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► **To cite this version:**

Ana Santos, Francisca Alves-Cardoso, Sandra Assis, Sébastien Villotte. The Coimbra Workshop in Musculoskeletal Stress Markers (MSM): an annotated review. *Antropologia portuguesa*, 2011, 28, pp.135 - 161. 10.14195/2182-7982\_28\_5 . hal-02266467

**HAL Id: hal-02266467**

**<https://hal.archives-ouvertes.fr/hal-02266467>**

Submitted on 14 Aug 2019

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# ***The Coimbra Workshop in Musculoskeletal Stress Markers (MSM): an annotated review***<sup>1</sup>

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**Abstract** The *Workshop in Musculoskeletal Stress Markers (MSM): limitations and achievements in the reconstruction of past activity patterns*, was held at the University of Coimbra, in Portugal (2<sup>nd</sup> – 3<sup>rd</sup> July 2009). The chief goal of the organizing committee was to provide a productive environment where researchers could discuss the methodologies and terminology employed for the study of *MSM* as well as assessing how well these enthesopathies serve as markers of occupational stress. The Workshop was organized in three major sessions, each one introduced by a keynote lecture: (1) Methodological issues; (2) *MSM* studies of archaeological samples and Identified Skeletal Collections; and (3) The multifactorial etiology of enthesopathies. The meeting was concluded with a Plenary Session where two annotators discussed the presentations; this was followed by a general discussion and the formation of three working groups focused on the topics of Methods, Terminology, and Occupations. Details of the Workshop and the presentations presented are available for download at <http://www.uc.pt/en/cia/msm/>. A blog (<http://coimbraworkshopsm.blogspot.com/>) was created to facilitate communications about individual experiences and to share knowledge among researchers in this field. We hope that this Workshop will help to standardize methodologies and terminology and promote the creation of a more integrated scientific approach to future studies of *MSM*.

**Key words** Standardization; enthesopathies; occupation; methodologies; terminology.

**Resumo** A Universidade de Coimbra acolheu, nos dias 2 e 3 de Julho de 2009, o Workshop intitulado “*Musculoskeletal Stress Markers (MSM): limitations and achievements in the reconstruction of past activity pattern*”. Com esta iniciativa,

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<sup>1</sup> This paper is based on the presentation made at the 3<sup>rd</sup> *Paleopathology Association Meeting in South America*, Necochea, Argentina, 14<sup>th</sup>-16<sup>th</sup> October 2009.

a Comissão Organizadora pretendeu facultar aos investigadores, um ambiente profícuo para a discussão de temáticas relacionadas com a metodologia, a terminologia e a validação científica das entesopatias (ou *MSM*) enquanto marcadores de stress ocupacional. Esta reunião científica foi estruturada em três sessões distintas e complementares, designadamente: (1) Aspectos metodológicos; (2) Análise de *MSM* em amostras esqueléticas de contextos arqueológicos ou de colecções identificadas; e (3) Etiologia multifactorial das entesopatias. Cada sessão foi introduzida por uma conferência inaugural. O Workshop encerrou com uma Sessão Plenária em que dois anotadores realizaram o balanço dos trabalhos e uma discussão geral da qual resultou a criação de três grupos de trabalhos adstritos à problemática da Metodologia, da Terminologia e da Actividade ocupacional. Informações sobre o Workshop e os estudos apresentados estão disponíveis para “download” em <http://www.uc.pt/en/cia/msm/>. A criação do blog <http://coimbraworkshopmsm.blogspot.com/> visa promover a troca de experiência e de conhecimento entre os investigadores nesta área. Esperamos que o Workshop contribua para uniformizar procedimentos e metodologias, permitindo o desenvolvimento de abordagens inovadoras nos trabalhos futuros.

