Preface to special issue Entheseal Changes and occupation: technical and theoretical advances and their applications.

HENDERSON, CY.[1] and ALVES CARDOSO, F.[2]

1. CIAS – Research Centre for Anthropology and Health, University of Coimbra, Portugal. Email: c.y.henderson@uc.pt
2. CRIA – Centro em Rede de Investigação em Antropologia (Centre for Research in Anthropology), Faculdade Ciências Sociais e Humanas, Universidade Nova de Lisboa, 1069-061 Lisbon, Portugal. Email: francicard@fcsh.unl.pt

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1002/oa.2298

1. Introduction

In 1998 this journal, the International Journal of Osteoarchaeology, published its second ever special issue entitled 'Stress Markers' (Peterson and Hawkey, 1998). That special issue provided the framework for study of activity-related stress using, what were then commonly called, 'musculoskeletal stress markers' (MSM). The papers in that issue proved seminal: defining a standard recording method (Hawkey and Merbs, 1995; Peterson, 1998; Steen and Lane, 1998), interpretative approach and research questions for over a decade. Since 1998, research on these markers continued, primarily focussing the interpretation of activity but increasingly questions started to be asked about their use as a direct (one-to-one relationship) between the expression of these markers and activity (Henderson, 2008; Henderson and Gallant, 2007; Villotte, 2006). These studies all highlighted anatomical problems with the methods used to record entheses (Henderson, 2003; Henderson and Gallant, 2007; Villotte, 2006) and the multifactorial aetiology of these changes (Alves Cardoso and Henderson, 2010; Henderson, 2008), for a review see (Jurmain *et al.*, 2012). These issues led to a workshop organised by CIAS - The Research Centre for Anthropology and Health in Coimbra, Portugal aimed at addressing these problems and moving the field forward (Santos *et al.*, 2012). This meeting highlighted that there were two trends in the research being undertaken: those applying the methods, and those questioning the methods and underlying theory. Consequently, it was decided that three working groups were needed to discuss the methodological and theoretical issues: terminology (Jurmain and Villotte, 2010), methodology (Henderson *et al.,* 2010; 2012) and the definition of occupation (Perréard Lopreno *et al.,* 2012).

Since 2009 these working groups have produced significant advances. They have standardised the terminology used. Musculoskeletal stress markers (MSM) have become entheseal changes (EC) to avoid the inherent aetiology stated within the old terminology (Jurmain and Villotte, 2010). The working group on methodology met in Geneva in 2010 to develop a standard method for recording fibrocartilaginous entheses (Henderson *et al.,* 2010) and the occupation group have been discussing approaches to understanding the activity-related stress associated with different occupations, as well as how these occupations are defined biologically, socially and culturally. The papers from the meeting in Coimbra and those that the working groups have subsequently produced have all been collated on the University of Coimbra website (http://www.uc.pt/en/cia/msm/msm_after) alongside a paper summarising the conference and highlighting the importance of the meeting (Santos *et al.*, 2012). This current research has led to a paradigm shift in the way that entheses, and entheseal changes are perceived. To raise awareness of this shift, a poster symposium was organised for all the working groups to present their research alongside others involved with innovative research in this field (Henderson and Alves Cardoso, 2012). This was held at the 81st Annual Meeting of the American Association of Physical Anthropologists in Portland, Oregon in 2012. The significant results of this symposium led to this special issue comprising three distinct groups of papers: technical and theoretical advances; theoretical issues on occupation; and applications of these advances.

2. Entheseal Changes: Relevance

The ability to understand daily lives in the past, how tasks were performed and who performed them, has been described as the Holy Grail of bioarchaeology (Jurmain *et al.*,

2012). While tools tell us what was used, they tell us little about who used them or made them. The aim of studying the skeleton to interpret activity is therefore to understand the divisions of labour within past societies. EC have become the dominant method for studying activity due to the perception that they record specific muscle use, that recording them involves low levels of intra- and inter-observer error (Hawkey and Merbs, 1995), and the apparent idea that they do not have a multi-factorial aetiology. This has led to their use to study many aspects (often more than one in each study) of life in the past, *e.g.* the effect of subsistence strategy changes or differences (Churchill and Morris, 1998; Clapper, 2006; Doying, 2010; Eshed *et al.*, 2004; Hawkey, 1988; Papathanasiou, 2005; Steen and Lane, 1998; Stefanovic and Porcic, 2011; Villotte *et al.*, 2010), cultural changes or differences (Al-Oumaoui *et al.*, 2004; Chapman, 1997; Groves, 2006; Lieverse *et al.*, 2008; Lieverse, 2011; Rojas-Sepúlveda, 2011; Shuler *et al.,* 2012; Zabecki, 2009), tool use, specific or habitual activities (Cope, 2007; Jordana *et al.*, 2006; Lai and Lovell, 1992; Lovell and Dublenko, 1999; Lukacs and Pal, 2003; Molnar, 2006; Molnar, 2008; Peterson, 1998; Üstündağ and Deveci, 2011; Weiss, 2007; Whittle *et al.*, 1998), sexual differences in labour (Aranda, 2009; Hagaman, 2009; Jiménez-Brobeil *et al.*, 2004; Perry, 2005; Rodrigues, 2005; Peterson, 2010), occupational differences (Milella *et al.*, 2012; Villotte *et al.*, 2009), social stratification (Havelková *et al.*, 2010; Palmer, 2012; Porčić and Stefanović, 2009; Rodrigues, 2005), and disability (Hawkey, 1998). They have also been analysed in early hominids and non-human primates (Belcastro *et al.*, 2006; Cashmore, 2009; Drapeau, 2008; Mariotti and Belcastro, 2011) as well as other mammals (Bendrey, 2008). This wide variety of research questions demonstrates their use and acceptance within the osteoarchaeological (used in this context to include physical anthropologists) community.

