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Cover image: Burial mound No. 6 from Plovdag necropolis in Nakhchivan (Azerbaijan)
Photo: Bahlul Ibrahimli
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STUDIES

PORTUGUESE WOMEN'S ACTIVITY IN THE PAST: COMPARING ENTHESEAL CHANGES THROUGH TIME*

CHARLOTTE Y. HENDERSON, SOLEDAD SALEGA, AND ANA MARIA SILVA**

Introduction

There has been a long history of studying labour divisions through skeletal analysis much of which focusses on the sexual division of labour. One of the more common methods to do this is to study entheseal changes (ECs), the visible changes on the skeleton where muscles and, more commonly, tendons attach to bone.[1] These changes are often considered to be a direct indicator of local muscle usage and have, therefore, been used to infer specific activities in both individuals and population samples.[2] These interpretations are often supported by artefactual evidence of activities within the community or grave goods.[3] However, the interpretation of who used which objects within an archaeological site could be biased by our own perceptions of gendered labour as well as gender-biased ethnography and anthropology.[4] A particular problem is the idea that some activities are exclusively consigned to males and others to females.[5]

It may be surprising that this occurs even when the skeletal remains themselves are studied as these should be unbiased records of lives. However, the problem lies not in the remains, but with how ECs have been recorded and

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* Charlotte Henderson would like to thank the curators of the Coimbra identified skeletal collection for access. Data she collected on the identified collection were undertaken as part of a postdoctoral bursary from Fundação para a Ciência e a Tecnologia (FCT) SFRH/BPD/82559/2011. FCT is supported by the European Union. Data collection by Soledad Salega was possible thanks to a doctoral scholarship granted by Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina.

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1 Robert Jurmain, Francisca Alves Cardoso, Charlotte Henderson, and Sébastien Villotte, "Bioarchaeology's Holy Grail: The Reconstruction of Activity," in *A Companion to Paleopathology*, Ed. Anne Grauer (Hoboken: Wiley-Blackwell, 2012), 531-542.

2 Ibid.

3 Robert Jurmain, *Stories from the Skeleton: Behavioral Reconstruction in Human Osteology* (Abingdon: Routledge, 2013).

4 Margaret W. Conkey and Janet D. Spector, "Archaeology and the Study of Gender," *Advances in Archaeological Method and Theory* 7 (1984): 1-38.

5 Ibid.

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interpreted. Firstly, the aetiology of many of the visible changes defined as ECs are not fully understood,[6] thus interpreting them as direct evidence of repetitive movement or one-off loading could be erroneous. Studies involving identified collections have shown that whatever gender, there is an increase in score and frequency of changes with increasing age.[7] It has also been shown that in general EC scores for muscles rank similarly in males and females,[8] indicating that ECs either show an overall picture of activity (one that is mostly the same for males and females) or that this is due to trends in EC "degeneration" (if it is really degeneration). The rank scores themselves being biased by age mean that while differences have been found, for example, higher scores in those living in industrial-style settings compared to agricultural communities, these differences may be down to differences in age profiles.[9] One approach to avoid this is considered to be within body ratios of scores, as the same structures should age at a similar rate.[10] Thus studying ratios may provide a way to avoid the impact of age and show differences in activity.

However, testing methods for identifying activity is most commonly done in males as identified collections typically provide data on occupation.[11] While occupation is often provided for females, these are less variable and the term "house wife" or domestic worker (*doméstica* in Portuguese) provide no indication of whether the woman had servants, did her own house work, or did housework on top of other paid (or unpaid) work, such as tending crops or livestock.[12] Nor does this describe other aspects of lifestyle which may have an

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[6] Charlotte Y. Henderson, Valentina Mariotti, Frédéric Santos, Sébastien Villotte, and Cynthia A. Wilczak, "The New Coimbra Method for Recording Entheseal Changes and the Effect of Age-at-Death," in *Bulletins et Mémoires de la Société d anthropologie de Paris* 29, 3-4 (2017): 140-149; Sébastien Villotte et al., "In Search of Consensus: Terminology for Entheseal Changes (EC)," in *International Journal of Paleopathology* 13 (2016): 49-55.

