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Comparison of the Enthesal Changes of the os coxae of Portuguese Males (19th–20th centuries) with Known Occupation

V. CAMPANACHOa,b* AND A. L. SANTOSb,c

ABSTRACT The possible association between enthesal changes and activity has been widely studied. However, many questions remain. This study aims to assess if occupation and physical activity influence the age at which enthesal changes appear in the iliac crest, retroauricular area, iliac tuberosity, ischial tuberosity and obturator foramen. Absence or presence of ossification exostosis and stress lesions was recorded in os coxae from 130 males (19 to 68 years old) from Lisbon and Coimbra identified skeletal collections. The individuals were divided into two groups, based upon to the recorded occupations: manual (n = 60) and non-manual (n = 61). The sample was also divided according to an osteological indicator of physical activity: the femur robusticity index (55 are robust and 54 are gracile femora). The individuals from manual and robust groups were considered to have had physically demanding occupations, while the non-manual and gracile groups represent individuals with less demanding activities. The asymmetry of enthesal changes between left and right sides of the same individuals was tested with a Chi-square test. And the influence of occupation and physical activities on the age of appearance of enthesal changes was tested using logistic regression. Statistically significant asymmetry was not found between left and right bones (p < 0.05). However, for the logistic regression calculations, the only valid result was obtained for the ossification exostosis on the iliac crest for the measure of femoral robusticity. For the iliac crest, physical activity did not influence the appearance of ossification exostosis. It was not possible to obtain valid logistic regression models, probably due to the distribution of individuals in each occupational and robusticity category. Therefore, it was not possible to assess the influence of occupation and physical activity on the age at which enthesal changes appeared for retroauricular area, iliac tuberosity, ischial tuberosity and obturator foramen. Copyright © 2012 John Wiley & Sons, Ltd.

Key words: enthesopathy; markers of occupational stress; musculoskeletal stress markers; robusticity

Introduction

The reconstruction of identity and lifestyle, including physical activity, is widely undertaken by those studying archaeological and forensic skeletal remains. Physical activity is normally assessed by analyzing markers of occupational stress, such as enthesal changes.

Enthesal changes (Jurmain & Villotte, 2010) are musculoskeletal markers (Hawkey & Merbs, 1995), possibly caused by enthesal inflammation or continuous stress (Jurmain, 1999; Mariotti et al., 2004). As with all bone changes, they can either be osteophytic or osteolytic (Mariotti et al., 2004). Therefore, enthesal changes have been used as an osteological evidence of occupation in past communities (e.g. Kennedy, 1983; Dutour, 1986; Angel et al., 1987; Hawkey & Merbs, 1995, Peterson, 1998; Steen & Lane, 1998; Al Oumaoui et al., 2004; Józsa et al., 2004; Molnar, 2006; Lieverse et al., 2009). Nevertheless, some authors argue (e.g. Jurmain, 1999; Weiss, 2003; Cardoso, 2008; Alves Cardoso & Henderson, 2010; Jurmain et al., 2012) that the connection between occupation and enthesal changes is not as direct as it was previously believed.

The possible association between enthesal changes and physical activity has been widely studied (Cunha & Umbelino, 1995; Jurmain, 1999; Mariotti et al., 2004, 2007; Cardoso, 2008; Alves Cardoso & Henderson,
2010; Villotte et al., 2010; Santos et al., 2011; Milella et al., 2012). However, many questions remain, particularly for the entheseal changes of the os coxae, which is less frequently investigated (Cunha & Umbelino, 1995; Pfaff & Dutour, 1995; Robb, 1998; Villotte, 2006; Cardoso, 2008) than long bones. The existing studies of the entheseal changes in the os coxae focus on three main areas: the ischial tuberosity, the iliac crest and the iliac tuberosity. Therefore, it is necessary to perform a more systematic study using identified collections (Alves Cardoso & Henderson, 2010; Mariotti et al., 2009).