More recently other considerations have come into play, the role of body size, mass and cross-sectional geometry (Godde, 2011; Niinimäki, 2009; Weiss, 2003; Weiss, 2010; Weiss *et al.*, 2010), age (Alves Cardoso and Henderson, 2010; Myszka and Piontek, 2011; Niinimäki, 2009; Niinimäki, 2012; Weiss, 2010), disease (Henderson, 2008) and most importantly anatomy (see Villotte and Knüsel 2012). It is also important to remember, as stressed early on in the history of EC, that muscles act in groups and not singly (Stirland, 1998).

Entheses also have a relevance beyond archaeology, i.e. in medicine, particularly the surgical repair of torn tendons, which is a particular problem in the elderly and in athletes (Curtis *et al.*, 2006; Forthman *et al.*, 2008; Minagawa *et al.*, 1998; Norwood *et al.*, 1989; Ruotolo *et al.*, 2004). Entheses have been used to model muscle geometry (Horsman *et al.*, 2007; Kepple *et al.*, 1997; Van der Helm and Veenbaas, 1991) which is useful for simulating orthopaedic procedures as well as study normal and pathological movement (Blemker and Delp, 2005). However, there is little sharing of data between osteoarchaeology, biomechanics and clinical sciences nor, based on referencing, of much awareness by osteoarchaeologists of this literature: a fact that should be addressed in future.

The significance of the studies in this volume is that they contribute to the re-evaluation of EC and reconsider their potential while highlighting limitations. The overall goal is to emphasize current research and trends and future research needs.

3. A Brief Overview of Papers in this Special Issue

This special issue was divided into three themes to cover the range of theoretical and technical advances and their applications. The papers in the section “Technical and

Theoretical Advances" cover methodological aspects, while those in "Theoretical Issues: Understanding Occupation" focus on our understanding of occupation and its effect on the skeleton. Those papers in "Applications of Entheseal Changes" all apply advances made in the last five years to answer specific research questions.

Technical and Theoretical Advances

New methodological approaches have been widely developed over the last few years (Cashmore and Zakrezwski, 2009; Galtés *et al.*, 208; Havelková and Villotte, 2007; Henderson, forthcoming; Henderson and Gallant, 2007; Mariotti *et al.*, 2004; Mariotti *et al.*, 2007; Myszka and Piontek, 2012; Pany *et al.*, 2009; Schlecht, 2012; Villotte, 2006; Villotte *et al.*, 2009; Zumwalt, 2005). This methodological research is discussed by Villotte and Knüsel in their commentary focussing on clinical data. They highlight the key differences between types of entheses, fibrocartilaginous and fibrous and explain why this differentiation is important for osteoarchaeological studies of entheses, but stress this is not a simple dichotomy. They also made clear the importance of considering other clinical literature on mechanical stress, overuse injuries as well as the growth and development of the musculoskeletal system. One of the key messages is that structures, such as bursae, are rarely considered when recording entheses and their footprints should be differentiated from that of the tendon enthesis.

The second paper of this section highlights a significant problem, also touched upon in the third paper, that of inter-observer error when using visual recording methods for EC (Davis *et al.,* 2012). This paper focuses on the most widely applied recording method (Hawkey and Merbs, 1995). Eight observers independently recorded entheses using this method and found that replicability was often not much above chance alone. Given the widespread use of this method and the comparisons made between researchers this paper highlights the need for good quality, annotated photographs when publishing visual recording methods. This paper also strengthens the case for a new method.

The importance of differentiating between fibrous and fibrocartilaginous entheses is again stressed in the subsequent paper (Henderson *et al.*, 2012) which describes a new recording method and some preliminary results. Developing a standard recording method was one of the goals set out at the Coimbra workshop in 2009 and this is the initial description of that method. The paper stresses the importance of considering anatomy, the types of changes that occur at entheses and the role of age in their expression. While the method is not ready for widespread use it does demonstrate the steps that are required in developing a visual recording method by committee and why this is useful when creating a standard method.

