/3
	25.0	**50.0**	**18.5**	**35.3**	**28.1**	**66.7**	**35.0**	**100**	**30.0**	**60.0**
Patella	23/1	4/2	13/4	17/12	13/1	9/4	10/2	5/3	3/1	2/1
	4.3	**50.0**	**30.8**	**70.6**	**7.7**	**44.4**	**20.0**	**60.0**	**33.3**	**50.0**
Tibial tuberos.	10/0	2/0	24/4	17/9	30/8	13/6	17/4	6/2	10/2	4/2
	0.0	**0.0**	**16.7**	**52.9**	**26.7**	**46.1**	**23.5**	**33.3**	**20.0**	**50.0**
Popliteal line	18/9	3/3	22/7	16/6	31/7	18/11	19/7	7/6	10/4	4/3
	50.0	**100**	**31.8**	**37.5**	**22.6**	**61.1**	**36.8**	**85.7**	**40.0**	**75.0**
Achilles tendon	20/10	4/2	18/13	17/14	21/5	8/3	12/6	8/7	9/7	3/3
	16.7	**50.0**	**72.2**	**82.3**	**23.8**	**37.5**	**50.0**	**87.5**	**77.8**	**100**
Spur	18/3	4/3	18/4	17/5	23/6	11/1	12/0	8/1	9/1	3/0
	16.7	**75.0**	**22.2**	**29.4**	**26.1**	**9.1**	**0.0**	**12.5**	**11.1**	**0.0**

Ya: young adults; Ma: mature adults; N: number of individuals; k: number of individuals with the trait.

significant differences for five male markers and one female marker, possibly because this series contained the greatest number of mature adults of both sexes.

Sex

Table 7 exhibits the frequency of markers observed by sex in the five populations. Table 8 shows the probability values obtained after comparison between the males and females using the χ^2 test.

The La Carada population showed no statistically significant differences between the sexes, although there was a tendency for marker frequencies to be higher in the males (with the exception of the deltoid marker). This was the population with least dimorphism in the arms and legs. Both sexes showed higher frequencies in the upper extremities.

In El Argar, the males presented a much higher frequency of markers versus the females, and for eight markers the differences were statistically significant. The greatest leg dimorphism was shown by the Argar population, with the women having a lesser leg development, whereas the dimorphism in the arms was intermediate.

In La Torrecilla, the muscle development of the males was much greater than that of the females, and there was a marked dimorphism in both arms and legs.

The population of Villanueva showed the least sexual dimorphism and the females presented strong muscle development, with a higher frequency in four markers, although only two

Table 5. Differences by age: females

Features	Carada		Argar		Torrecilla		Villanueva		Baudelio	
	Ya	Ma	Ya	Ma	Ya	Ma	Ya	Ma	Ya	Ma
	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)
Pectoralis major	7/5	2/1	25/5	10/5	36/4	10/2	21/6	6/4	10/1	0/0
	71.4	50.0	20.0	50.0	11.1	20.0	28.6	66.7	10.0	0.0
Teres major	7/2	2/1	22/3	10/3	34/4	11/2	21/4	6/1	10/0	0/0
	28.6	50.0	13.6	30.0	11.8	18.2	19.0	16.7	0.0	0.0
Deltoid	10/3	2/1	22/2	11/2	36/6	8/5	19/5	6/4	10/0	0/0
	30.0	50.0	9.1	18.2	16.7	62.5	26.3	66.7	0.0	0.0
Olecranon	20/1	3/1	25/2	12/1	30/2	6/0	14/4	4/3	10/2	0/0
	5.0	33.3	8.0	8.3	6.7	0.0	28.6	75.0	20.0	0.0
Supinator	34/10	5/2	23/3	12/5	36/7	10/3	18/6	5/1	10/1	0/0
	29.4	40.0	13.0	41.7	19.4	30.0	33.3	20.0	10.0	0.0
Radius	27/9	5/2	24/3	12/6	34/1	12/5	21/1	5/4	10/2	0/0
	33.3	40.0	12.5	50.0	2.9	41.7	23.8	80.0	20.0	0.0
Great. trochanter	7/0	3/0	20/1	11/1	29/2	4/1	17/9	2/1	11/1	0/0
	0.0	0.0	5.0	9.1	6.9	25.0	52.9	50.0	9.1	0.0
Les. trochanter	9/0	3/0	20/0	10/1	34/3	5/0	16/3	5/4	12/1	0/0
	0.0	0.0	0.0	10.0	8.8	0.0	18.7	80.0	8.3	0.0
Linea Aspera	7/3	3/0	23/1	10/1	34/5	9/4	18/5	6/4	11/0	0/0
	42.9	0.0	4.3	10.0	14.7	44.4	27.8	66.7	0.0	0.0
Patella	19/2	4/0	17/2	8/2	11/1	0/0	8/2	2/1	2/1	0/0
	10.5	0.0	11.8	25.0	9.1	0.0	25.0	50.0	50.0	0.0
Tibial tuberos	6/0	0/0	16/0	8/1	28/3	8/1	14/2	5/1	13/0	0/0
	0.0	0.0	0.0	12.5	10.7	12.5	14.3	20.0	0.0	0.0
Popliteal line	7/2	2/1	19/2	10/1	36/2	7/1	16/4	5/3	12/1	0/0
	28.6	50.0	10.5	10.0	5.6	14.3	25.0	60.0	8.3	0.0
Achilles tendon	18/0	4/0	23/3	9/5	16/1	3/0	13/3	4/4	7/3	0/0
	0.0	0.0	13.0	55.5	6.3	0.0	23.1	100.0	42.8	0.0
Spur	15/1	4/1	23/2	9/3	18/0	2/0	13/1	4/2	7/0	0/0
	6.7	25.0	8.7	33.3	0.0	0.0	7.7	50.0	0.0	0.0