Occupation and physical activity are two different concepts. Occupation refers to the individuals’ professions stated in the collection's records, and physical activity the level of bone mechanical loading by physical actions, assessed by an osteological parameter, e.g. the femur robusticity. The hypothesis to be tested was that entheseal changes would appear earlier in those individuals with a more demanding occupation and physical activity. The present study aims to test this hypothesis on the os coxae of adult males from Portuguese identified skeletal collections.

Materials and methods

The male individuals analyzed belong to two Portuguese identified skeletal collections, which include data on occupation, sex and age at death. Sixty seven skeletons are from the Department of Life Sciences, University of Coimbra (Rocha, 1995; Santos, 2000) and 63 from the National Museum of Natural History, University of Lisbon (Cardoso, 2006). During the selection of the sample, individuals with pathological changes visible on the os coxae and possible cases of spondyloarthropathies and diffuse idiopathic skeletal hyperostosis (DISH) were excluded, according to the data provided by Francisca Alves Cardoso (personal communication) and Carina Marques (personal communication and in Marques, 2007). Women were not included because their occupations were mainly recorded as ‘domésticas’, a word that includes housekeepers and housewives, not allowing the distinction between individuals who had a more or a less demanding occupation. Male individuals were selected in order to have a similar number of skeletons by age class in each occupation group.

From the 130 male individuals, 257 (98.9%) os coxae were studied, and three were excluded due to poor preservation. These individuals have ages at death ranging from 19 to 88 years (Figure 1), with a mean age of 46.5 years old and standard deviation of 17.1 years.

According to the occupation stated in the collections' records, the sample was divided into two groups: 61 non-manual individuals (e.g. priest, student), with age at death from 20 to 88 years old (mean = 45 years; median = 43 years; standard deviation = 17.5 years), and 69 manual individuals (e.g. farmer, carpenter), with age at death from 19 to 79 years old (mean = 48 years; median = 47 years; standard deviation = 16.7 years). The division was made taking in consideration the texts from Armstrong (1972) and Cardoso (2008). As stated by Alves Cardoso & Henderson (2010), the division into manual and non-manual was an attempt to determine the possible association between the entheseal changes and general levels of activity.

The assumption was made that the manual group and robust individuals all had physically demanding occupations/activities, as opposed to the non-manual group and gracile individuals for whom the assumption was that the activities and occupations were less intense (Campanacho et al., 2012). In the present study, a distinction was made between the terms occupation and physical activity. Occupation refers to the professions reported, and physical activity is based in an osteological measure of activity, the femur robusticity. The occupations recorded may only refer to the last occupation of the individual and may not correspond to in vivo physical strain. Also, the records may not be

![Figure 1. Distribution of the 130 male individuals by age at death range.](image-url)
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Table 1. Distribution of the individuals by groups of occupation and robusticity

<table>
<thead>
<tr>
<th>Sample</th>
<th>Robust group</th>
<th>Gracile group</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
</tr>
<tr>
<td>Non-manual group</td>
<td>21</td>
<td>42.9</td>
<td>28</td>
</tr>
<tr>
<td>Manual group</td>
<td>34</td>
<td>56.7</td>
<td>26</td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
<td>50.5</td>
<td>54</td>
</tr>
</tbody>
</table>

There is not a total correspondence between the robusticity and the occupational groups for the 109 individuals (Table 1). Therefore, the associations between occupation and enthesal changes, and robusticity and enthesal changes were tested separately. Due to differential preservation, the number of individuals differs in the occupational and robusticity groups.

The absence or presence of ossification exostosis and stress lesions (cortex pitting that resembles a lytic lesion) (Hawkey & Merbs, 1995) at entheses was recorded separately in the following areas: iliac crest, retroauricular area, iliac tuberosity, ischial tuberosity and obturator foramen. Figure 2 demonstrates a normal enthesis, an ossification exostosis and a stress lesion. In the present study, as in Cardoso (2008), the enthesal changes were recorded in osteological areas instead of recording by the enthesis boundaries of ligaments and muscles. This procedure avoided the need to establish the proper enthesis limits and the error associated with an incorrect delineation. Table 2 lists the ligaments and the muscles that are attached in the studied areas and the number of individuals by each area analyzed along with the number of ossification exostosis and stress lesions observed for the total sample.

