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Skeletal markers of occupational stress in the toes: a case report from Alcabideche (Cascais, Portugal)

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Abstract The analysis and interpretation of skeletal markers of occupational stress play an important role in the reconstruction of activity patterns and socio-economic life of prehistoric and historic populations. In this paper, skeletal markers on the phalanges of the feet are described in an adult skeleton recovered from the archaeological excavation carried out in the churchyard of the S. Vicente Church (12^{th}-19^{th} centuries) in Alcabideche (Cascais, Portugal). These markers refer to well-developed flexor ridges on the proximal phalanges of the lateral four toes. The morphology and location of these alterations indicate strong flexor tendons and suggests that they were probably produced by stress brought about by frequent or repeated plantarflexion of the toes. Considering that farming and gardening would be frequent activities in this rural population, the authors suggest that the use of a hoe might be the regular or habitual activity that might have produced these alterations.

Key words Skeletal markers of occupational stress; enthesopathies; socio-economic practices; Alcabideche; Portugal.

Resumo No esqueleto humano, a análise dos marcadores de stresse ocupacional desempenha um papel importante na reconstituição das actividades e aspectos socioeconómicos de populações históricas ou pré-históricas. Os autores descrevem as entesopatias observadas nas zonas de inserção das baínhas dos músculos extensores do pé nas falanges proximais do segundo ao quinto dedos, de um esqueleto adulto recuperado durante a escavação arqueológica efectuada no adro da Igreja de São Vicente (Séc. XII-XIX) em Alcabideche (Cascais, Portugal). A morfologia e localização destas estruturas ósseas indicam a presença de tendões robustos que se desenvolveram, provavelmente, em

consequência de stresses mecânicos provocados por frequente ou repetida flexão plantar dos dedos. Sendo os trabalhos de lavoura e a manutenção de pequenos quintais as ocupações mais frequentes desta população rural, sugerimos que as modificações ósseas observadas se deram em resultado de uma actividade regular que envolvia o uso frequente da enxada.

Palavras-chave Marcadores de stresse ocupacional; entesopatias; práticas socioeconómicas; Alcabideche; Portugal.

Introduction

The reconstruction of past socio-economic practices has been one of the major goals in anthropological and historical investigation of past human societies. When documentary sources are scarce or absent the researcher has to rely mainly on material evidence recovered from the archaeological record. Although archaeological studies have contributed predominantly to the reconstruction of various aspects of historic and prehistoric socio-economic life when such documentary sources are limited, physical anthropology can also play an important role in this kind of research. The contribution of physical anthropology derives from the study of skeletal markers of occupational stress (SMOS), which refers to irregularities of skeletal or dental tissue that develop under conditions of prolonged or continued stress imposed by some habitual or occupational activity that is not attributable to disorders of disease, metabolism, biochemical, hormonal or enzymatic imbalances or neuronal and vascular disorders (Kennedy, 1989). Briefly, continual stress or pressure of external and internal forces in a daily, repetitive task creates a skeletal record of the individual's habitual activity or occupation. Therefore, if we can recognize these skeletal changes and link them to specific physical activities, SMOS can provide an important source of information about past socio-economic practices such as work patterns and sexual division of labour. However, the study of SMOS in archaeological skeletal samples should not be used separately from archaeological evidence collected from the

excavation of settlements (e.g. economic activity) and cemeteries (e.g. social status) and from documentary information (e.g. historical records), when available.

SMOS are usually classified into four types: degenerative joint disease, enthesopathic lesions or musculoskeletal stress markers; dental attrition and stress fractures or trauma (Garreta, 1999; Kennedy, 1989). Although this classification is based on different types of stressors the same activity will not produce necessarily only one kind of marker or induce one kind of stress. Habitual activities frequently exert multiple mechanical loads and stresses, such that a specific occupation is seldom associated with a single marker. Certain life ways may also include a wide variety of different activities that exert different pressures in different skeletal systems. Therefore, occupation-skeletal stress marker relations are not a straightforward link and are also dependent on other factors such as sex, age and health of the individual.

This preliminary analysis of a single case study was initiated to describe bony changes on the proximal phalanges of the feet and other associated SMOS on an adult skeleton. Based on the supposed stress factors involved in the formation of such skeletal structures the authors attempt to link them to a specific occupational activity. Although this research was limited to the observation of only one case it refers to a skeletal marker which appears not to be described in the literature and as such it is meant to call attention to case studies of frequently unrecognised skeletal features.