**Palavras-chave** Estandarização; entesopatias; actividade ocupacional; terminologia; metodologia.

## Introduction

The study of activity patterns through bone analysis is one of the major topics of research on paleopopulations (Kennedy, 1989; Larsen, 1997; 2000). The analysis of bony changes at sites of insertion of muscle and ligaments, normally called enthesopathies or Musculoskeletal Stress Markers (*MSM*), has been a major focus in this research (e.g. Dutour, 1986; Crubézy, 1988; Kennedy, 1989; Lai and Lovell, 1992; Robb, 1994; Cunha and Umbelino, 1995; Hawkey and Merbs, 1995; Pálfi and Dutour, 1992; Chapman, 1997; Kennedy, 1998; Steen and Lane, 1998; Eshed *et al.*, 2004; Mariotti *et al.*, 2004, 2007; Rodrigues-Carvalho, 2004; Molnar, 2006; Assis, 2007; Alves-Cardoso, 2008; Villotte, 2009b). Several methodological approaches have been developed for the analysis of human skeletal remains from different contexts and chronologies, all aimed at inferring behavior (Crubézy, 1988; Hawkey and Merbs, 1995; Al Oumaoui *et al.*, 2004; Mariotti *et al.*, 2004; Galtés *et al.*, 2006; Villotte, 2006). However, in recent decades, several researchers have questioned the validity of this approach and its correlation with past human lifestyles (Jurmain, 1999; Weiss, 2003).

The different perspectives that have characterized *MSM* research in the past inspired us to organize a thematic meeting where the problems that underline this topic could be addressed. Our proposal for a scientific meeting was promptly accepted by *CIAS*<sup>2</sup>, which promoted the organization of the *Workshop in Musculoskeletal Stress Markers (MSM): limitations and achievements in the reconstruction of past activity patterns*. This Workshop sought to bring together key researchers from the various fields of *MSM* analysis and to provide a productive environment to discuss the methodologies and terminology as well as the effectiveness of analyzing enthesopathies as markers of occupational stress.

This paper's objectives are threefold: firstly, to introduce the theoretical and methodological problems associated with the study of musculoskeletal stress markers (*MSM*); secondly, to summarize the body of works presented and discussed during the workshop; and, finally, to state the main achievements of the Workshop, in order to inform future researchers of the revaluation of particular issues in *MSM* analysis.

### **Brief state of the art**

The term Musculoskeletal Stress Markers (*MSM*) was introduced by Diane Hawkey and Charles Merbs in 1995. According to these authors (1995: 324), a *MSM* can be defined as “a distinct skeletal mark that occurs where a muscle, tendon or ligament inserts onto the periosteum and into the underlying bone cortex”. *MSM* are also referred to as enthesopathies, a direct reference to the bony changes that occur at the attachment sites (from the Greek word *enthesis* which means “insertion” (Anderson, 1994 in Steen and Lane, 1998). These enthesal changes include surface irregularity, hyperostotic reactions (*i.e.* enthesophytes), osteolytic reactions (erosions) and neo vascularization (Mariotti *et al.*, 2004, 2007; Cardoso and Henderson, 2010; Villotte *et al.*, 2010).

Clinically, enthesopathies are commonly identified as inflammatory or non-inflammatory reactions (Freemont, 2002). Enthesopathies associated

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<sup>2</sup> *CIAS – Centro de Investigação em Antropologia e Saúde – “Research Centre for Anthropology and Health”* – is an Unit of Investigation and Development in the area of Biological Anthropology. One focus of *CIAS* is the study of human skeletal remains to infer past human demography, pathology and behaviour. The Workshop was held on 2-3 July 2009 at the former Department of Anthropology, University of Coimbra, Portugal.

with inflammatory changes tend to be classified with seronegative spondylarthropathies (Ball, 1971; Paolaggi *et al.*, 1984a, 1984b; McGonagle *et al.*, 1998; Benjamin and McGonagle, 2001). As a result, enthesopathies are currently used as a diagnostic criterion of seronegative spondylarthropathies in living people (Paolaggi *et al.*, 1984a, 1984b; Fournié, 2004) and in paleopathology (Rogers and Waldron, 1995; Martin-Dupont *et al.*, 2006). Inflammatory enthesopathies can occur secondary to synovitis in rheumatoid disease (Ball, 1971; McGonagle *et al.*, 1998). Erosive enthesopathies were also described in some cases of calcified tendinitis (*e.g.* Chadwick, 1989; Flemming *et al.*, 2003).

The non-inflammatory enthesopathies (Resnick and Niwayama, 1983; Freemont, 2002) can be described as:

- (1) traumatic – resulting from single episodes of extreme loading, such as sports injuries;
- (2) degenerative – occurring in response to tissue damage due to chronic and repetitive charges. This type can also be associated with increased age and is sometimes asymptomatic, despite its radiological identification;
- (3) metabolic – occurring as a consequence of the abnormal deposition of crystals, such as calcium pyrophosphate and hydroxyapatite, in the ligament or tendon;
- (4) idiopathic – caused by conditions such as DISH (diffuse idiopathic skeletal hyperostosis), an unknown disorder that is characterized by bone outgrowths at attachments of tendons and ligaments, ligamentous calcification, and ossification.