[7] Francisca Alves Cardoso, *A Portrait of Gender in Two 19th and 20th Century Portuguese Populations: A Palaeopathological Perspective* (PhD diss., University of Durham, 2008).

[8] Charlotte Y. Henderson, "Subsistence Strategy Changes: The Evidence of Entheseal Changes," in *HOMO - Journal of Comparative Human Biology* 64, 6 (2013): 491-508.

[9] Ibid.

[10] Charlotte Y. Henderson, "Do Muscle Attachments Change because of Occupation? Asymmetries in the Coimbra Identified Collection," (in preparation); Sébastien Villotte and Christopher J. Knüsel, "I Sing of Arms and of a Man…": Medial Epicondylosis and the Sexual Division of Labour in Prehistoric Europe," in *Journal of Archaeological Science* 43 (2014): 168-174.

[11] Francisca Alves Cardoso and Charlotte Y. Henderson, "The Categorisation of Occupation in Identified Skeletal Collections: A Source of Bias?," in *International Journal of Osteoarchaeology* 23, 2 (2013): 186-196; Cardoso, *A Portrait*, 118; Charlotte Y. Henderson, Davina Craps, Anwen Cedifor Caffell, Andrew Millard, and Rebecca L. Gowland, "Occupational Mobility in 19th Century Rural England: The Interpretation of Entheseal Changes," in *International Journal of Osteoarchaeology* 23, 2 (2013): 197-210.

[12] Francisca Alves Cardoso, "Lives Not Written in Bones: Discussing Biographical Data Associated

impact on activity, for example caring for children. Other occupation categories, such as seamstress and waitress are much less common.[13] However, where male occupations have been categorised, the expected findings from EC studies that heavy manual workers can be differentiated from non-manual workers based on EC is rarely found.[14] Another study created clusters of occupations based on EC presence and these clusters differed markedly from the occupational categories widely used.[15] This may indicate that the categorisation approach is flawed for capturing biomechanics or that ageing may also be playing a role, as has been found in another study using a machine learning approach.[16] Studies of EC in broader temporal and geographic contexts have, however, shown trends which may be indicative of biomechanics rather than ageing alone.

Previous research, where both left and right sides are reported by sex, has shown that in general in both males and females the right sides have either higher scores or higher frequencies of EC than the left side. A reversal of this trend is found in only three studies of the biceps brachii in females.[17] There is

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with Identified Skeletal Collections," in *Identified Skeletal Collections: The Testing Ground of Anthropology?*, Eds. Charlotte Y. Henderson and Francisca Alves Cardoso (Oxford: Archaeopress, 2018), 151-168.

[13] Cardoso, *A Portrait*, 121.

[14] Cardoso and Henderson, "The Categorisation," 186-196; Cardoso, *A Portrait*; Henderson, "Do Muscle Attachments Change"; Effrossny Michopoulou, Efthymia Nikita, and Efstratios D. Valakos, "Evaluating the Efficiency of Different Recording Protocols for Entheseal Changes in Regards to Expressing Activity Patterns Using Archival Data and Cross-Sectional Geometric Properties," in *American Journal of Physical Anthropology* 158, 4 (2015): 557-568; Effrossny Michopoulou, Efthymia Nikita, and Charlotte Y. Henderson, "A Test of the Effectiveness of the Coimbra Method in Capturing Activity-Induced Entheseal Changes," in *International Journal of Osteoarchaeology* 27, 3 (2017): 409-417; Marco Milella, Maria G. Belcastro, Christoph P. E. Zollikofer, and Valentina Mariotti, "The Effect of Age, Sex, and Physical Activity on Entheseal Morphology in a Contemporary Italian Skeletal Collection," in *American Journal of Physical Anthropology* 148, 3 (2012): 379-388; Sébastien Villotte, Dominique Castex, Vincent Couallier, Olivier Dutour, Christopher J. Knüsel, and Dominique Henry-Gambier, "Enthesopathies as Occupational Stress Markers: Evidence from the Upper Limb," in *American Journal of Physical Anthropology* 142, 2 (2010): 224-234.