Ya: young adults; Ma: mature adults; N: number of individuals; k: number of individuals with the trait.

Table 6. Differences by age in each sex: probability values

Features	Carada		Argar		Torrecilla		Villanueva		Baudelio	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Pectoralis major	0.86	0.44	0.29	0.17	0.37	0.83	0.95	0.22	0.96	—
Teres major	0.14	0.54	0.57	0.54	0.52	0.97	0.98	0.64	0.96	—
Deltoid	0.87	0.75	<0.001	0.85	0.37	0.02	0.22	0.19	0.72	—
Olecranon	0.67	0.94	0.53	0.54	0.82	0.74	0.42	0.27	0.73	—
Supinator	0.75	0.38	0.51	0.14	0.40	0.78	0.79	0.98	0.49	—
Radius	0.95	0.62	0.01	0.04	0.08	<0.001	0.01	0.06	0.57	—
Great. trochanter	0.91	—	0.03	0.75	0.45	0.80	<0.001	0.50	0.85	—
Les. Trochanter	0.64	—	<0.001	0.72	0.06	0.83	<0.001	0.06	0.85	—
Linea aspera	0.38	0.68	0.37	0.87	0.01	0.14	<0.001	0.22	0.58	—
Patella	0.97	0.67	0.07	0.80	0.13	—	0.33	0.86	0.58	—
Tibial tuberos	—	—	0.03	0.72	0.37	0.62	0.94	0.68	0.18	—
Popliteal line	0.32	0.54	0.98	0.55	0.01	0.98	0.07	0.36	0.55	—
Achilles tendon	0.59	0.58	0.76	<0.001	0.78	0.33	0.21	0.03	1.00	—
Spur	0.64	0.94	0.93	0.24	0.69	—	0.83	0.23	0.55	—