The intra-observer error of the recording method for enthesal changes was established by the number and percentage of different scores between the two observations of 20 left and right os coxae (from 13 individuals) two weeks after the first analysis. The intra-observer error for femoral measurements was calculated for 20 left femora using the technical error of measurement, the mean absolute difference and the coefficient of reliability (Ulijaszek & Kern, 1999).

The asymmetry of the presence of enthesal changes between the right and left os coxae from the same individual, by area, was tested using a Chi-square test for the total sample. This test was chosen to compare

![Image A represents an obturator foramen without enthesal changes. In contrast, images B and C represent ossification exostosis and stress lesions, respectively.](image)

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asymmetry in entheseal changes (e.g. whether they occur more frequently on one side than another) by individual.

Logistic regression was used to determine the age of transition (percentile 50 or median) from the stage absence to presence of entheseal changes for each occupational and robusticity group. The lower and upper quartiles as a measure of variability around the median were also calculated. The logistic regression model’s validity was evaluated by the significance of the Wald statistic. Whenever a logistic regression model could not be successfully fitted to the data for a certain variable, due to the non-significance of Wald, the model was considered invalid and subsequently was eliminated from the analysis.

The evaluation of the existence of statistically significant differences between groups and to assess if the occupational and physical activity had some influence on entheseal changes was analysed using logistic regression by comparing the medians of the age of transitions. Thus, the median age was compared between manual and non-manual groups, and between robust and gracile individuals, treated as covariates. Outliers were considered to be two times superior to the standard deviation (Maroco, 2007). Outliers were removed during the logistic regression to test whether these affected the significance of the Wald statistic.

Chi-square test and logistic regression were performed in SPSS 17. It was considered to be statistically significant when p < 0.05.

Results

Intra-observer error (Table 3) was low for all entheses except for the osteophytic changes on the ischial tuberosity. Therefore, ossification exostosis on the ischial tuberosity was excluded from the Chi-square and logistic regression analysis. For the femoral measurements, the intra-observer error is low as shown on Table 4.

No statistically significant difference was found in the asymmetry in entheseal changes between left and right os coxae for the same individual (p < 0.05). Thus, only the left innominate data was included in the logistic regression analysis (right innominate data was used when the left was unavailable). Due to the improved significance of the Wald statistic for the logistic regression model without the outliers, only the results obtained without the outliers are presented. Only the ossification exostosis on the iliac crest for the

Table 2. Number of individuals (N) by ossification exostosis and stress lesions for the total sample and anatomical structures affected on each observed bone area

<table>
<thead>
<tr>
<th>Bone area</th>
<th>Ossification exostosis</th>
<th>Stress lesions</th>
<th>Anatomical structure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Absence</td>
<td>Presence</td>
<td>Absence</td>
</tr>
<tr>
<td>Iliac crest</td>
<td>35</td>
<td>68</td>
<td>101</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retroauricular area</td>
<td>3</td>
<td>113</td>
<td>116</td>
</tr>
<tr>
<td>Iliac tuberosity</td>
<td>29</td>
<td>89</td>
<td>118</td>
</tr>
<tr>
<td>Ischial tuberosity</td>
<td>45</td>
<td>74</td>
<td>108</td>
</tr>
<tr>
<td>Obturator foramen</td>
<td>19</td>
<td>103</td>
<td>122</td>
</tr>
</tbody>
</table>

Table 3. Number and percentage of different scores between the two different observations (intra-observer error)

<table>
<thead>
<tr>
<th>Bone area</th>
<th>Type</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iliac crest</td>
<td>Ossification exostosis</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Stress lesion</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Retroauricular area</td>
<td>Ossification exostosis</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Iliac tuberosity</td>
<td>Ossification exostosis</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Ischial tuberosity</td>
<td>Ossification exostosis</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Stress lesion</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Obturator foramen</td>
<td>Ossification exostosis</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>
Comparison of Enthreeal Changes of Male os coxae