Despite the typology presented, it should be noted that there is no consensus in the classification of enthesopathies. Another source of disagreement is related to the structural and functional heterogeneities of entheses, an aspect commonly neglected in the bioarchaeological analysis. There are two types of entheses (Benjamin *et al.*, 1986; Benjamin *et al.*, 2002):

- (1) fibrous – characteristic of tendons that attach to a diaphysis, *e.g.* the insertion of the deltoid muscle on the humerus, and the area of muscle attachment on the *linea aspera* of the femur;
- (2) fibrocartilaginous – found on an epiphyses or apophysis. Different tissues are involved: tendons or ligaments, non calcified fibrocartilage, calcified fibrocartilage, and bone.

In paleopathology, the primary assumption is that *MSM* (or enthesopathies) develop as the result of activity of the musculature attached to the entheses and, as a consequence, they might reflect the occupation or activity of the individual. For these reasons *MSM*/ enthesopathies have been interpreted as Markers of Occupational Stress (*MOS*). Other proposed *MOS* include the degenerative joint lesions, referred to by some authors as osteoarthritis, the stress or fatigue fractures, and postural stress indicators, *e.g.*, squatting and kneeling accessory facets; all of these, that are believed to reflect routine habitual activities that are mechanically demanding and/or repetitive (Ubelaker, 1979; Kennedy, 1989; Larsen, 1997; Capasso *et al.*, 1999; Boulle, 2001). In addition to these features, other indicators have been described by Kennedy (1989), Capasso *et al.* (1999) and Wilczak and Kennedy (1998).

The searches for skeletal signs useful for the *reconstruction of past activity patterns* started in the 1980s. In 1983, Kenneth A. R. Kennedy described a high incidence of supinator and anconeus enthesal changes among Mesolithic Gangetic populations and related these modifications to the activity of spear-throwing. A similar study was published by Olivier Dutour in 1986 on two Neolithic skeletal samples from the Sahara. The researcher considered the occurrence of enthesal changes as pathological and interpreted them in the light of clinical medical data. In this study, the enthesopathies were classified as present or absent and the variations observed were viewed in terms of environmental and behavioural differences (fishers in lacustrine environments *vs* hunter-gatherers). Thus, enthesopathies of the upper limbs were interpreted as the consequence of throwing activities (the medial epicondyle of the right humerus), archery (the *triceps brachii* on the left side and the *biceps brachii* on the right side) and wood cutting, while enthesopathies of the lower limbs were related to walking and running over hard ground (the Achilles tendon and *adductor hallucis*). In 1987, J. Lawrence Angel and colleagues compared the occurrence of enthesal changes in a Free Black community and a Black slave population. As a recording method, they used a scoring system that classified the bone alterations in various stages from 'absent' to 'showing strong development'. The results indicated a less strenuous way of life for the Free Black population. Additionally, the authors also attempted to recognize signs of specific activities like horse riding, but (unlike Kennedy and Dutour) without any medical references. A year later, Eric Crubézy and Diane Hawkey were the first authors to

propose, independently, a systematic method for scoring bone changes at entheses in a readily reproducible manner. In his PhD thesis, Crubézy (1988) created a scoring system composed of four degrees of severity based on the dimension of the exostosis at the entheses site. This new procedure, when applied to a French medieval sample, revealed a possible sexual division of labour. The author's interpretations focused on comparisons between the physiological and pathogenesis patterns of the lesions observed and contextual archaeological and iconographical data. In addition, he attempted to discuss general trends and levels of activity instead of identifying specific individual activities.

A third scoring method was proposed by Dianne Hawkey (1988) in her MA thesis and applied to ancient Thule Eskimos groups. In this new system, the *MSM* manifestations were classified according to the presence of three distinct bone features: (1) ossification exostosis; (2) robusticity marker; and (3) stress lesions. After the publication of this study (co-authored with Charles Merbs) in 1995 in the *International Journal of Osteoarchaeology (IJOA)*, it became a standard reference, as indicated by the number of citations (73 according to Google Scholar and 43 in the Web of Knowledge – as of January 8, 2010 – making it the 5<sup>th</sup> most frequently cited paper published in *IJOA*). In this study, the concept “robusticity” refers to “hypertrophy of bone, in the form of a robust muscle attachment [...] the direct result of increased stress and continual stress of a muscle in daily, repetitive tasks “ (p. 324). Thus, almost all *MSM* were considered as physiological adaptations, not pathological changes, and comparisons were not made with clinical data on enthesopathies, but instead with kinematic and electromyographic studies.

