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

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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 enthesal 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 enthesal 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. Enthesal 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 Enthesal 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., 2008; 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 Enthesal 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.

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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


Doying A.2010. *Differentiation of labor-related activity by means of musculoskeletal*
markers. University of South Florida: Florida.


Anthropological Science.


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