

A contribution to the study of enthesal changes

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El objetivo de este estudio es realizar una aportación a la metodología del análisis de las modificaciones de las entesas a partir del estudio de 109 individuos, con sexo y edad conocido, fechados en el siglo XX. Se ha empleado el método de Al Oumaoui et al. (2004) y los resultados obtenidos se han comparado con los de otras poblaciones del pasado. Los varones del siglo XX no difieren excesivamente de los de las otras poblaciones pero las mujeres presentan frecuencias altas de modificaciones de las entesas que pueden obedecer a la influencia de la edad y los cambios hormonales. Se concluye que en los estudios dirigidos al análisis de estos marcadores se deben excluir a los individuos mayores de 50 años y a los que presenten calcificaciones y anquilosis. Por otro lado, sólo se podrán comparar poblaciones genéticamente próximas y con similar estructura por clases de edad.

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Introduction

The reconstruction of past lifestyles and activity patterns has been widely undertaken by physical anthropologists and paleopathologists in recent years. The most common method is by studying entheses, also known as enthesopathies or musculoskeletal stress markers (MSM). Entheses are sites at which a tendon, capsule or ligament attaches to bone (Ball, 1971; Benjamin et al., 2002) and there are two types, fibrocartilaginous and fibrous (Benjamin et al., 2002). Fibrocartilaginous entheses appear at the epiphyses of bones and on short bones and some parts of vertebrae and can be histologically classified as tendon/ligament, uncalcified fibrocartilage, calcified fibrocartilage or subchondral bone (Benjamin et al., 2006; Villotte et al., 2010). Fibrous entheses attach tendons and muscles to diaphyses either directly or via the periosteum (Benjamin et al., 2002).

Among the various terms for these entities in the anthropological literature, the most widely used are enthesopathies (Alves Cardoso and Henderson, 2010; Ball, 1971; Dutour, 1986; Mariotti et al., 2004; Villotte et al., 2010), MSM (Al Oumaoui et al., 2004; Chapman, 1997; Hawkey and Merbs, 1995; Weiss et al., 2010) or simply entheses (Henderson and Gallant, 2007; Mariotti et al., 2007). Diverse scoring procedures have also been applied (Al Oumaoui, et al., 2004; Mariotti et al., 2004 and 2007; Villotte, 2006 among others), and a workshop was held in Coimbra University in July 2009 to agree on a standardised methodological approach.

At this workshop, entitled “Musculoskeletal stress markers: limitations and achievements in the reconstruction of past activity patterns”, Jurmain and Villotte (2010) proposed exclusive use of the term “enthesal changes”, on the grounds that “enthesopathy”, a designation created by clinical researchers, implies a pathological condition and is therefore not appropriate for highly common and probably asymptomatic changes. However, it should be born in mind that anthropologists have often made an arbitrary distinction between their physiological and pathological nature of these changes (Villotte et al., 2010). Jurmain and Villotte also considered MSM to be an unsuitable term, arguing that the aetiology of enthesal changes is multifactorial, with other conditions besides physical activity playing a role, including age (Al Oumaoui et al., 2004; Alves Cardoso and Hen-

derson, 2010; Stirland, 1998; Villotte et al., 2010; Wilczak, 1998); degenerative diseases, such as DISH or seronegative spondyloarthropathies (Al Oumaoui et al., 2004; Aufderheide and Rodríguez Martín, 1998; Ball, 1971; Benjamin and McGonagle, 2001; Resnick and Niwayama, 1983; Rogers et al., 1997); genetic factors (Al Oumaoui et al., 2004; Wilczak, 1998); and biological sex differences, e.g., hormonal factors and body size (Gettler et al., 2010; Weiss et al., 2010; Wilczak, 1998). Given these limitations, the selection of entheses for study is critical (Villotte et al., 2010), and there is a need to control as far as possible for the different factors implicated in their development (Al Oumaoui et al., 2004; Alves Cardoso and Henderson, 2010). However, enthesal changes cannot yield precise information about the physical activities of past populations (Al Oumaoui et al., 2004), and their utilisation as an activity marker has been oversimplified (Alves Cardoso and Henderson, 2010).