Table 4. Intra-observer results for the femoral maximum length and perimeter

<table>
<thead>
<tr>
<th>Calculations</th>
<th>Maximum length (mm)</th>
<th>Perimeter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>392</td>
<td>76</td>
</tr>
<tr>
<td>Maximum</td>
<td>503</td>
<td>99</td>
</tr>
<tr>
<td>Mean</td>
<td>438.95</td>
<td>87.15</td>
</tr>
<tr>
<td>Median</td>
<td>438</td>
<td>87</td>
</tr>
<tr>
<td>Technical error of measure</td>
<td>0.387</td>
<td>0.418</td>
</tr>
<tr>
<td>Coefficient of reliability</td>
<td>0.9998</td>
<td>0.9959</td>
</tr>
<tr>
<td>Mean average difference</td>
<td>0.100</td>
<td>0.150</td>
</tr>
</tbody>
</table>

The statistical non-significance of the influence of physical activity on the age of appearance of ossification exostoses on the iliac crest could be caused by the fact that entheseal changes are also influenced by other factors than occupation, e.g. diet, body size, locomotion, metabolism and pathologies such as DISH and spondyloarthropathies (Ball, 1971; Chadwick, 1989; McGonagle et al., 1998; Jurmain, 1999; Fleming et al., 2003; Weiss, 2003, 2004; Martin-Dupont et al., 2006; Marques, 2007; Cardoso, 2008). Although, possible cases of DISH and spondyloarthropathies were eliminated from the sample, no pathological analysis of the entire skeleton was performed. Consequently, other pathologies may have influenced entheseal changes in the os coxae. Also, the reliability of the femoral robusticity as an osteological measure of physical activity must be questioned. However, due to the aforementioned problems associated with the occupational records, this was chosen as another indicator of physical activity. The femur robusticity index measures bone deformation due to biomechanical stresses (Ruff, 2008). The external measurements may incorrectly express the femoral robusticity. Although,

male individuals from the 19th and 20th centuries is presented. This was assessed by comparing the median age of entheseal changes between groups with different levels of physical demand. Only one valid sample could be tested using logistic regression: the ossification exostosis on the iliac crest for the robusticity groups. The valid result for the iliac crest was obtained by removing four outliers all mature adults ≥ 60 years old without an ossification exostosis in the iliac crest. In this sample, physical activity of the individuals does not seem to have influenced the development of ossification exostosis in the iliac crest. The median age of appearance of ossification exostoses is similar for robust and gracile individuals, occurring on the fourth decade of life, as shown in Table 5. Thus, physical activity did not influence the appearance of entheseal changes. Studies of individuals of both sexes with known occupation found similar results. Cunha & Umbelino (1995) studied the association between occupation and entheseal changes in the post cranial skeleton from 151 individuals of both sexes from the Coimbra identified skeletal collection. The authors applied a different method (Crubézy, 1988) to record entheseal changes at the iliac crest, the ischial tuberosity and the ‘bridge’ between the ilium and sacrum. Their study revealed no association with occupation (Umbelino & Cunha, 2009). A study of a larger sample of the Lisbon and Coimbra identified skeletal collections found no association between occupation and entheseal changes of the iliac crest or ischial tuberosity (Cardoso, 2008).

The statistically non-significant difference in the age of appearance of ossification exostosis on the iliac crest between robust and gracile individuals, for the occupation and robusticity groups; on the ischial tuberosity occur in less than 10% of the individuals, for the occupation and robusticity groups; (i) stress lesions only occur in two individuals; (ii) ossification exostosis are present in the retroauricular area for all robust individuals, while in the gracile group is absent in two individuals, in the manual (n = 2) and non-manual groups are absent only in three individuals; (iii) stress lesions are absent in the obturator foramen, retroauricular area, and ischial tuberosity in occupation and robusticity groups, and for iliac crest for the manual and robust groups.