The final paper in this section (Nolte and Wilczak, 2012) presents a quantitative method for recording entheses. This method uses a three-dimensional laser scanner to record surface area of the *biceps brachii* enthesis and assesses the variation with body size, sex and age. The statistical advantages of using a quantitative method of this nature, as opposed to visual scoring methods, are highlighted. Body size, year of birth and age all explain some of the variation found in the size of the area of the enthesis footprint.

Theoretical Issues: Understanding Occupation

Identified skeletal collections have been widely used to test the relationship between EC and occupation, as well as age (Alves Cardoso, 2008; Alves Cardoso and Henderson, 2010; Cunha and Umbelino, 199; Milella *et al.*, 2012; Villotte *et al.*, 2010). The first paper (Perréard-Lopreno *et al.*, 2012) in this section explores the approaches considered to categorise occupation. These reflect different methodologies of exploring the known occupation at death of individuals from identified skeletal collections, and ultimately highlights the lack of comparability in categorisation method between different studies. They therefore advocate the standardization of the concept of occupation and the manner it is perceived socially, culturally and biologically, reinforcing the need for an interdisciplinary approach. This is particularly important for those studies which use the results of these tests as models for studies on past populations.

The second paper (Alves Cardoso and Henderson, 2012) evaluates the impact of the categorisation of occupation on the analysis and interpretation of results. Data on presence and absence of EC collected from identified skeletal collections are used to test the effect of using different methods for categorising occupation on the relationship between occupation and EC. Combined with the results of the paper by Perréard-Lopreno *et al.* (2012), this research illustrates the point that methods used to categorise occupation must be standardised, otherwise inter-population comparisons are unreliable. Alves Cardoso and Henderson (2012) also reinforce that age has to be taken into account in all studies that address EC, as none of the methods used found a relationship between occupation and EC. The importance of life history of individuals is another key factor which has been consistently overlooked, primarily due to the lack of data available. The final paper in this section (Henderson *et al.* 2012) highlights the importance of considering life course by addressing the fact that occupation at death does not reflect the variety found in life. Historical data combined with the associated skeletal remains underlines the variability of occupation and daily tasks throughout life. This illustrates the point that EC cannot be reduced to a reflection of one occupation, but may be a manifestation of total life course.

Applications of Entheseal Changes

This section focuses on applications of EC to specific archaeological and biological questions. While these papers emphasize important considerations and new methods, they are less theoretical than those in the previous sections, and show a more practical use of EC. The first paper in this section (Ibáñez-Gimeno *et al.,* 2012) tests the relationship between pronosupination, as measured by the orientation of the humeral medial epicondyle and EC, to determine whether the orientation of this feature can be used as a marker of activity. The results found that the angle of the medial epicondyle increases the efficiency of the pronation range when the elbow is extended. However, despite the fact that no simple relationship was found between this angle and EC, this paper accentuates the importance of considering functional biology when studying EC.

The second paper in this section (Niinimäki and Sotos, 2012) also focuses on the relationship between biomechanics and EC, this time testing the effect of body size, occupation and age on EC in the lower limb. Entheses of the lower limb have been less regularly studied than those of the upper limb making this an important contribution to our understanding of EC.

Surprisingly there was no relationship between EC and body size, nor were consistent relationships found between EC, activity or age. It is probable that the lack of relationship between body size and EC is due to the difficulty of assessing body mass at death using skeletal material, even in identified skeletal collections (as used in this paper). This paper contributes to the discussion of the problems of assessing activity from EC in the lower limb, stressing once again the lack of simple associations between EC and human remains.

The paper by Campanacho and Santos (2012) focuses on the relationship between occupation, physical activity and EC in the pelvis. Very few studies have recorded EC in the *os coxae*, probably due to an underlying sense that changes would not be associated with activity. Two identified skeletal collections were used to test the relationship between occupation, physical activity, age and EC. Data on occupation was differentiated from physical activity which was measured using the femoral robusticity index. These results found that the age at which entheseal changes occurred was not affected by occupation or physical activity. These results are different from many others concluded in identified collections, and show the importance of discussing different methods of analysis in EC studies and the points illustrated by other papers (Alves Cardoso and Henderson 2012; Perréard-Lopreno *et al.,* 2012) in this issue.

Unlike the previous paper, the final paper (Havelková *et al.,* 2012) focuses on an archaeological population and explores the relationship between EC and hierarchy. Exploratory statistics are used to determine if grave goods, grave type (including depth) and EC relate. This is a novel approach, as exploratory statistics are rarely used for the study of EC, researchers tend to apply inferential statistics to search for significant differences or correlations and not patterns. However, this paper and its results demonstrate their value, as there are clear relationships between some characteristics of hierarchy and EC. These results support the use of this approach to assess the relationship between occupation and EC, particularly since the social construct of occupation has not been found to relate to its biological effect, i.e. EC (if such exists).