Table 7. Frequency of markers by sex

Features	Carada		Argar		Torrecilla		Villanueva		Baudelio	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k (%)	N/k/ (%)	N/k/ (%)	N/k/ (%)	N/k/ (%)
Pectoralis major	16/14	9/6	41/24	31/7	47/15	44/5	29/22	25/10	13/5	10/1
	87.5	**66.7**	**58.5**	**20.0**	**31.9**	**11.3**	**75.9**	**40.0**	**38.5**	**10.0**
Teres major	16/9	9/3	40/17	32/6	47/15	44/5	29/17	26/5	13/6	10/0
	66.3	**33.3**	**42.5**	**18.7**	**31.9**	**11.3**	**58.6**	**19.2**	**46.1**	**0.0**
Deltoid	21/5	12/4	40/10	31/4	47/21	43/10	28/16	27/1	13/5	10/0
	23.8	**33.3**	**25.5**	**12.9**	**44.7**	**23.2**	**57.1**	**37.0**	**38.5**	**0.0**
Olecranon	30/10	23/2	35/10	25/3	40/11	27/2	25/4	15/3	16/10	10/2
	33.3	**8.7**	**28.6**	**10.0**	**27.5**	**7.4**	**16.0**	**20.0**	**62.5**	**20.0**
Supinator	35/16	39/12	35/19	27/5	46/14	40/9	29/4	23/6	16/8	10/1
	45.7	**30.8**	**54.3**	**25.0**	**30.4**	**22.5**	**13.8**	**26.1**	**50.0**	**10.0**
Radius	39/14	32/11	35/14	29/7	47/21	43/5	26/13	21/7	15/10	10/2
	35.9	**34.4**	**40.0**	**21.9**	**44.7**	**11.6**	**50.0**	**33.3**	**66.7**	**20.0**
Great.trochanter	10/1	10/0	29/9	24/1	30/5	25/2	20/7	18/9	15/6	11/1
	10.0	**0.0**	**31.0**	**7.7**	**16.7**	**8.0**	**35.0**	**50.0**	**40.0**	**9.1**
Les. Trochanter	7/1	12/0	30/10	23/0	29/10	34/2	25/10	19/6	15/6	12/1
	14.3	**0.0**	**33.3**	**0.0**	**34.5**	**5.9**	**40.0**	**31.6**	**40.0**	**8.3**
Linea aspera	10/3	10/3	39/10	29/2	45/18	43/8	30/16	23/9	15/6	11/0
	60.0	**30.0**	**25.6**	**6.7**	**40.0**	**18.6**	**53.3**	**39.1**	**40.0**	**0.0**
Patella	27/3	23/2	28/15	18/3	17/3	7/1	14/4	8/2	5/3	2/1
	11.1	**8.7**	**53.6**	**16.7**	**17.6**	**14.3**	**28.6**	**25.0**	**60.0**	**50.0**
Tibial tuberos.	12/0	6/0	35/11	25/2	38/10	33/3	22/6	16/2	13/4	13/0
	0.0	**0.0**	**31.4**	**8.0**	**26.3**	**9.1**	**27.3**	**12.5**	**30.7**	**0.0**
Popliteal line	21/12	9/3	33/12	27/3	47/15	41/1	26/12	21/6	13/4	12/1
	57.1	**33.3**	**36.4**	**11.1**	**31.9**	**2.4**	**46.1**	**28.6**	**53.8**	**8.3**
Achilles tendon	24/12	22/0	30/23	32/7	25/7	18/1	19/12	12/3	12/10	7/3
	50.0	**45.5**	**76.7**	**21.9**	**28.0**	**5.5**	**63.1**	**25.0**	**83.3**	**42.8**
Spur	22/6	19/2	29/7	32/4	29/5	18/0	18/1	12/0	12/1	7/0
	27.3	**10.5**	**24.1**	**12.5**	**17.2**	**0.0**	**5.6**	**0.0**	**8.3**	**0.0**

N: number of individuals; k: number of individuals with the trait.

humerus markers showed statistically significant differences. There was a large muscle development in both sexes. We highlight the minimal dimorphism in the lower extremities.

Table 8. Differences by sex: probability values

Features	Carada	Argar	Torrecilla	Villanueva	Baudelio
Pectoralis major	0.47	<0.001	0.03	0.02	0.29
Teres major	0.49	0.05	0.03	<0.001	0.07
Deltoid	0.84	0.33	0.04	0.22	0.09
Olecranon	0.07	0.22	0.08	0.83	0.08
Supinator	0.28	<0.001	0.54	0.15	0.09
Radius	0.91	0.28	<0.001	0.39	0.06
Great.trochanter	1.00	0.03	0.54	0.37	0.19
Les. trochanter	0.78	<0.001	0.02	0.87	0.15
Linea aspera	0.37	0.09	0.06	0.53	0.05
Patella	0.85	0.02	0.91	0.75	0.55
Tibial tuberos.	—	0.06	0.10	0.82	0.10
Popliteal line	0.43	0.05	<0.001	0.55	0.04
Achilles tendon	0.99	<0.001	0.14	0.54	0.19
Spur	0.34	0.40	0.42	0.46	0.78

San Baudelio is the population with greatest dimorphism in the arms, and there was also dimorphism in the legs, although only two markers were found to be significantly different.