[15] Marco Milella, Francisca Alves Cardoso, Sandra Assis, Geneviève Perréard Lopreno, and Nivien Speith, "Exploring the Relationship between Entheseal Changes and Physical Activity: A Multivariate Study," in *American Journal of Physical Anthropology* 156, 2 (2015): 215-223.

[16] Charlotte Y. Henderson, "Multidimensional Scaling for Determining the Effect of Occupation on Entheseal Changes" (paper presented at the *19th Annual Conference of the British Association for Biological Anthropology and Osteorchaeology,* Liverpool, UK, 8-10 September 2017).

[17] Kristin R. Hagaman, *Activity-Induced Musculoskeletal Stress Marker Analysis of the Windover Population* (Masters diss., Florida State University, 2009); Anna Myszka and Janusz Piontek, "Variation of Musculoskeletal Stress Markers in the Medieval Population from Cedynia (Poland) - Proposal of Standardized Scoring Method Application," in *Collegium Antropologicum* 36, 3 (2012): 1009-1017; Melissa Zabecki, *Late Predynastic Egyptian Workloads: Musculoskeletal Stress*

no consistent trend between subsistence strategy type or geographic location: one study is of a native American hunter-gatherer community,[18] another is of middle Kingdom Egyptians,[19] and the final one is of a mediaeval Polish town population.[20] It is unlikely to relate to the researcher (at least not in all cases) as two out of the three periods studied by Zabecki showed the normal trend.[21] The normal trend was also seen in sites from a varied geographic and temporal spread from hunter-gatherers in South America to nineteenth-century Britain.[22] In contrast, the reversal of this trend in males is more common (and not only because there are more publications on males). Specifically, the trend is seen in industrial (postmediaeval) populations in Portugal and the Netherlands,[23] but not in London or the USA.[24] This reversal also occurs in mediaeval Poland, Spain, as well as Old Kingdom Egypt and pre-hispanic Azapa, Chile.[25] However, it does not occur in other Egyptian periods, other agricultural or in any hunter-gatherer economies.[26] This suggests that reversal of asymmetry trends are less

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Markers at Hierakonpolis (PhD diss., University of Arkansas, 2009).

[18] Hagaman, *Activity-Induced*, 1-130.

[19] Zabecki, *Late Predynastic*, 1-300.

[20] Myszka and Piontek, "Variation," 1009-1017.

[21] Zabecki, *Late Predynastic*, 1- 300.

[22] Myszka and Piontek, "Variation," 1009-1017; Henderson et al., "Occupational Mobility," 197-210; Sarah Inskip, *Islam in Iberia or Iberian Islam: Bioarchaeology and the Analysis of Emerging Islamic Identity in Early Medieval Iberia* (PhD diss., University of Southampton, 2014); Kendall M. McGowan, *The Use of Musculoskeletal Stress Markers in Determining the Effects of Subsistence Change on the Inhabitants of the Nan Ranch Ruin* (PhD diss., California State University, 2009); Jessica L. A. Palmer, Menno H. L. Hoogland, and Andrea L. Waters-Rist, "Activity Reconstruction of Post-Medieval Dutch Rural Villagers from Upper Limb Osteoarthritis and Entheseal Changes," in *International Journal of Osteoarchaeology* 26, 1 (2016): 78-92; Paola Ponce, *A Comparative Study of Activity-Related Skeletal Changes in 3rd-2nd Millennium BC Coastal Fishers and 1nd Millenium AD Inland Agriculturists in Chile, South America* (PhD diss., Durham University, 2010); Elizabeth Weiss, "Muscle Markers Revisited: Activity Pattern Reconstruction with Controls in a Central California Amerind Population," in *American Journal of Physical Anthropology* 133, 3 (2007): 931-940.