4. Conclusions

The papers in this special issue all highlight a variety of aspects and approaches to the study of EC. There are clear problems relating to methodology and the relationship between EC, occupation and biomechanics. The major conclusion of these papers are the emphasis on the need for new research directions which will, if adopted, improve our understanding of EC and allow their use for the study of past populations.

References

Al-Oumaoui I, Jiménez-Brobeil S, and du Souich P. 2004. Markers of Activity Patterns in some Populations of the Iberian Peninsula. *International Journal of Osteoarchaeology 14:*343-359. DOI: 10.1002/oa.719.

Alves Cardoso F. 2008. *A Portrait of Gender in Two 19th and 20th Century Portuguese Populations: A Palaeopathological Perspective*. PhD thesis, Department of Archaeology, Durham University.

Alves Cardoso F. and Henderson C. Y. 2012. The Categorisation of Occupation in Identified

Skeletal Collections: A Source of Bias? *International Journal of Osteoarchaeology*. DOI: 10.1002/oa.2285

Alves Cardoso F, and 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. DOI: 10.1002/ajpa.21171.

Aranda G, Montón-Subías S, Sánchez-Romero M, and Alarcón E. 2009. Death and everyday life The Argaric societies from Southeast Iberia. *Journal of social Archaeology 9:*139-162. DOI: 10.1177/1469605309104134.

Belcastro MG, Mariotti V, Facchini F, and Bonfiglioli B. 2006. Musculoskeletal Stress and Adult Age Markers in the Krapina Hominid Collection: the Study of Femora 213 Fe. 1 and 214 Fe. 2. *Periodicum Biologorum 108:*319-329.

Bendrey R.2008. An analysis of factors affecting the development of an equid cranial enthesopathy. *Veterinarija and Zootechnika 41:*25-32.

Blemker SS, and Delp SL. 2005.Three-dimensional representation of complex muscle architectures and geometries. *Annals of Biomedical Engineering 33:*661-673.

Campanacho V, and Santos AL. 2012. Comparison of the entheseal changes in the hip bone of Portuguese males (19^{th}-20^{th} centuries) with known occupation. *Internatinal Journal of Osteoarchaeology.*

Cashmore L. 2009. Can hominin 'handedness' be accurately assessed? *Annals of Human Biology 36:*624-641. DOI: 10.1080/03014460902956733.

Cashmore , and Zakrzewski SR. 2009. The expression of asymmetry in hand bones from the medieval cemetery at Écija, Spain. In *Proceedings of the Ninth Annual Conference of the British Association for Biological Anthropology and Osteoarchaeology,* Lewis ME and Clegg M (eds.). Oxford, GB,Archaeopress, 79-92. (British Archaeological Reports International Series, 1918).

Chapman NEM. 1997. Evidence for Spanish Influence on Activity Induced Musculoskeletal Stress Markers at Pecos Pueblo. *International Journal of Osteoarchaeology 7:*497-506. DOI: 10.1002/(SICI)1099-1212(199709/10)7:5<497::AID-OA394>3.0.CO;2-H.

Churchill S, and Morris A.1998.Muscle marking morphology and labour intensity in prehistoric Khoisan foragers. *International Journal of Osteoarchaeology 8:*390-411. DOI: 10.1002/(SICI)1099-1212(1998090)8:5<390::AID-OA435>3.0.CO;2-N.

Clapper T. 2006. *The new world and the Natufian Musculoskeletal stress markers of hunter-gatherer lifeways*. Southern Illinois University: Carbondale.

Cope JM. 2007. *Musculoskeletal Attachment Site Markers and Skeletal Pathology of the Forearm and Carpal Bones from Tell Abraq, United Arab Emirates, C. 2300 BC*. University of Massachusetts: Amherst.

Cunha E, and Umbelino C. 1995.What can bones tell about labour and occupation: the analysis of skeletal markers of occupational stress in the Identified Skeletal Collection of the Anthropological Museum of the University of Coimbra (preliminary results). *Antropologia Portuguesa* 13: 49 - 68.

Curtis AS, Burbank KM, Tierney JJ, Scheller AD, and Curran AR. 2006. The Insertional Footprint of the Rotator Cuff: An Anatomic Study. *Arthroscopy 22:*603-609. DOI: 10.1016/j.arthro.2006.04.001.

Davis CB, Shuler KA,Danforth ME, and Herndon KE. 2012.Patterns of Interobserver Error in the Scoring of Entheseal Changes. *International Journal of Osteoarchaeology*. DOI: 10.1002/oa.2277

Doying A.2010. *Differentiation of labor-related activity by means of musculoskeletal*

markers. University of South Florida: Florida.

Drapeau MS.2008. Enthesis bilateral asymmetry in humans and African apes. *HOMO-Journal of Comparative Human Biology 59:*93-109. DOI: 10.1016/j.jchb.2007.12.004.

Eshed V, Gopher A, Galili E, and Hershkovitz I. 2004. Musculoskeletal Stress Markers in Natu.an Hunter- Gatherers and Neolithic Farmers in the Levant: The Upper Limb. *American Journal of Physical Anthropology 123:*303-315. DOI: 10.1002/ajpa.10312.