This brief ‘state of the art’ outline presents some of the basic disagreements amongst researchers. For Dutour (1986) and Crubézy, (1988) enthesal changes were called enthesopathies, as in the medical literature, and interpreted according to clinical studies from sports and occupational medicine. In Hawkey and Merbs (1995) and Angel and colleagues (1987) studies, such changes were not considered as pathological. This terminological and conceptual opposition is still present today. There are also differences in the interpretations. In the studies by Dutour (1986) and that of Hawkey and Merbs (1995), for example, specific activities were recognized, in contrast to other researches who seemed to prefer to deal with general amounts of stress. Some of these issues were discussed in the symposium titled *Activity patterns and Musculoskeletal Stress Markers: an*

*integrative approach to Bioarchaeological questions*, co-organized by Jane Peterson and Diane Hawkey in 1997 (abstracts in the *American Journal of Physical Anthropology* (*AJPA*), supplement 24 (1997), presented at the 66th Annual Meeting of the American Association of Physical Anthropologists in St. Louis, Missouri). The papers in this symposium appeared the following year in a special issue of *IJOA* with a preface and 8 papers (Peterson and Hawkey, 1998). Some of the questions addressed in that symposium are still being discussed today, such as the influence of confounder variables like age and sex, enthesis morphology, the subjectivity of the methods used, and their universally indiscriminate application to entheses. Several researchers have warned against the pitfalls of false positives and the influence of multiple confounding factors and pathologies, mainly spondylarthropathies and DISH (Dutour, 1992; Pálfi and Dutour, 1996; Wilczak, 1998; Jurmain, 1999). John Robb, in his 1998 paper warned against oversimplification of statistical analyses of *MSM*. More recently, Elisabeth Weiss (2003; 2004) has proposed that body size can also be a confounding factor.

The basic assumption of the relationship between osseous changes at entheses and muscular activities was questioned by Eugénia Cunha and Cláudia Umbelino (1995) in their study of enthesopathies. Their application of Crubézy's (1988) scoring system to a known-occupation sample – the Coimbra Identified Skeletal Collection – failed to find differences between activity groups. The same negative result was obtained by Ann Zumwalt, in 2006 in an experimental test using an animal model (adult sheep). Descriptions of other attempts to reconstruct past behaviours from bone analysis can be found in Jurmain (1999) and in Pearson and Buikstra (2006). After the Workshop, several papers that discussed the occurrence of enthesal changes in known occupation samples (Alves-Cardoso and Henderson, 2010; Niinimäki, *in press*; Villotte *et al.*, 2010) and archaeological samples (Molnar, 2010; Molnar *et al.*, *in press*) have been published.

In spite of the disagreements described, *MSM* continue to be used in reconstructions of behavior, and in the past two decades many authors have attempted to distinguish general activity patterns in past populations on the basis of these markers. Consequently, in different countries several PhD and MA theses have been produced on this topic (Table 1).



**Table 1.** Examples of PhD and Master thesis about MSM conducted worldwide in the last decade.

Author	Date	Thesis	Title	Country
Nagy, B.	2000	PhD	<i>The life left in bones: evidence of habitual activity patterns in two Prehistoric Kentucky populations</i>	U. S. A.
Hartnett, K.	2002	Master	<i>Habitual activity patterns at the historic period Mayan site of Tipu, Belize</i>	Belize/ U. S. A.
Rodrigues-Carvalho, C.	2004	PhD	<i>Marcadores de estresse ocupacional em populações Sambaqueiras do Litoral Fluminense</i>	Brazil
Groves, S.	2006	PhD	<i>Spears or ploughshares: multiple indicators of activity related stress and social status in four early medieval populations from the North East of England</i>	U. K.
Assis, S.	2007	Master	<i>A memória dos rios no quotidiano dos homens: contributo de uma série osteológica proveniente de Constância para o conhecimento dos padrões ocupacionais</i>	Portugal
Myszka, A.	2007	PhD	<i>Reconstruction of the somatic structure of man on the basis of selected skeletal traits</i>	Poland
Alves-Cardoso, F.	2008	PhD	<i>A portrait of gender in two late 19th and early 20th century Portuguese populations: a palaeopathological perspective</i>	Portugal/ U. K.
Molnar, P.	2008	PhD	<i>Tracing Prehistoric activities: life ways, habitual behaviour and health of hunter-gatherers on Gotland</i>	Sweden
Ponce, P.	2009	PhD	<i>A comparative study of activity-related skeletal changes in 3rd-2nd millennium BC coastal fishers and 1st millennium AD inland agriculturists in Chile, South America</i>	Chile/ Argentina/ U. K.
Henderson, C.	2009b	PhD	<i>Musculo-skeletal stress markers in bioarchaeology: indications of activity levels or human variation?</i>	U. K.
Villotte, S.	2009b	PhD	<i>Enthésopathies et activités des hommes préhistoriques: recherche méthodologique et application aux fossiles européens du Paléolithique Supérieur et du Mésolithique</i>	France