Comparisons

Comparisons among the different populations were performed using cluster analysis. The series were separated by sex and site; in addition, given the differences in frequencies of markers between upper and lower limbs, the arm and leg variables were analysed separately before being analysed together. Figure 6 depicts the dendrograms corresponding to these cluster analyses.

In the dendrogram corresponding to the cluster analysis of upper limb variables (top of Figure 6), the males are separated from the females, although the women of Villanueva and

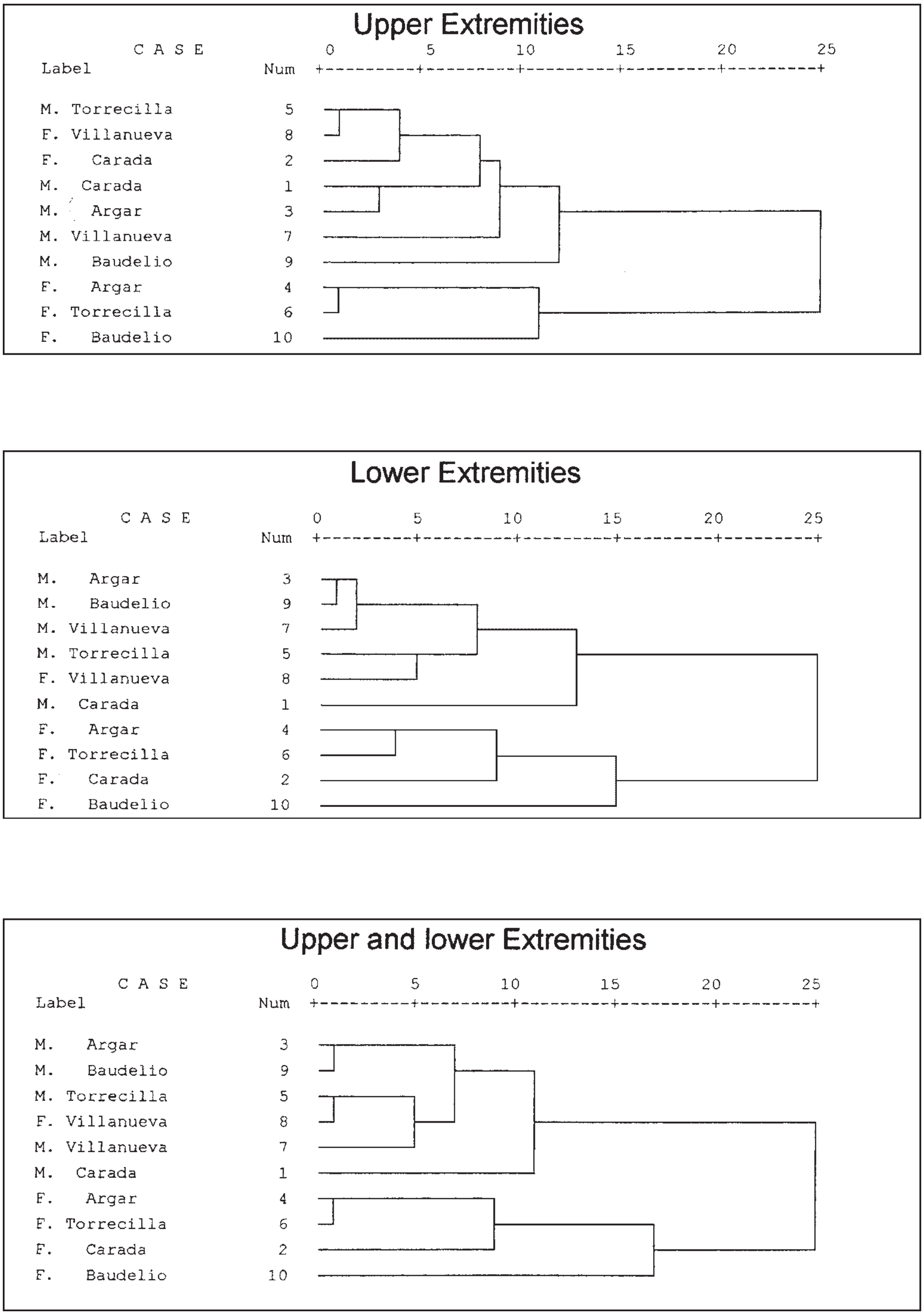

Figure 6. Cluster analysis (M: men; F: women).