Forthman CL, Zimmerman RM, Sullivan MJ, and Gabel GT. 2008. Cross-sectional anatomy of the bicipital tuberosity and biceps brachii tendon insertion: Relevance to anatomic tendon repair. Journal of Shoulder and Elbow Surgery. *J Shoulder Elbow Surgery17:*522-526. DOI: 10.1016/j.jse.2007.11.002.

Galtés I, Jordana X, Manyosa J, and Malgosa A.2008. Functional implications of radial diaphyseal curvature. *American Journal of Physical Anthropology 138:*286-292. DOI: 10.1002/ajpa.20926.

Godde K, and Taylor RW. 2011.Musculoskeletal stress marker (MSM) differences in the modern American upper limb and pectoral girdle in relation to activity level and body mass index (BMI). *Forensic science international 210:*237-242. DOI: 10.1016/j.forsciint.2011.03.014 .

Groves SE. 2006. *Spears or ploughshares : multiple indicators of activity related stress and social status in four early medieval populations from the North East of England*. Durham University: Durham.

Hagaman KR. 2009. *Activity-Induced Musculoskeletal Stress Marker Analysis of the Windover Population.*Florida State University: Florida.

Havelková P, and Villotte S. 2007. Enthesopathies: Test of reproducibility of the new scoring system based on current medical data. *Slovenská Antropológia 10:*51-57.

Havelková P, Hladík M, and Velemínský P. 2012. Entheseal changes: Do they reflect socioeconomic status in the Early Medieval Central European population? (Mikulčice, Great Moravian Empire, 9th – 10th century). *International Journal of Osteoarchaeology.*

Havelková P, Villotte S, Velemínský P, Poláček L, and Dobisíková M. 2010.Enthesopathies and activity patterns in the Early Medieval Great Moravian population: Evidence of division of labour. *International Journal of Osteoarchaeology 21:*487-504. DOI: 10.1002/oa.1164.

Hawkey DE. 1988.Use of Upper Extremity Enthesopathies to Indicate Habitual Activity Patterns. Arizona State University: Arizona.

Hawkey DE. 1998.Disability, Compassion and the Skeletal Record: Using Musculoskeletal Stress Markers (MSM) to Construct an Osteobiography from Early New Mexico. *International Journal of Osteoarchaeology 8:*326-340. DOI: 10.1002/(SICI)1099-1212(1998090)8:5<326::AID-OA437>3.0.CO;2-W.

Hawkey DE, and 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. DOI: 10.1002/oa.1390050403.

Henderson CY. 2003. Rethinking Musculoskeletal Stress Markers (Poster). *British Association of Biological Anthropology and Osteoarchaeology (BABAO) 5th Annual Conference*.

Henderson CY. 2008. When hard work is disease: the interpretation of enthesopathies. In *Proceedings of the Eighth Annual Conference of the British Association for Biological Anthropology and Osteoarchaeology,* Brickley M, and Smith M (eds.). Oxford: British Archaeological Reports: International Series, pp. 17-25.

Henderson CY. forthcoming. Technical note: Quantifying size and shape of entheses.

Anthropological Science.

Henderson CY, and Alves Cardoso F. 2012. Working nine to five: the future of activity-related stress. *American Journal of Physical Anthropology* 147 (S54): 163. DOI: 10.1002/ajpa.22033.

Henderson CY, and Gallant AJ. 2007. Quantitative Recording of Entheses. *Paleopathology Newsletter* 137:7-12.

Henderson CY, Mariotti V, Pany-Kucera D, Villotte S, and Wilczak CA. 2012.Recording specific features of fibrocartilaginous entheses: preliminary results of the Coimbra standard method. *International Journal of Osteoarchaeology.* DOI: 10.1002/oa.2287.

Henderson CY, Caffell AC, Craps DD, Millard AR, and Gowland R. 2012. Occupational mobility in nineteenth century rural England: the interpretation of entheseal changes. *International Journal of Osteoarchaeology.* DOI: 10.1002/oa.2286.

Henderson CY, Mariotti V, Pany-Kucera D, Perréard-Lopreno G., Villotte S, and Wilczak C. 2012. The effect of age on entheseal changes at some fibrocartilaginous entheses. *American Journal of Physical Anthropology 147(S54)*: 163. DOI: 10.1002/ajpa.22033.

Henderson CY, Mariotti V, Pany-Kucera D, Perréard-Lopreno G, Villotte S and Wilczak C. 2010. *Scoring entheseal changes: proposal of a new standardised method for fibrocartilaginous entheses*. 18th European Meeting of the Paleopathology Association, Vienna, Austria. 23rd -26th of August. URL: https://www.uc.pt/en/cia/msm/Vienna2010.pdf. Accessed 8th of March, 2012.