[23] Zabecki, *Late* Predynastic,1-300; McGowan, *The Use* 1-100; Cardoso and Henderson, "The Categorisation of Occupation," 186-196.

[24] Annette Doying, *Differentiation of Labor-Related Activity by Means of Musculoskeletal Markers* (Masters diss., University of South Florida, 2010); Charlotte Y. Henderson and Efthymia Nikita, "Accounting for Multiple Effects and the Problem of Small Sample Sizes in Osteology: A Case Study Focussing on Entheseal Changes," in *Archaeological and Anthropological Sciences* 8, 4 (2016): 805-817.

[25] Inskip, *Islam in Iberia* 1-481; Myszka and Piontek, "Variation," 1009-1017; Ponce, *A Comparative Study*, 1-359; Zabecki, *Late Predynastic*, 1-300.

[26] Hagaman, *Activity-Induced*, 1-130; Inskip, *Islam in Iberia*, 1-481; McGowan, *The Use*, 1-100; Ponce, *A Comparative Study*, 1-359; Joachim Wahl et al., "Neue Erkenntnisse Zur Frühmittelalterlichen Separatgrablege von Niederstotzingen, Kreis Heidenheim," in *Fundberichte Aus Baden-Württemberg* 34, 2 (2014): 341-390; Weiss, "Muscle Markers Revisited," 931-940; Zabecki, *Late Predynastic*, 1-300.

common in females and that differences between males and females may not all be caused by biology or ageing. However, these comparisons are not for within body asymmetries but are based on the whole sample frequencies or mean scores. Where within body asymmetries have been studied for both sexes, by comparing the common flexor and extensor origins, they support the assertion that females are more likely to follow the general pattern (in this case more EC at the common extensor than the flexor origin) and that reversals may be indicative of specific activities.[27]

The aim of this paper is, therefore, to study EC in females from the mediaeval to modern period in Portugal, to study broad trends in lifestyle through time in score and within body asymmetries: left and right and between agonist and antagonist muscles (e.g. common extensor and common flexor origin). By using within body asymmetries, the sample size can be maintained rather than divided into age categories, because age should no longer be a factor. This will be tested using the modern identified collection of skeletons. Overall expectations based on previous studies are that: 1) the modern skeletons will have the highest frequencies of changes; 2) that within body asymmetries are independent of age, and 3) right side frequencies will be higher particularly for EC related to wear and tear.

Materials and methods

The analysed material comes from the identified skeletal collection, as well as from mediaeval and early modern sites curated in the Department of Life Sciences of the University of Coimbra, Portugal (Table 1). The identified skeletal collection represents individuals living in Coimbra and the surrounding area in the early twentieth century.[28] In this study females with an occupation listed as *doméstica* (roughly translated as a domestic worker) were included, in order to avoid biases from other occupations which are only represented by a small number of individuals. Materials from eight archaeological sites from the central belt of Portugal were studied. These were grouped into two chronological periods to create sufficiently large samples for comparison with the modern data.[29] The mediaeval sites (400 to 1499) included: Monte da Nora (Elvas), Rua dos Barcos (Santarém), Capela de Nossa Senhora da Vitória (São Jorge, Batalha) and São Francisco Convent (Santarém).[30] The early modern

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[27] Villotte and Knüsel, "I Sing of Arms," 168-174.

[28] Maria Augusta Rocha, "Les Collections Ostéologiques Humaines Identifiées Du Musée Anthropologique de l'Université de Coimbra," in *Antropologia Portuguesa* 13 (1995): 7-38.

[29] Soledad Salega, Charlotte Henderson, and Ana Maria Silva, "Cambios Entesiales En Portugal: Un Estudio Diacrónico Utilizando El Nuevo Método Coimbra," in *Revista Del Museo de Antropología* 10, 2 (2017): 137-144.