With the aim of elucidating the main factors involved in the aetiology of enthesal changes, the objective of this study was to analyze an osteological sample from a contemporary population with a known lifestyle in order to provide reference data for studies of ancient populations and for comparisons with other groups from the same geographical area with the same genetic background, controlling for some known influential factors.

Material and Methods

We studied a sample of 119 individuals of known sex and age and in a good state of preservation from the cemetery of the city of Granada who were born at the beginning of the 20th century. No records are available on the occupation of these individuals, but they had been exhumed at 10 years after the burial because their families did not pay for an extension of this time period, therefore it can be assumed that they were not from the more privileged social classes. In order to avoid the confounding effect of diseases that produce enthesal changes, we excluded 10 individuals with presence of ankylosis between vertebrae or in sacroiliac joint. The final study sample therefore comprised 109 individuals: 55 males and 54 females.

We used the method proposed by Al Oumaoui et al. (2004) and included an additional marker: the presence of enthesophytes below the glenoid fossa of the scapula, making a total of 15 markers (Table 1).

Table 1. Selected enthesal changes. (Villotte et al., 2010)

FC = fibrocartilaginous entheses; F = fibrous entheses

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

The study population was compared with other collections of the same genetic origin and studied by the same method in order to avoid the confounding factors of genetic differences in the formation of enthesal changes and disparities in the scoring approach. For this purpose, we selected populations from the Iberian Peninsula with known activity patterns: a Bronze Age population of the Argar culture (several sites from the

province of Granada) with mixed economy in a rugged terrain (Al Oumaoui et al., 2004; Jiménez-

Brobeil et al., 2004); Motilla del Azuer (Daimiel, Ciudad Real), another Bronze Age population with mixed economy who lived between flat and rugged lands (Jiménez-Brobeil et al., 2008); San Baudelio (Casillas de Berlanga, Soria), a Mediaeval livestock farm in a low mountain area (Al Oumaoui et al., 2004; Andrio and Loyola, 1992); La Torrecilla (Arenas del Rey, Granada), a Mediaeval village of Muslim peasants on flat lands (Al Oumaoui et al., 2004; Souich, 1979); and Villanueva (Villanueva de Soportilla, Burgos), a Mediaeval population of Christian peasant-soldiers on flat lands (Al Oumaoui et al., 2004; Souich et al., 1991).

In the original studies of these populations, senile individuals and those with signs attributable to diffuse idiopathic skeletal hyperostosis (DISH) were excluded because of the influence of advanced age and this disease on the formation of enthesal changes. These populations contain comparable percentages of adult and mature adults ($\chi^2 = 1.85$; $P = 0.60$).

Based on data from the above studies, an MMD (Mean Measure of Distance) matrix was created (Berry and Berry, 1967), using the squared Euclidean distance method as measure of proximity (Bisquerra, 1989; Peña, 2002), and a cluster analysis was performed, using the average linkage between groups.

Results and Discussion

In the 20th century population from Granada, non significant differences in markers were found between right and left upper limbs in either males or females although there are higher frequencies in right limbs. As expected, non significant differences were found between left and right lower limbs. Consequently, data for upper and for lower limbs were pooled for each sex (Table 2).

Table 2. Frequencies of enthesal changes in 20th century males and females

	MALES			FEMALES			χ^2	P
	N	n	%	N	n	%		
Glenoid fossa	96	35	36.4	95	35	36.8	0.01	0.92
Pectoralis major	88	66	75.0	84	51	60.7	3.4	0.06
Teres major	91	48	52.7	88	40	45.5	0.68	0.41
Deltoid	87	44	50.6	88	45	51.1	0.01	0.94
Olecranon	86	10	11.6	82	11	13.4	0.01	0.91
Supinator	92	31	33.7	78	16	20.5	3.04	0.08
Radius	94	30	31.9	78	23	29.5	0.03	0.86
Great trochanter	94	19	20.2	86	32	37.2	5.58	0.02
Lesser trochanter	97	28	28.9	83	21	25.3	0.14	0.71
Linea aspera	98	36	36.7	88	36	40.9	0.19	0.67
Patella	59	10	16.9	55	12	21.8	0.18	0.67
Tibial tuberosity	95	22	23.2	95	6	6.30	9.42	<0.001
Popliteal line	97	35	36.1	92	34	37.0	0.00	0.98
Achilles tendon	90	19	21.1	75	16	21.3	0.02	0.87
Spur	89	16	18.0	77	18	23.4	0.44	0.50

No significant differences in upper limb values were found between males and females and similar results were obtained for the lower limbs, with the exception of a significantly higher frequency of enthesophytes in the greater trochanter in the females versus the males and in the tibial tuberosity in the males versus the females. These are unexpected results, because they denote similar activity patterns between the sexes, contrasting with the usual finding in other populations of a higher development of enthesal changes in males due to their more strenuous activity and greater body size or the action of testosterone (Gettler et al., 2010; Weiss et al., 2010; Wilczak, 1998).