## The Coimbra Workshop on MSM

Being aware of the problems that surround the use of *MSM*, the organizers of this meeting sought to focus on the theoretical and methodological points of divergence through discussions of a set of studies

conducted on specific skeletal samples. To pursue this goal, the format of a Workshop was chosen, with the intent of attracting not a general audience in paleopathology but instead a smaller group of people who share an explicit interest in this topic. Despite its narrow focus, 75 researchers from 21 different countries attended to the Coimbra Workshop on *MSM*.

The scientific programme was organized in three major sessions, each one dealing with a specific subject.

### Session 1 – Methodological issues

The first open session was centred in the methodological issues. Charles F. Merbs, well known to the participants in the context of *MSM* studies, presented the keynote lecture: *MSM – perhaps not a superstar but an important member of the team* (Merbs, 2009: 30). In this presentation, the author highlighted the importance of *MSM* in archaeological, forensic and anatomical cases. Merbs argued persuasively that, in addition to the *MSM* themselves, such studies should also include anatomical features, postural markers, and osteoarthritis that are classified as *MOS*.

The papers that followed were very much in synchrony with the aims of methodological discussion. Although no explicit criticism was made of the more classic methodologies, the papers presented explored new quantitative or qualitative methods developed in the past five years. All of the authors noted the advantages and the drawbacks of their methods and stressed the need to test them in specific samples.

A reevaluation of the Hawkey and Merbs (1995) method was presented by Valentina Mariotti and co-authors (2009). This new standardised scoring method was developed in Mariotti's PhD research (Mariotti et al., 2004; 2007); the method is designed to make data collection more systematically reproducible and comparable. Bearing in mind the multifactorial aetiology of *MSM*, Mariotti and co-authors presented possible solutions to various problems, and they advocated the study of identified skeletal collections (*e.g.* Frassetto collection) or clinical cases where sex and age are known. The researchers suggested that clear pathological cases should be excluded from *MSM* analysis and advised a careful interpretation of the results (*i.e.*, by sex and age group). For the study of occupational indicators, they proposed the use of homogeneous samples in agreement with other activity markers and clinical data.

Sébastien Villotte (2009a) presented a methodological proposal, developed during his PhD project (Villotte, 2006), on Coimbra, Spitalfields, Sassari and Bologna identified collections. This method was based on medical data which distinguished at least two types of attachment sites: fibrous and fibrocartilaginous. The author recommended that activity related studies should be based on fibrocartilaginous entheses, because he found no correlation between fibrous attachments and the various intensity of manual labor analysed in the in four populations studied.

During her PhD research, Charlotte Henderson (2009b) developed a two dimensional quantitative method to record entheses through a combination of macroscopic and metric data. Henderson (2009a) concluded that variations in enthesopathies can be quantified by studying the size and shape of entheses. The author also emphasises the need to use anatomical data, in particular the distinctions between fibrous and fibrocartilaginous attachment sites, for a better understanding of skeletal enthesal changes.

*MSM* studies have recently benefitted from several technological improvements. Doris Pany and co-authors (2009) presented a three-dimensional method to quantify entheses. After scanning and creation of a 3D model, various features of the attachment can be quantified including: areas, perimeters and measures of surface complexity. The three-dimensional digital casts are invaluable in reburial scenarios. This method “could provide a basis for creating new standards for visual scoring of entheses and joint features” (Pany *et al.*, 2009: 34).

Using a pQCT (peripheral Quantitative Computed Tomography) scan, Milton Nunez and co-authors (2009) evaluated the cross-sectional shape, bone distribution, and the bone mineral density (BMD) of *MSM* on the radial tuberosity area (RTA). Their research, on an identified collection housed at the Central Natural History Museum, revealed that under biomechanical stress the radial tuberosity does increase its thickness or BMD. Ageing and muscle forces seem to affect the biomechanics of the *MSM* area. However, the destruction of bone integrity is considered a drawback of this method.