Discussion and conclusion

The possible influence of occupation and physical activity on entheseal changes of the os coxae in documented...
Wescott (2006) and Stock & Shaw (2007) argued that robusticity can be obtained by external measurements, it is possible that the formula used was not appropriate to measure mechanical loading. Other factors also influence bone robusticity, such as age (Ruff & Hayes, 1983), pathologies (Brothwell & Browne, 2002) and diet (Sahni et al., 2010) all of which may have had an impact on these results.

For the majority of areas analyzed, excepting the ossification exostosis of the iliac crest, no valid logistic regression models were obtained. Therefore, it was not possible to infer the influence of occupation and physical activity on the median age at which enthesal changes appeared. This could be the result of the distribution of the stages absence and presence of enthesal changes. For example, in some areas (Table 2), stress lesions were absent in all individuals. It could also be the result of the limitations associated with the collection records or a methodological problem.

Recorded occupation represents the last occupation and not the overall physical demands throughout life (Campanacho et al., 2012). The biographic data for both collections offers the occupation of the individuals at death. It is unknown whether the individuals performed the same occupation all their lives or if it changed (Alves Cardoso & Henderson, 2010). Also, the reliability of the occupation recorded is unknown (Armstrong, 1972; Vidal, 2004), and as was stated by Henderson and co-authors (in press), in their study of a 19th century rural population, occupation recorded is not sufficiently informative to study enthesal changes. Categorization of occupations is difficult, and as was recently demonstrated by Alves Cardoso & Henderson (in press), the results of a study can be influenced by the categories used to group the individuals. Another aspect can be associated with the fact that individuals placed in the non-manual and gracile groups may also have had demanding occupations and physical activities not recorded in the collections’ files (Alves Cardoso & Henderson, 2010, Campanacho et al., 2012). It is unknown if the individuals performed others activities outside their main work (Alves Cardoso & Henderson, 2010), and hierarchy within the same occupation may have existed since individuals can perform different tasks that involve different workload (Alves Cardoso & Henderson, 2010). However, these hypothetical situations are not among the data available for any of the Portuguese identified skeletal collections.

The authors also take into consideration the possibility that the recording method used for enthesal changes is not suitable. The methodology used (registration of presence and absent of ossification exostosis) is adapted from Hawkey & Merbs (1995), which ignores the new clinical information regarding entheses morphology and changes, particularly the two distinct morphologies (fibrous and fibrocartilaginous) of entheses (Villotte, 2006; Villotte & Knüsel, in press; Jurmain et al., 2012). Moreover, there is no standard scoring method available for the os coxae. The majority of methods were established without the analysis of the os coxae, e.g. Crubézy (1988), Hawkey & Merbs (1995), Mariotti et al. (2004, 2007); Henderson et al., 2010, Villotte et al. (2010), the only exception is the scoring methods developed for the ischial tuberosity by Robb (1998) and Villotte (2006).

Few stress lesions were recorded in the overall sample. This might be due to the difficulty of differentiating normal porosity from lytic lesions. It is, therefore, possible that osteolytic lesions were underscored in this sample.

There were no statistically significant differences between the right and left os coxae from the same individual in the presence of enthesal changes. In contrast, Cardoso (2008) found a significant asymmetry of enthesal changes in the iliac crest in female individuals. Probably, the difference obtained in these two studies results from the methodologies applied for enthesal changes recording.

This study analyzed the enthesal changes of os coxae, a skeletal region less frequently studied than the upper and lower limbs. From authors’ knowledge, this was the first time that the possible influence of occupation and physical activity on the enthesal changes appearance in the obturator foramen area was assessed. As has been concluded in other studies, the relationship between enthesal changes and individual activity is complex and requires further research using identified skeletal collections. The results of this paper do not support the hypothesis that enthesal changes occur earlier in those with physically more demanding occupations.

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References


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