The comparative data in table 3 show that the frequency of markers was slightly higher in the 20th century males from Granada than in the males from the other populations. Figure 1 depicts the cluster analysis based on the MMD matrix of the 15 markers. As expected, the prehistoric and

mediaeval populations with mixed economy, which inhabited rugged terrain, are clustered together, whereas the peasants who lived on flat lands are in a distinct cluster, close to the modern males.

Table 3. Frequencies of enthesal changes in males of various populations

Ar: Argar culture; Mot: La Motilla del Azuer; Bau: San Baudelio de Berlanga; Tor: La Torrecilla; Vill: Villanueva de Soportilla; Gra: Granada (20th century).

Males	Ar	Mot	Bau	Tor	Vill	Gra
Pectoralis major	58.5	71.0	38.5	31.9	75.9	75.0
Teres major	42.5	34.3	46.1	31.9	58.6	52.7
Deltoid	25.5	41.7	38.5	44.7	57.1	50.6
Radius	40.0	42.4	66.7	44.7	57.1	50.6
Great trochanter	31.0	21.0	40.0	16.7	35.0	20.2
Linea aspera	25.6	57.6	40.0	40.0	53.3	36.7
Popliteal line	36.4	51.9	53.8	31.9	46.1	36.1
Spur	24.1	18.2	8.3	17.2	5.6	18.0

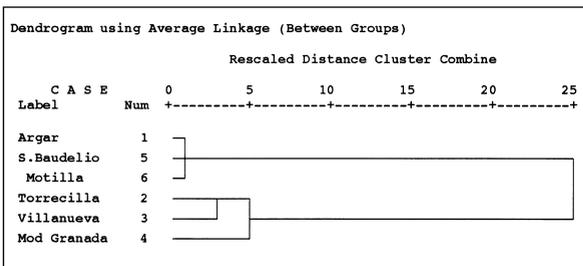


Figura 1. Cluster analysis of male samples

Table 4. Frequencies of enthesal changes in females of various populations

Ar: Argar culture; Mot: La Motilla del Azuer; Bau: San Baudelio de Berlanga; Tor: La Torrecilla; Vill: Villanueva de Soportilla; Gra: Granada (20th century).

Females	Ar	Mot	Bau	Tor	Vill	Gra
Pectoralis major	20.0	50.0	10.0	11.3	40.0	60.7
Teres major	18.7	30.0	0.0	11.3	19.2	45.5
Deltoid	12.9	23.1	0.0	23.2	37.0	51.1
Radius	21.9	44.4	20.0	11.6	33.3	29.5
Great trochanter	7.7	28.6	9.1	8.0	50.0	37.2
Linea aspera	6.7	7.1	0.0	18.6	39.1	40.9
Popliteal line	11.1	0.0	8.3	2.4	28.6	37.0
Spur	12.5	18.2	0.0	0.0	0.0	23.4

Cluster analysis results were very different for the females, with the modern sample showing higher marker frequencies in comparison to the other populations (Table 4). For the earlier populations, one cluster (Figure 2) includes women known to be largely engaged in domestic work, whereas the other contains women known to participate in agricultural work, as in Villanueva (Al Oumaoui et al., 2004). The apparently higher muscle development in the modern females cannot be explained by greater physical activity. Although domestic appliances such as washing machines were not available to these women, who all lived in the first half of the 20th century, running water was supplied locally or in the home, and domestic work would have been less strenuous than for females in the Mediaeval and Bronze Age populations.

Given the genetic similarity of the modern females with the other populations studied and their less demanding physical activity, their greater development of enthesal changes may be explained by the effects of age (Al Oumaoui et al., 2004; Alves Cardoso and Henderson, 2010; Stirland, 1998; Villotte et al., 2010; Wilczak, 1998). The mean age of the modern sample was 68.49 years (65.98 years for the males and 71.47 years for the females), and all except four of the females were over 50 yrs old, i.e., postmenopausal.