[30] Carina Marques and Ana M. Silva, "Developmental Defects Detected on the Vertebral Column of a Medieval Portuguese Male Skeleton from the Capela de Nossa Senhora Da Vitória (Porto de

(1500-699) is represented by Largo Cândido dos Reis (Santarém) Cemitério beside Rua Joaquim António de Aguiar (Sousa Bastos, Coimbra), Rabaçal (Coimbra) and Castelo of Alcácer do Sal.[31] Pooling into these temporal periods does not reflect the different lifestyles that would have existed between these sites. Rua dos Barcos, for example, is on a river which would have been fished, while Monte da Nora is inland and is thought to represent individuals of higher status. Alcacer do Sal, in contrast, consists of nuns. However, differences in occupation have not been detected using EC in the Portuguese identified collections,[32] and the aim here is to detect broader trends in lifestyle through time.

Ageing and sexing methods were not required for the identified skeletal collection, but only those with fused or fusing long bone epiphyses were included in this analysis to ensure comparability with the mediaeval and early modern sites. Methods for sexing the mediaeval and early modern period skeletons have been previously described.[33] The identified skeletal collection was divided into young adult and old adult based on the state of medial clavicle fusion: unfused and partially fused were considered young even if the contralateral side had fused. If this bone was absent, the individual was considered "adult".

Mós-Leiria)" (paper presented at the *XV Congreso de La Union Internationale Des Sciences Pré Historiques et Protohistoriques*, Lisboa, September 4-9, 2006); Ana M. Silva, "Estudo Paleobiológico Dos Esqueletos Exumados Do Convento de São Francisco de Santarém Na Campanha de 1996. 3o Relatório" [Paleobiological Study of the Exhumed Skeletons from Convento de São Francisco de Santarém of the 1996 Season. 3rd Report] (Report, 1999); Ana M. Silva, "Relatório Antropológico Dos Restos Humanos Exumados Do Monte Da Nora (Terrugem, Elvas)" [Anthropological Report of the Exhumed Human Remains of Monte Da Nora (Terrugem, Elvas)] (Report, 1999).

31 Eugénia Cunha and Ana M. Silva, "Intervenção Antropológica No Castelo de Alcácer Do Sal. Relatórios Mensais de Fevereiro a Setembro" [Archaeological Intervention in Castelo de Alcácer Do Sal. Monthly Reports from February to September] (Report, 1994); Ana M. Silva, Gonçalo Carnim, Joana Isidoro, Marta Pinto Reis, Vìtor Miguel Jacinto Matos, and Ana Carina Marques, "A Necrópole Do Século XVI Instalada Na Villa Romana Do Rabaçal," [The 16th Century Necropolis Installed in the Roman Villa of Rabaçal] in *Roteiro: Rabaçal - Aldeia Cultural*, ed. Miguel Pessoa, Lino Rodrigo, and Sandra Steinert Santos (Penela: Câmara Municipal de Penela, 2001), 20-22; Ana M. Silva and Sónia Codinha, "Antigo Cemitério Da Alta de Coimbra. Estudo de Uma Amostra Óssea Humana Exumada Junto À Rua Joaquim António de Aguiar (Coimbra)" [Old Cemetery of Alta de Coimbra. Study of an Exhumed Human Bone Sample Next to Rua Joaquim António de Aguiar (Coimbra)] (Report, 2002); Sofia Tereso, *Memórias No Largo: Estudo de Uma Amostra Osteológica Humana Exumada No Largo Cândido Dos Reis Santarém (XVI-XVIII)* [Memories of Largo: Study of a Human Osteological Sample Exhumed from Largo Cândido Dos Reis Santarém (16th-18th centuries)] (Masters diss., University of Coimbra, 2009).