Horsman K, Koopman HFJM, Van der Helm FCT, Prosé LP, and Veeger HEJ. 2007.Morphological muscle and joint parameters for musculoskeletal modelling of the lower extremity. *Clinical Biomechanics 22:*239-247. DOI: 10.1016/j.clinbiomech.2006.10.003.

Ibáñez-Gimeno P, Galtés I, Jordana X, Fiorin E, Manyosa J, and Malgosa A. 2012. Entheasal changes and functional implications of humeral medial epicondyle shape. *International Journal of Osteoarchaeology.*

Jiménez-Brobeil SA, Al-Oumaoui I, and Esquivel JA. 2004. Physical activity according to sex in the argar culture. An approach based on the human remains. *Trabajos de Prehistoria 61:*141-153.

Jordana X, Galtés I, Busquets F, Isidro A, and Malgosa A. 2006.Clay-Shoveler's Fracture: An Uncommon Diagnosis in Palaeopathology. *International Journal of Osteoarchaeology 16:*366-372. DOI: 10.1002/oa.829.

Jurmain R, Alves Cardoso F, Henderson CY and Villotte S. 2012. Bioarchaeology's Holy grail: the reconstruction of activity. In *Companion to Paleopathology,* Grauer AL (ed.). Wiley/Blackwell: Malden; 531-552.

Jurmain RD, and Villotte S. 2010. Terminology – entheses in medical literature: a brief review. In *Workshop in Musculoskeletal Stress markers (MSM): Limitations and Achievements in the Reconstruction of Past Activity Patterns*. URL: http://www.uc.pt/en/cia/msm/MSM_terminology3.pdf. Accessed 9th of March, 2012.

Kepple TM, Sommer III HJ, Siegel KL, and Stanhope SJ. 1997. A three-dimensional musculoskeletal database for the lower extremities. *Journal of biomechanics 31:*77-80. DOI: 10.1016/S0021-9290(97)00107-3.

Lai P, and Lovell NC. 1992. Skeletal Markers of Occupational Stress in the Fur Trade: a Case Study from a Hudson's Bay Company Fur Trade Post. *International Journal of Osteoarchaeology 2:*221-234. DOI: 10.1002/oa.1390020306.

Lieverse AR, Bazaliiskii VI, Goriunova OI, and Weber AW. 2008. Upper limb musculoskeletal stress markers among middle Holocene foragers of Siberia's Cis-Baikal

region. *American Journal of Physical Anthropology 138:*458-472. DOI: 10.1002/ajpa.20964.

Lieverse AR, Stock JT, Katzenberg MA, and Haverkort CM. 2011.The bioarchaeology of habitual activity and dietary change in the Siberian Middle Holocene. In *Human Bioarchaeology of the Transition to Agriculture,* Pinhasi R and Stock JT (eds.). Chichester: John Wiley and Sons, Ltd., pp. 263-291.

Lovell NC, and Dublenko AA. 1999. Further Aspects of Fur Trade Life Depicted in the Skeleton. *International Journal of Osteoarchaeology 9:*248-256. DOI: 10.1002/(SICI)1099-1212(199907/08)9:4<248::AID-OA484>3.0.CO;2-P.

Lukacs JR, and Pal JN. 2003.Skeletal variation among Mesolithic people of the Ganga Plains: new evidence of habitual activity and adaptation to climate. *Asian Perspectives 42:*329-351. 10.1353/asi.2003.0042.

Mariotti V, and Belcastro MG. 2011. Lower limb entheseal morphology in the Neandertal Krapina population (Croatia, 130 000 BP). *Journal of Human Evolution 60:*694-702. DOI: 10.1016/j.jhevol.2010.12.007.

Mariotti V, Facchini F, and Belcastro MG. 2004.Enthesopathies - Proposal of a Standardized Scoring Method and Applications. *Collegium Anthropologicum 28:*145-159.

Mariotti V, Facchini F, and Belcastro MG. 2007. The Study of Entheses: Proposal of a Standardised Scoring Method for Twenty-Three Entheses of the Postcranial Skeleton. *Collegium Anthropologicum 31:*291-313.

Milella M, Belcastro MG, Zollikofer CP, and Mariotti V. 2012.The effect of age, sex, and physical activity on entheseal morphology in a contemporary Italian skeletal collection. *American Journal of Physical Anthropology 148:*379-388. DOI: 10.1002/ajpa.22060.

Minagawa H, Itoi E, Konno N, Kido T, Sano A, Urayama M, and Sato K. 1998. Humeral Attachment of the Supraspinatus and Infraspinatus Tendons: An Anatomic Study. *Arthroscopy 14:*302-306. DOI: 10.1016/S0749-8063(98)70147-1.

Molnar P. 2006. Tracing Prehistoric Activities: Musculoskeletal Stress Marker Analysis of a Stone-Age Population on the Island of Gotland in the Baltic Sea. *American Journal of Physical Anthropology 129:*12-23. DOI: 10.1002/ajpa.20234.