The production of oestrogen significantly decreases with menopause and there is an increase in testosterone, enhancing enthesal changes development (Gettler et al., 2010). Therefore, the higher values for enthesal changes observed in the 20th century women

may be due to advanced age and hormonal changes. The longer life expectancy of the modern population represents a confounding factor, and the higher frequency of enthesal changes detected is likely related to a greater proportion of older individuals than in the osteological collections rather than to differences in their activities.

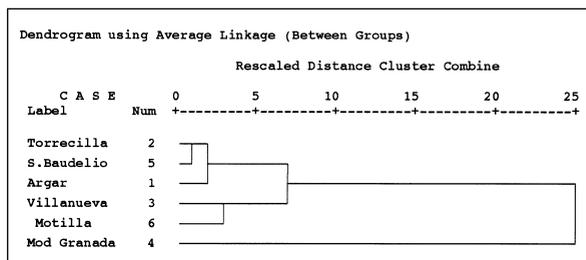


Figura 2. Cluster analysis of female samples

Conclusions

In conclusion, further studies on skeletons from individuals with known work activities are needed to develop this research line. However, they must take account of all influences on enthesal changes, comparing only populations of the same genetic background with similar body size and excluding individuals older than 50 years of age and with the presence of calcifications and ankylosis between vertebrae or in sacroiliac joint. Importantly, only populations with the same age class distribution can be compared because, as evidenced in our study, age may have a greater influence on enthesal changes than genetic makeup or physical activity.

Bibliografía

- AL OUMAOU I., JIMÉNEZ-BROBEIL SA. y SOUICH P. (2004) Markers of activity patterns in some populations of the Iberian Peninsula. *International Journal of Osteoarchaeology* 14: 343-359.
- ALVES CARDOSO F. y HENDERSON CY. (2010) Enthesopathy formation in the humerus: data from known age-at-death and known occupation skeletal collections. *American Journal of Physical Anthropology* 141: 550-560.
- ANDRÍO J. y LOYOLA E. (1992) Necrópolis medieval de San Baudelio de Casillas de Berlanga. *Colección de Temas Sorianos* 20: 1070-1086.
- AUFDERHEIDE A. y RODRÍGUEZ MARTIN C. (1998) *The Cambridge Encyclopedia of Human Paleopathology*. Cambridge University Press. Cambridge.
- BALL J. (1971) Enthesopathy of rheumatoid and ankylosing spondylitis. *Annals of the Rheumatic Diseases* 30: 213-223.
- BENJAMIN M., KUMAI T., MILZ S., BOSZCZYK BM., BOSZCZYK AA. y RALPHS JR. (2002) The skeletal attachment of tendons-tendon "entheses". *Comparative Biochemistry and Physiology A* 133: 931-945.
- BENJAMIN M., TOUMI H., RALPHS JR., BYDDER G., BEST TM. y MILZ S. (2006) Where tendons and ligaments meet bone: attachment sites ('entheses') in relation to exercise and/or mechanical load. *Journal of Anatomy* 208: 471-490.
- BENJAMIN M. y Mc GONAGLE D. (2001) The anatomical basis for disease localisation in seronegative spondyloarthropathy at entheses and related sites. *Journal of Anatomy* 199: 503-526.
- BERRY AC. y BERRY RJ. (1967) Epigenetic variation in the human cranium. *Journal of Anatomy* 101: 361-379.
- BISQUERRA R. (1989) *Introducción conceptual al análisis multivariable*. PPU. Barcelona.
- CHAPMAN NE. (1997) Evidence for Spanish influence on activity induced musculoskeletal stress markers at Pecos Pueblo. *International Journal of Osteoarchaeology* 7: 497-506.
- DUTOUR O. (1986) Enthesopathies (lesions of muscular insertions) as indicators of the activities of Neolithic Saharan populations. *American Journal of Physical Anthropology* 71: 221-224.
- GETTLER LT., AGUSTIN SS. y KUZAWA CW. (2010) Testosterone, physical activity, and somatic outcomes among Filipino males. *American Journal of Physical Anthropology* 142: 590-599.
- HENDERSON CY. y GALLANT AJ. (2007) Quantitative recording of entheses. *Paleopathology Newsletter* 137: 7-12.
- HAWKEY DE. y MERBS CF. (1995) Activity-induced musculoskeletal stress markers (MSM) and subsistence strategy changes among ancient Hudson Bay Eskimos. *International Journal of Osteoarchaeology* 5: 324-338.
- JIMÉNEZ-BROBEIL SA., AL OUMAOU I. y ESQUIVEL JA (2004) Actividad física según sexo en la cultura Argárica. Una aproximación desde los restos humanos. *Trabajos de Prehistoria* 61 (2): 141-153.