La Carada, those with greatest female arm muscle development, are clustered with the men of La Torrecilla, those with the lowest male arm muscle development. A second group contains the prehistoric men of La Carada and El Argar, who present similar frequencies and are separated from the men of Villanueva and San Baudelio, who share a strong arm muscle development. The last group is formed only by females (the women of San Baudelio show lesser arm development than the women of El Argar and La Torrecilla).

According to the squared Euclidian distances, the series with widest dissimilarities are the males of Villanueva and the men and women of San Baudelio, those with greatest muscle development among the men and the least among the women, respectively. In general, the cluster of the arm variables classifies the series according to the greater or lesser muscle development they present, and indicates that the women of La Carada and Villanueva performed very intense activities with their upper extremities.

In the analysis of the lower limbs (middle of the Figure 6), two main clusters are separated: one contains only women and the other only men, except for the inclusion of the women of Villanueva. This cluster contains a smaller cluster of men from El Argar and San Baudelio, predominantly herdsmen, along with the Villanueva farmers, who were peasant-soldiers, and another cluster including the men of La Torrecilla and the women of Villanueva. The men of La Torrecilla lived on flat lands and were predominantly agriculturalists, whereas the women of Villanueva, who showed considerable development of their lower limbs, must have played a major role in hard tasks. The La Carada men form a separate group within the first main cluster because of the different frequencies they showed.

The second primary cluster contains the women of El Argar and La Torrecilla. They differ from the women of La Carada and San Baudelio, who present greater muscle development in their lower extremities. The values of the squared Euclidean distance are higher than those obtained with the matrix made with upper extremity variables, indicating that there is less similarity among the populations in the musculoskeletal markers of the legs.

In the third cluster analysis (bottom of Figure 6), performed using all variables, there are two primary clusters. The first contains all the men plus the women of Villanueva, who are grouped with the men of La Torrecilla, who had least muscle development among the males. Once more, individuals from the Argar culture and San Baudelio are found together; these populations lived in the most mountainous terrain and herding played a major role in both economies. The other groups contain the populations (La Torrecilla, Villanueva, and La Carada) that practised agriculture and lived in flat lands. Once again, the women of Villanueva are grouped with the men of La Torrecilla, emphasizing the marked physical activity of these women.

In the second cluster, the women of San Baudelio, with the least muscle development, form one line. A separate group is formed by the women of El Argar and La Torrecilla who show a lesser leg development. The women of La Carada also form a separate group, presenting strong arms and less developed legs.

Discussion

Laterality

In general, given the equal work of each leg in locomotion, the arms are usually more asymmetrical than the legs; around 95% of modern humans present right handedness. A minimal difference between sides is an indicator of heavy work, in which both arms participate equally (Steele, 2000). Among present-day populations, the greatest asymmetry is presented by sedentary workers who carry out light work, using their hands more than their arms (Steele, 2000).

We observed a slight dominance of the right arm over the left arm in all series reflecting the above-mentioned predominance. The population with least arm asymmetry was that of Villanueva, both in males and females. The sample with the greatest arm asymmetry was that of San Baudelio, although these differences were not statistically significant. The distribution of asymmetry by sex followed no clear tendency: in some populations it was slightly greater among males and in other populations among females. These small differences can be attributed to random effects rather than to sex-based divisions of labour.

Age

Although the age groups were comparable according to the cross tabulations, we cannot know whether the results obtained were more or less influenced by the small size of some samples or whether they correspond to differences in activity between the different populations (Table 1). We found 11 differences among males and only four differences among the females. Wilczak (1998) pointed out that differences due to age are more marked among males, which she attributed to the delay in physical maturation of the male sex. However, this may also in part reflect gender differences in activity, given that males may perform more strenuous tasks throughout their life, subjecting their muscles to a greater number of microtraumas. There was no clear pattern in the distribution of age differences between the extremities. The distribution was irregular in each population and sex, making discussion of possible interpretations unrewarding.