Molnar P. 2008. Patterns of Physical Activity and Material Culture on Gotland, Sweden, During the Middle Neolithic. *International Journal of Osteoarchaeology 20:*1-14. DOI: 10.1002/oa.1000.

Myszka A, and Piontek J. 2011. Shape and size of the body vs. musculoskeletal stress markers. *Anthropologischer Anzeiger 68:*139-152.

Myszka A, and Piontek J. 2012.Variation of musculoskeletal stress markers in the medieval population from Cedynia (Poland)–proposal of standardized scoring method application. *Collegium Anthropologicum 36:*1009-1017.

Niinimäki S. 2009.What do muscle marker ruggedness scores actually tell us? *International Journal of Osteoarchaeology 21:*292-299. DOI: 10.1002/oa.1134.

Niinimäki S. 2012. The relationship between musculoskeletal stress markers and biomechanical properties of the humeral diaphysis. *American Journal of Physical Anthropology 147:*618-628. DOI: 10.1002/ajpa.22023.

Niinimäki S, and Sotos LB. 2012. The relationship between intensity of physical activity and entheseal changes on the lower limb. *International Journal of Osteoarchaeology*.

Nolte, M. Wilczak, C. 2012. Three-dimensional surface area of the distal bipecps enthesis, relationship to body size, sex, age, and secular changes in a 20th century American sample. *International Journal of Osteoarchaeology.* DOI: 10.1002/oa.2292.

Norwood L, Barrack R, and Jacobson K. 1989. Complete tears of the rotator cuff. *Journal of*

*Bone and Joint Surgery 71-A:*499-505.

Palmer J. 2012. *Busy Bones Osteoarthritis and musculoskeletal markers as evidence of physical activity and social differentiation in post-medieval the Netherlands*. University of Leiden: Leiden.

Pany D, Viola T, and Teschler-Nicola M.2009. The scientific value of using a 3D surface scanner to quantify entheses: Workshop in Musculoskeletal Stress Markers (MSM): limitations and achievements in the reconstruction of past activity patterns., July 2-3, 2009. Coimbra, CIAS – Centro de Investigação em Antropologia e Saúde. . CIAS – Centro de Investigação em Antropologia e Saúde. University of Coimbra: http://www.uc.pt/en/cia/msm/MSM_podium.

Papathanasiou A. 2005.Health Status of the Neolithic Population of Alepotrypa Cave, Greece. *American Journal of Physical Anthropology 126:*377-390. DOI: 10.1002/ajpa.20140.

Perry EM. 2005. *Bioarchaeology of labor and gender in the prehispanic American Southwest.* University of Arizona: Arizona.

Perréard Lopreno G, Alves Cardoso F, Assis S, Milella M, and Speith N. 2012. Working activities or workload? Categorization of occupation in identified skeletal series for the analysis of activity-related osseous changes. *American Journal of Physical Anthropology* 147: 236. DOI:10.1002/ajpa.22035.

Perréard Lopreno G, Alves Cardoso F, Assis S, Milella M, and Speith N. 2012. Categorization of occupation in documented skeletal collections: Its relevance on the interpretation of activity-related osseous changes. *International Journal of Osteoarchaeology*.

Peterson J. 1998.The Natufian Hunting Conundrum: Spears, Atlatls, or Bows? Musculoskeletal and Armature Evidence. *International Journal of Osteoarchaeology 8:*378-389. DOI: 10.1002/(SICI)1099-1212(1998090)8:5<378::AID-OA436>3.0.CO;2-I.

Peterson J. 2010. Domesticating gender: Neolithic patterns from the Southern Levant. *Journal of Anthropological Archaeology 29*: 249-264. DOI: 10.1016/j.jaa.2010.03.002.

Peterson J, and Hawkey DE. 1998. Preface. *International Journal of Osteoarchaeology* 8(5): 303-304. DOI: 10.1002/(SICI)1099-1212(1998090)8:5<303::AID-OA450>3.0.CO;2-N.

Porčić M, and Stefanović S. 2009.Physical activity and social status in Early Bronze Age society: The Mokrin necropolis. *Journal of Anthropological Archaeology 28:*259-273. DOI: 10.1016/j.jaa.2009.06.001.

Rodrigues T. 2005. Gender and social differentiation within the Turner population, Ohio, as evidenced by activity-induced musculoskeletal stress markers. In *Gathering Hopewell:* Interdisciplinary Contributions to Archaeology, Car C, and Case, T (ed.). Springer US: New York; 405-427. DOI: 10.1007/0-387-27327-1_10.

Rojas-Sepúlveda CM, Rivera-Sandoval J, and Martín-Rincón JG. 2011.Paleoepidemiology of pre-Columbian and Colonial Panamá Viejo: a preliminary study. *Bulletins et mémoires de la Société d'anthropologie de Paris 23:*70-82. DOI: 10.1007/s13219-011-0033-3.