- JIMÉNEZ-BROBEIL SA., AL OUMAOU I., NÁJERA T. y MOLINA F. (2008) Salud y enfermedad en la población de la Edad del Bronce de la Motilla del Azuer (Ciudad Real). *Revista Española de Antropología Física* 28: 56-65.
- JURMAIN R. y VILLOTTE S. (2010) Terminology. Entheses in medical literature and physical anthropology: a brief review. Workshop in musculoskeletal stress markers (MSM): limitations and achievements in the reconstruction of past activity patterns. Available at http://www.uc.pt/en/cia/msm/MSM_terminology3.pdf
- MARIOTTI V., FACCHINI F. y BELCASTRO MG. (2004) Enthesopathies-proposal of a standardised scoring method and applications. *Collegium Anthropologicum* 28: 145-159.
- MARIOTTI V., FACCHINI F. y BELCASTRO MG. (2007) The study of entheses: proposal of a standardised scoring method for twenty-three entheses of the postcranial skeleton. *Collegium Anthropologicum* 31: 191-313.
- PEÑA D. (2002) Análisis de datos multivariantes. Mc Graw-Hill. Madrid.
- RESNICK D. y NIWAYAMA G. (1983) Entheses and enthesopathy. *Radiology* 146: 1-9.
- ROGERS J., SHEPSTONE L. y DIEPPE P. (1997) Bone formers: osteophyte and enthesophyte. *Annals of the rheumatic diseases* 56: 85-90.
- SOUICH Ph. du (1979) Estudio antropológico de la necrópolis medieval de La Torrecilla (Arenas del Rey, Granada). *Antropología y Paleoecología Humana* 1: 27-40.
- SOUICH Ph. du, BOTELLA MC. y RUIZ L. (1991) Antropología de la población medieval de Villanueva de Sopotilla (Burgos). *Antropología y Paleoecología Humana* 6: 57-83.
- STIRLAND A. (1998) Musculoskeletal evidence for activity: problems of evaluation. *International Journal of Osteoarchaeology* 8: 354-362.
- VILLOTTE S. (2006) Connaissances médicales actuelles, cotation des enthésopathies. *Bulletin et Mémoires de la Société d'Anthropologie de Paris* 18: 65-85.
- VILLOTTE S., CASTEX D., COUALLIER V., DUTOUR O., KNÜSSEL CJ. y HENRY-GAMBIER D. (2010) Enthesopathies as occupational stress markers: evidence from the upper limb. *American Journal of Physical Anthropology* 142: 224-234.
- WEISS E., CORONA L. y SCHULTZ B. (2010) Sex differences in musculoskeletal stress markers: problems with activity pattern reconstructions. *International Journal of Osteoarchaeology* DOI: 10.1002/oa.1183
- WILCZAK CA. (1998) Consideration of sexual dimorphism, age, and asymmetry in quantitative measurements of muscle insertion sites. *International Journal of Osteoarchaeology* 8: 311-325.

Abstract

The objective of this investigation was to contribute to the analysis of enthesal changes by studying 109 individuals from the 20th century of known sex and age. The method of Al Oumaoui et al. (2004) was used, comparing findings with those in past populations. Little difference was found between the males from the 20th and those in more ancient populations, whereas females showed a higher frequency of enthesal changes, which may be attributable to the influence of age and hormonal changes. Our results suggest that individuals over 50 and those showing calcifications and ankylosis should be excluded from studies on these markers and that only genetically close populations with a similar age group structure should be compared.

Key words: enthesal changes, activity patterns, musculoskeletal stress markers

A contribution to the study of enthesal changes