The 6<sup>th</sup> presentation of this first session was by Cynthia Wilczak (2009a), a well known researcher in this field. Wilczak presented a new three-dimensional method to evaluate the surface nature of the radial tuberosity area, using the low cost Next Engine 3D Scanner. The author emphasized the

value of quantitative measurements in partitioning the variation to control for confounding variables such as body size differences and age. Geneviève Perréard Lopreno (2009) adopted a sequential recording system to the study of the clavicular entheses. According to the researcher, the method allows the differentiation between minor and major markers of activity in bone sample from SIMON identified skeletal collection (Switzerland).

During this first session, all the authors referred the advantages and drawbacks on their methods and the need to test them in specific samples. Even so, the distinct *MSM* methods have been used to reconstruct past activity patterns.

## **Session 2 – *MSM* studies: applications to archaeological and to identified samples**

The second session discussed the results of *MSM* analysis of archaeological and identified skeletal samples. A major question was posed: is it possible to discover activity patterns, or should *MSM* being viewed as *muscle stress markers*?

Christopher Knüsel (2009) introduced the session with a keynote lecture titled *When Adam delved and Eve span, there were, of course, no gentlemen*, in which he explored the topic of *Muscles, movements, and activity-related skeletal change* according to Social Theory Discourse, which emphasizes the need for interpreting the data within appropriate social and cultural contexts. Knüsel noted that the social environment allows more or less expression of the genetic background and in the same time modifies its form (epigenetic factors).

This session continued with the presentation of sixteen works, ten focused on the application of *MSM* methodologies on archaeological samples (Table 2), five on identified skeletal collections, and one based on ethnographical data.

**Table 2.** Summary of the works presented on archaeocological samples.

Sample		Method	Major results	Authors
Chronology	Location			
Mesolithic / Neolithic	Sudan	---	MSM non useful to non-masticatory dental use	Jakob, 2009
Neolithic / Bronze Age	Thailand	Hawkey and Merbs, 1995	Body size	Foster <i>et al.</i> , 2009
Neolithic / Natufian	Southwest Asia	---	Environmental/Activities	Peterson, 2009
Neolithic	Portugal	Crubézy, 1988	Mobility/Pastoral activities	Silva, 2009
Bronze Age	Spain	Al Oumaoui <i>et al.</i> , 2004	Environmental	Al Oumaoui <i>et al.</i> , 2009
Neolithic / Modern	Poland	Hawkey and Merbs, 1995	Body size	Lorkiewicz <i>et al.</i> , 2009
9-10 <sup>th</sup> century	Czech Republic	Villotte, 2006	Environmental/Social	Havelková, 2009
11-14 <sup>th</sup> century / Pre-European	Gran Canaria / Spain	Galtés <i>et al.</i> , 2006	Daily activities	Cabrera <i>et al.</i> , 2009
14-19 <sup>th</sup> century	Portugal	Mariotti <i>et al.</i> , 2004	Fishing activities	Assis, 2009
16 <sup>th</sup> century / Pre-Columbian	Peru	---	Weaving activities	Morán <i>et al.</i> , 2009

The chronology of the archaeological samples varied from the Mesolithic to the Modern period and represented eight countries in South America, Asia and Europe. In ten studies, skeletal individuals or commingled bones were scrutinized applying six different methodological approaches developed by Crubézy (1988), Hawkey and Merbs (1995), Mariotti and co-authors (2004), Al Oumaoui and colleagues (2004), Villotte (2006) and Galtés and colleagues (2006). The *MSM* interpretation by each author(s) was quite interesting, as follows:

Tina Jakob (2009) pointed out the common problems of sample size and bone preservation in *MSM* studies and concluded that *MSM* on the mandibles may not reflect non-masticatory dental use.

Jane Peterson (2009), Ana Maria Silva (2009), Petra Havelková (2009), Jonathan Cabrera and co-authors (2009), Sandra Assis (2009) and José António Morán and colleagues (2009) related *MSM* to daily activities; in some cases the patterns showed sexual dimorphism. These studies were based on archaeological, historical and ethnographic data.

Jane Peterson (2009) and Al Oumaoui and co-authors (2009) viewed environmental constraints as responsible for the different patterns observed in their samples, while Aimee Foster and colleagues (2009) and Wieslaw Lorkiewicz and co-authors (2009) claimed that body size (not sexual division of labour or physical activity, respectively) was the main factor affecting *MSM* expression.