Nevertheless, most differences among the males were in the lower extremities, which does not contradict the fact that the lower extremities work more constantly in locomotion throughout the life span.

Sex

In general, the males in all the populations presented higher frequencies of musculoskeletal stress markers compared with the females. This is the general norm in human populations, although the degree of sexual dimorphism differed among the populations and also between the arms and legs. Wilczak (1998) reported that populations with agriculture-based economies present the least dimorphism in lower extremities. Indeed, in the present study, the two populations with greatest dimorphism in legs (El Argar & San Baudelio) were the most involved in livestock raising and lived in the steepest lands (Table 1), whereas the economies of the populations with no leg dimorphism (La Carada & Villanueva) were based on agriculture. The high leg dimorphism of the people of Torrecilla, also a community of agriculturalists, indicates the clear sexual division of labour consistent with the Muslim culture, with the women involved in very different activities from the men (López de la Plaza, 1992). The marked differences between the males and females of San Baudelio may also suggest a clear sexual division of labour. In the Argar culture, women may also have engaged in different activities from the men, a finding supported by the study of arthrosis and trauma in this population (Botella *et al.*, 1995; Jiménez-Brobeil *et al.*, 1995). On the other hand, the women of La Carada and Villanueva were engaged in strong physical activity that was almost as intense as that of the men.

Comparisons

The cluster with arm variables (top of Figure 6) classifies the series according to the greater or lesser muscular development that they present. We highlight that the women of La Carada and Villanueva carried out very intense activities with their upper members.

The second cluster (middle of Figure 6) better reflects the environmental and cultural differences among the series (Table 1). It closely groups the men from El Argar (mixed economy) with those from San Baudelio (herding), and associates them with the Villanueva men, who were peasant-soldiers. The grouping of the men from La Torrecilla with the Villanueva women reflects the overall gracility of these men (Souich, 1979), and underlines the participation of the Villanueva women in hard tasks.

The third cluster (bottom of Figure 6) again groups together the men of El Argar and San Baudelio, who lived in the most mountainous terrains (rugged) and had economies in which animal rearing played a major role (Table 1). Interestingly, another group contains agriculturalists, those from La Carada, La Torrecilla, and Villanueva, who lived on flat lands. Regarding the females, the Argaric women and those from La Torrecilla show an average arm development and a lesser leg development, indicating that their activities were more domestic and very different from those of the men. The high frequencies of the three last variables of the leg in the Argaric women are consistent with their habitat in steep hilly areas (rugged). The cluster again underlines the intense physical activity of the women from Villanueva and separates them from the La Carada women who, despite the strong development of their arms, lived on flat lands and had less developed legs.

Conclusions

The results obtained have proven to be consistent with the historical and archaeological knowledge available. However, our analysis of musculoskeletal stress markers cannot yield precise information on the physical activities carried out by these populations.

The individuals of La Carada (Early Copper Age) showed very little sexual dimorphism. Both sexes likely practised similar activities. The strong muscle development of the upper extremity and the lesser development of the lower extremity are consistent with their agricultural activity on flat lands.

The individuals of La Torrecilla, (Medieval) showed considerable sexual dimorphism. Although their agricultural activity was on flat lands, women may not have participated and just carried out domestic activities.

The men of El Argar, (Bronze Age) and San Baudelio, (Medieval) had a similar appearance, which may confirm that both groups practised livestock raising and had to walk over very rough terrain. In contrast, the activity of the women of El Argar was possibly centred on the home, involving much less walking, which may explain their similarity with the women of La Torrecilla.

The women of San Baudelio formed a separate cluster in our statistical analysis because of the very low arm muscle development. However, the development of their lower extremities could reflect arduous walking on the rough terrain of their environment. There was considerable sexual dimorphism, although our conclusions are limited by the small skeleton sample.

The major muscle development of the men and women of Villanueva, (Medieval) is consistent with their equal participation in agricultural work and with the military activity of the males. The similar muscle development of the lower and upper extremities indicates hard walking and intense work.

The broad agreement between the results obtained for these populations and the known historic and archaeological data is an important finding. It indicates that this methodology could be applied to the study of the modes and means of life of other populations on which there are inadequate data, providing a minimum base for results interpretation and minimizing gratuitous speculation.

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