Ruotolo C, Fow JE, and Nottage WM. 2004. The Supraspinatus Footprint: An Anatomic Study of the Supraspinatus Insertion. *Arthroscopy 20:*246-249. DOI: 10.1016/j.arthro.2004.01.002.

Santos AL, Alves-Cardoso F, Assis S, and Villotte S. 2011. The Coimbra Workshop in Musculoskeletal Stress Markers (MSM): an annotated review. *Antropologia Portuguesa* 28:135-161

Schlecht SH. 2012. *A histomorphometric analysis of muscular insertion regions: understanding enthesis etiology*. Ohio State University: Ohio.

Shuler KA, Hodge SC, Danforth ME, Funkhouse LJ Stantis C, Cook DN, and Zeng P. 2012.

In the shadow of Moundville: a bioarchaeological view of the transition to agriculture in the central Tombigbee valley of Alabama and Mississippi. *Journal of Anthropological Archaeology 31:* 586-603. DOI: 10.1016/j.jaa.2012.07.001.

Steen SL, and Lane RW. 1998. Evaluation of Habitual Activites among Two Eskimo Populations Based on Musculoskeletal Stress Markers. *International Journal of Osteoarchaeology 8:*341-353. DOI: 10.1002/(SICI)1099-1212(1998090)8:5<341::AID-OA441>3.0.CO;2-B.

Stefanovic S, and Porcic M. 2011. Between-group Differences in the Patterning of Musculo-skeletal Stress Markers: Avoiding Confounding Factors by Focusing on Qualitative Aspects of Physical Activity. *International Journal of Osteoarchaeology.* Online early view DOI: 10.1002/oa.1243.

Stirland A. 1998. Musculoskeletal evidence for activity: problems of evaluation. *International Journal of Osteoarchaeology 8:*354-362. DOI: 10.1002/(SICI)1099-1212(1998090)8:5<354::AID-OA432>3.0.CO;2-3.

Üstündağ H, and Deveci A. 2011.A possible case of Scheuermann's disease from Akarçay Höyük, Birecik (Şanlıurfa, Turkey). *International Journal of Osteoarchaeology 21:*187-196. DOI: 10.1002/oa.1120 .

Van der Helm FCT, and Veenbaas R.1991. Modelling the mechanical effect of muscles with large attachment sites: application to the shoulder mechanism. *Journal of Biomechanics 24:*1151-1163. DOI: 10.1016/0021-9290(91)90007-A.

Villotte S. 2006. Connaissances Médicales Actuelles, Cotation des Enthésopathies: Nouvelle Méthode. *Bulletins et Mémoires de la Société d'Anthropologie de Paris 18* : 65-85. URL : http://bmsap.revues.org/1325.

Villotte, S. and Knüsel, CJ. 2012. Understanding entheseal changes: definition and life course changes. *International Journal of Osteoarchaeology*. DOI: 10.1002/oa.2289.

Villotte S, Castex D, Couallier V, Dutour O, Knüsel CJ, and Henry-Gambier D. 2009. Enthesopathies as occupational stress markers: evidence from the upper limb. *American Journal of Physical Anthropology 142:*224-234. DOI: 10.1002/ajpa.21217.

Villotte S, Churchill SE, Dutour OJ, and Henry-Gambier D.2010. Subsistence activities and the sexual division of labor in the European Upper Paleolithic and Mesolithic: Evidence from upper limb enthesopathies. *Journal of Human Evolution 59:*35-43.DOI: 10.1016/j.jhevol.2010.02.001.

Weiss E. 2003. Understanding Muscle Markers: Aggregation and Construct Validity. *American Journal of Physical Anthropology 121:*230-240. DOI: 10.1002/ajpa.10226.

Weiss E. 2007. Muscle markers revisited: activity pattern reconstruction with controls in a central California Amerind population. *American Journal of Physical Anthropology 133:*931-940. DOI: 10.1002/ajpa.20607.

Weiss E. 2010. Cranial muscle markers: A preliminary examination of size, sex, and age effects. *HOMO-Journal of Comparative Human Biology 61:*48-58. DOI: 10.1016/j.jchb.2009.11.001.

Weiss E, Corona L, and Schultz B.2010.Sex differences in musculoskeletal stress markers: Problems with activity pattern reconstructions. *International Journal of Osteoarchaeology 22:*70-80. DOI: 10.1002/oa.1183.

Whittle A, Wysocki M, Richards M, Rouse A, Walker E, and Zienkiewicz L 1998. Parc le Breos Cwm transepted long cairn, Gower, West Glamorgan: Date, contents, and context. *Proceedings of the Prehistoric Society 64:*139-182.

Zabecki M. 2009.*Late Predynastic Egyptian Workloads: Musculoskeletal Stress Markers at*

Hierakonpolis. University of Arkansas: Arkansas.
Zumwalt AC. 2005. A New Method for Quantifying the Complexity of Muscle Attachment Sites. *The Anatomical Record (Part B) 286B:*21-28. DOI: 10.1002/ar.b.20075.