The importance of using identified skeletal collections in the study of *MSM* is that this approach allows the control of confounding variables such as sex, age and occupation. Five presentations in this session focused on individuals who lived and died during the late 19<sup>th</sup> and mid-20<sup>th</sup> centuries, representing identified skeletal collections.

Cláudia Umbelino and Eugénia Cunha (2009) looked back on their 1995 study that applied Crubézy's method of scoring (1988) to the Coimbra Identified Skeletal Collection. In that particular analysis no correlations were found between occupation and development of enthesopathies. The authors argue "that the main problem is due to the lack of definition of the occupations, for both sexes [...] and the impossibility to know for how long the concerned individuals practiced the referred occupations" (p. 40).

Francisca Alves-Cardoso (2009) explored issues of sex, gender, age and *MSM* in Lisbon and Coimbra Identified Skeletal Collections, and concluded that age at death, not sex nor activity patterns, was the major variable in *MSM* development. She also drew attention to the fact that individuals' life histories cannot be summarized solely by their occupations at the time of death.

Sylvia Jiménez-Brobeil and co-authors (2009) analysed a collection from the city of Granada (Spain), according to the methodology of Al Ouamoui *et al.* (2004). Except for some differences found between males and females, they attributed the variations mainly to increasing age.

Marco Milella and co-workers (2009) studied skeletons from shoemakers and porters from the Frassetto and Sperino collections, both from Italy, using Mariotti and colleagues' methodology (2004: 31). "The results highlight greater robusticity in the porters for all the functional complexes, in particular for the elbow and for the hip". For future works this team recommends the "study of other homogenous samples representing specific activities".

Hugo Cardoso and co-authors (2009) presented their study of the toes of individuals from the Lisbon Identified Skeletal Collection. Searching

for the presence or absence of bony ridges along the diaphyses, they found differences between the sexes and age groups, but these were not related to occupational categories.

The work of Sandra Assis and co-authors (2009), based on ethnographic and iconographic data from Angola and Mozambique, showed that fishing and hunting are multi-task activities not exclusive to only one sex.

### Session 3 – Multifactorial etiology of enthesopathies

A third session was dedicated to the multifactorial aetiology of enthesopathies. The keynote lecture, presented by Robert Jurmain (2009), was marked by one of the most sceptical approaches to *MSM* use: even the name of the Workshop itself was questioned, albeit with a sense of humour. The title of Jurmain's presentation is self explanatory, the perfect introduction to the final session: "*Understanding "musculoskeletal stress markers": their multifactorial etiology and constraints on simplistic interpretations*". From the medical viewpoint, enthesopathies can be induced by dozens of conditions, ranging from pathological to behavioural. According to Jurmain (2009: 23) "it is becoming increasingly apparent that simplistic interpretations of "MSM" as reliable indicators of habitual adult activities are scientifically untenable."

This opening address was followed by Paula Kyriakou (2009) who studied medieval and post medieval samples from Scotland. The author provided a differential diagnosis for the presence of *MSM* in the lower limb, emphasizing the recognition of incipient cases of DISH where the more obvious spinal manifestations are absent.

Carina Marques (2009) studied the presence of spondyloarthropathies in individuals from the Lisbon identified collection. She recommended that when studying enthesopathies, mainly in the axial skeleton, attention should be given to the anatomical distribution pattern of enthesal lesions since they can be caused by spondyloarthropathies.

And, finally, Ian Magee (2009), in individuals from the Spitalfields named collection, questioned the impact of activity on the auricular surface of the ilium, which is considered as an enthesis by some authors (*e.g.* Benjamin and McGonagle, 2001), as a way to refine the methodologies to estimate age at death.

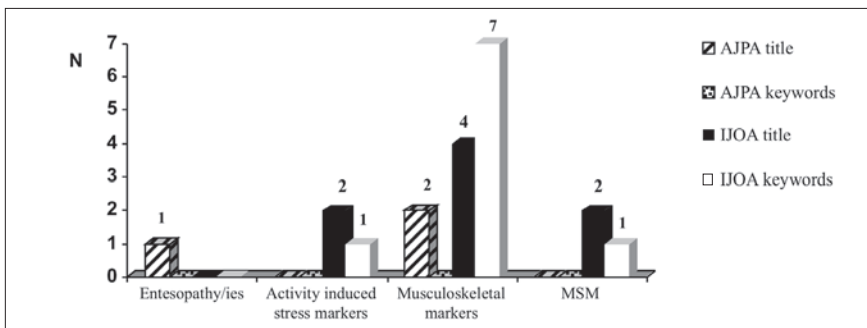
## Plenary session

The meeting concluded with a Plenary Session in which two annotators, Charlotte Roberts and Charles Merbs, reviewed the presentations and debates that took place during the Workshop. In the general discussion, participants expressed their opinions on many topics, including the urgent need for a standardized, accurate terminology as well as the benefits and pitfalls of scaling *versus* presence/ absence methods. The aim of promoting a vibrant exchange of perspectives, ideas and solutions was successfully achieved, and resulted in the creation of three working groups:

A. The *Methods* group consists of Charlotte Henderson, Cynthia Wilczak (coordinator), Doris Pany, Sébastien Villotte, and Valentina Mariotti. They proposed “to promote standardized data collection methods that will facilitate the comparison of results across studies” (Wilczak, 2009b).

B. The *Terminology* group members are Geneviève Perréard Lopreno, Robert Jurmain (coordinator), Sébastien Villotte, Valentina Mariotti. A quick survey in September 2009 of the Websites of the *AJPA* and *IJOA* (Figure 1) revealed that ‘musculoskeletal markers’ is the preferred phrase in both titles and keywords of *IJOA* articles and in the titles of *AJPA*, followed by ‘MSM’ and ‘enthesopathies’ in both journals. ‘Activity-induced stress markers’ was only found in the title and keywords of papers published in *IJOA*.

C. The *Occupation* group is formed by Francisca Alves-Cardoso, Geneviève Perréard Lopreno (coordinator), Marco Milella, Nivien Speith, Rose Drew, Sandra Assis; their charge is to attempt to standardize the occupation groups defined in the major identified skeletal collections.



**Figure 1.** MSM terminology frequencies in *American Journal of Physical Anthropology* (*AJPA*) and *International Journal of Osteoarchaeology* (*IJOA*) titles and keywords.



## Final comments

The goal of the Workshop organizers – to bring together a variety of researchers, both experts on the musculoskeletal markers and those new to *MSM* studies, to discuss the methodologies, terminology, and the effectiveness of enthesopathies as markers of occupational stress – was very successful, as attested by the participation of researchers from Asia, the Caribbean, Europe, North and South America, and Oceania. Moreover, for the first time, authors of different *MSM* methods were brought face to face for discussions.

The importance of the work presented, as well as the discussions that took place, on 2-3 July, 2009 extends far beyond the brief summary presented here. This paper attempts to synthesize 31 presentations and the main developments achieved at the *Workshop in Musculoskeletal Stress Markers*. We, the authors, are aware that there may be errors or omissions in our summaries of the issues addressed and the opinions presented, and we recommended that any researcher interested in a specific work contact the author(s) of the presentations directly. Moreover, we also suggest a visit to the Workshop website (<http://www.uc.pt/en/cia/msm/>), where 29 of the works presented are available for download, as well as the Program & Abstracts book (Santos *et al.*, 2009). To this date, as a point of interest, from 4<sup>th</sup> July 2009 (the day after the Workshop ended) and 8<sup>th</sup> January 2010, the website was visited 491 times, with 3187 pages viewed, according to Google Analytics. Visitors to the site came from Europe, North and South America and Oceania. Moreover, this website is continuously updated, as resolved at the Plenary Session. The first document uploaded responded to one of the main points of agreement in the Workshop: *MSM* is not the most appropriate term given the multitude of factors that have been implicated in the development of enthesopathies. Thus, Jurmain and Villotte (2010), from the *Terminology* group, suggested the use of the terms “enthesal change” or “enthesal changes”.

The website has another function: to permit all the researches with a common interest in *MSM* studies can join in the discussion. Thus, in January 2010 a blog (<http://coimbraworkshopmsm.blogspot.com/>) was created.

All of the researches who share a common interest in *MSM* studies are welcome to join the discussion to contribute to more uniform and reliable analyses *in the reconstruction of past activity patterns*. We hope that this

Workshop and further developments will help create a more unified scientific approach to this important area of study.

## Acknowledgments

We would like to express our gratitude to all the participants of the Workshop in *MSM* (Coimbra), to the Honorary and Scientific Commissions, to the Sponsors and Supporters, to the Volunteers and to the Working groups. Thanks are also due to the Organization Committee of the 3<sup>rd</sup> PAMinSA and to Cláudia Rodrigues-Carvalho to their invitation to present the reflections from the Coimbra Workshop in Necochea (Argentina). We acknowledge the reviewers for their suggestions and edits.

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Artigo recebido a 10 de Fevereiro de 2010 e aceite a 12 de Abril de 2010.