Materials and methods

The skeletal material comprises an almost complete but poorly preserved skeleton (burial 18) (Figure 1) recovered in 2001 from a salvage excavation carried out by the Associação Cultural de Cascais and the authors in the churchyard of the S. Vicente Church (Alcabideche, Cascais, Portugal). This excavation retrieved over 100 burials dated provisionally from about the 12th to the late 19th century. Although there is no precise chronology for burial 18, the

Figure 1. Burial 18. Lighter areas represent lime deposition and skeletal destruction is visible mainly on the thoracic region.

fact that it was one of the top burials to be excavated suggests a 19th century inhumation. Fragments of clothing, such as buttons, hooks and traces of cloth, were the only kinds of artefacts associated with the skeleton, also suggesting a recent burial. It also provided residues of lime deposition, which was a clear indication of a modern inhumation and responsible for significant skeletal destruction.

All the bones were examined visually during fieldwork and briefly re-examined in the laboratory. Only the best-preserved bones were photographed. Age and sex were determined by using standard methods (Ferembach *et al.*, 1980) showing the skeleton to be that of a young adult male. The stature was estimated to approximately 159 cm (± 5,96 cm) according to Mendonça (2000).

Because we need to discuss the sample in the appropriate context it is important to broadly characterize the past socio-cultural milieu of Alcabideche. Although now it is a densely urbanised area, until relatively late in the twentieth century Alcabideche was mainly a rural and agricultural region where farmland, orchards and small-owned gardens dominated the landscape. Right until the nineteenth century around 70% of the labour force worked in the primary sector (Ventura, 1990).

Description of skeletal structures and stress factors involved

The bony changes refer to well-developed ridges of attachment for fibrous sheaths of the flexor tendons on the medial and lateral

sides of the proximal phalanges of the lateral four toes (Figure 2)in both feet. The fibrous sheath is an osseoaponeurotic canal (*Vaginae synoviale digitorium pedis*) that contains the terminal portions of the tendons of the long (*Flexor digitorium longus*) and short (*Flexor digitorium brevis*) flexor muscles of the foot (Gray, 1959). Both feet were recovered, which allowed the observation that the ridges were more prominent in the right foot. These ridges are classified as musculoskeletal stress markers because they refer to bone changes in the area "where a muscle, tendon or ligament inserts onto the periosteum and into the underlying bony cortex" (Hawkey and Merbs, 1995: 324) and an increased stress load due to greater muscular activity leads to hypertrophy of the bone in the place of that muscular attachment (the "entheses" and thus "enthesopathies").

Figure 2. Proximal phalanges of the right foot showing flexor ridges (arrow). Plantar view.

These ridges are similar to the marked lines of attachment for flexor ligaments on palmar surfaces of the first phalangeal row of the hand (Kennedy *et al.*, 1986). While in the hands these lines result from the stress imposed by flexion when holding a tool or an instrument in a firm grasp, in the feet the stress factor involved is a force exerted by the tendon flexor sheaths upon the lateral digits when the toes plantarflex. The crests represent a structural reinforcement of the diaphysis against habitual mechanical loads placed upon the phalanges by the digital flexors. These bony crests in the feet are considered common in apes, but not in human pedal phalanges (Stern and Susman, 1983; Aiello and Dean, 1990) and only in Neandertals are they considered to be of modest development (Trinkaus and Hilton, 1996).

Occupational activities and behavioural interpretation

In apes (Aiello and Dean, 1990) and early hominids (Stern and Susman, 1983) well-developed flexor ridges are associated with grasping feet and hands for arboreal locomotion. In modern humans, however, stress factors on the muscles associated with flexion of the foot must bear a relation to other kinds of physical activity.

The authors suggest that the flexor muscles of the foot would be frequently or repeatedly active in a situation where there is a constant need for body balance while performing repeated movements that require the momentary loss of equilibrium to the front. Cultivating using a hoe (Figure 3) represents such a situation. This sort of activity requires repeated bending forward and the contraction of the plantar flexors of the toes to help re-balance the body and resume the repetitive movement with the hoe.

Because SMOS must be interpreted in relation to the entire individual and not as isolated phenomena (Kennedy, 1998), it is important to analyse associated markers that might corroborate the hypothesized activity pattern. The presence of a bony spur (Figure 4)

Figure 3. Reconstitution of the proposed activity pattern: cultivating with a hoe.

where the short plantar ligaments of the foot inserts, suggests that the foot is subjected to strong mechanical forces in the sole. This ligament is important for arch support (Aiello e Dean, 1990) and is probably under considerable stress in a constant upright position.

Figure 4. Right calcaneus showing bony spur where the short plantar ligament inserts (arrow). Medial view.

Joint degeneration in the lumbar vertebra (Figure 5) is consistent with an activity that requires repeated bending forward and mechanical stress on the lower back. Markings, although not very well developed, of muscle attachments for the deltoid tuberosity in the clavicle and humerus are also compatible with repeated movements of the arm when it is raised above the head.

Alternative scenarios for the proposed activity pattern are as follows. Repeated action of the flexor muscles could be required in a squatting position that would demand constant hyper-dorsiflexion of the metatarso-phalangeal joints. However, skeletal evidence for squatting, such as flattening of the femur condyles, and squatting facets on the distal tibia and the talus (Trinkaus, 1975), were not observed. Since the flexor tendons and their associated muscles also contract in the latter stages of the stance phase (Sutherland, 1966), long distance walkers or runners could presumably have the same kind of bony crests. However, the characteristic enthesopathy of the Achilles tendon is very

Figure 5. Fifth lumbar vertebra showing extensive joint degeneration and osteophyte formation. Anterior view.

subtle, indicating that habitual walking or running might not be the cause for the changes observed in the proximal phalanges of the toes.

Nevertheless, there are some weaknesses in the proposed hypothesis that are worth mentioning. One might expect that the kind of repetitive activity that requires holding a hoe for prolonged periods of time would exert significant stress on the flexor muscles of the hand. However, the hands lack the prominent ridges for attachment of these muscles. In addition, because the lower limbs were not completely re-examined in the lab the authors could not confirm the presence or absence of any other compatible kind of musculoskeletal lesions. A more complete analysis in the lab of the whole skeletal sample could also provide a clearer picture of a wider range of physical activities and work patterns.

Discussion

Reconstructing people's occupations and physical activity or work patterns through the study of skeletal markers of occupational stress can provide important insights into various socio-economic aspects of past human societies. However, diagnosis is not an exact science and there is not a complete understanding of occupation-skeletal stress marker relations. When we rely solely on skeletal evidence, interpreting such traces must be tentatively pursued.

Enthesopathies or musculoskeletal stress markers can show which muscles, tendons or ligaments were more heavily used or under strain, but they do not tell us what sort of activity the individual carried out regularly. Thus, although it may be difficult or impossible to link specific markers to specific activities, the association between different markers to match patterns of activity will establish a consistent pattern with the hypothesised habitual occupation or activity. Even if such a pattern can be established, we probably should not attribute a specific modification of bone tissue to a single pattern of activity. Rather, it is the overall pattern of stress which best describes the habitual activities in which an individual may have engaged in life. In some cases diagnosis must be

restricted to stating that an individual had engaged in some form of demanding labour and in others we may be able to isolate markers of habitual stress to certain anatomical regions, such as the bones of the upper extremities, lower extremities or thorax. From these observations it is possible to suggest a range of cultural practices, which may have formed these skeletal modifications with reference to archaeological or historical records. In short, SMOS must not be interpreted as an isolated phenomenon but in relation to the entire individual, the population and the socio-cultural context.

Therefore, to further test the validity of the proposed hypothesis a population approach would be required to determine the frequency of skeletal changes and other associated SMOS. Sexual differences in the frequency of these structures would also be important since it represents evidence of some kind of sexual division of work. Finally, a comparison with other contemporary skeletal samples from a rural and agricultural milieu could further enhance the potential for hypothesis testing. Unfortunately, smaller bones, such as feet phalanges, are frequently not as well preserved in skeletal samples and thus may represent an additional obstacle for this research. Comparison with forensic cases of documented occupation and background would probably provide the decisive confirmation for the present proposition.

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The picture in Figure 1 is courtesy of Dr. Guilherme Cardoso (Associação Cultural de Cascais, Cascais, Portugal).

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