32 Cardoso and Henderson, "The Categorisation of Occupation," 186-196; Henderson, "Do Muscle Attachments Change".

33 Salega et al., "Cambios Entesiales," 137-144.

Entheseal changes were recorded using the new Coimbra method.[34] They were recorded in both the upper and lower limb, but lower limb EC are more likely related to mobility than activity and, as activity studies typically focus on the upper limb, this is the focus of this study. Entheses included are infra- and supraspinatus (recorded as one because the fibres merge close to the enthesis), subscapularis, biceps brachii and triceps brachii insertions and the common extensor and flexor origins. This method records an enthesis using eight features to capture the variability of changes with scores ranging from 0 to 2 (except for textural change: only recorded as 0 or 1).[35] To calculate EC frequencies and odds ratios, scores of one and two were pooled into "present," while scores of zero were considered "absent".

Asymmetry scores were calculated by subtracting the left side from the right side, thus positive scores represent a right side with a higher score than the left. Scores for these data ranged from -2 to 2 (except for textural change which ranged from -1 to 1). The asymmetry between muscles working as agonists and antagonists was also calculated using the same formula but between entheses (and both sides scores separately): biceps brachii minus triceps brachii, common extensor origin minus common flexor origin, and infra- supraspinatus minus subscapularis. These formulae are based on a previous study comparing published data[36] and, just as with the side asymmetry data, should typically present positive scores. For statistical analysis, these scores were simplified to positive (1 and 2), equal (0) and negative (-1 and -2).

All individuals who may have had diseases or conditions which are associated with the formation of entheseal changes, for example, diffuse idiopathic skeletal hyperostosis and the seronegative spondyloarthropathies were removed from the analysis as were individuals who lacked elements required for such a diagnosis. This followed previously published approaches to avoid inflating EC frequencies.[37]

Data were collected by two researchers: the identified collection by Henderson and the less recent material by Salega, following training by Henderson. Interobserver and intra-observer repeatability for EC has been tested with percentage agreement, which was typically high for all features and

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[34] Charlotte Y. Henderson, Valentina Mariotti, Doris Pany-Kucera, Sébastien Villotte, and Cynthia Wilczak, "The New "Coimbra Method": A Biologically Appropriate Method for Recording Specific Features of Fibrocartilaginous Entheseal Changes," in *International Journal of Osteoarchaeology* 26, 5 (2016): 925-932.

[35] Ibid.

[36] Charlotte Y. Henderson, "Opposites React: A Meta-Analysis of Entheseal Changes" (paper presented at the *17th Annual Conference of the British Association for Biological Anthropology and Osteorchaeology*, Sheffield, UK, September 18-20, 2015).

[37] Henderson and Nikita, "Accounting for Multiple Effects," 805-817.

entheses of the upper limb.[38] Cohen's kappa for the interobserver error of the subscapularis and common extensor origin (excluding cavitations and textural change) was 0.64 (substantial agreement) and intraobserver error for the same features 0.84. This compares favourably with the published repeatability for this and other visual recording methods.[39]

All calculations were performed in R version 3.0.2. Descriptive statistics were used to describe the data by chronological age for the identified collection and by age category for all sites. These were also used to describe the skeletons by period, entheseal changes and their asymmetry. Due to the limited number of young adults (Table 1), skeletal age was not used for further statistical analysis. Kruskall-Wallis tests were used to determine differences in age by asymmetry for those cases where there was a difference of 20 or more years and an $n>4$. These values were chosen based on past experience and to avoid Type 1 errors. The effect size epsilon-squared was used to determine how large an effect was and these were interpreted following an approach used for R^2.[40] A post hoc Mann-Whitney U was used to determine which groups showed differences using a Benjamini-Hochberg to adjust p-values to control for false discovery rates.

Odds ratios were calculated to compare periods using the more modern period as the control. These were calculated using the absence/presence data for each enthesis and feature. Fisher's exact test was used to compare groups for odds ratios of two or more or 0.5 or less (except 0). Fisher's exact test, alongside the effect size measure Cramer's V was used to study differences in asymmetry between periods. Using Cohen's recommendations 0.3 was considered a medium effect.[41]

Results

In the identified sample, there are 172 females (excluding those with disease) aged between 17 and 89 (median 46, median absolute deviation 20.8). The age range is not normally distributed ($W=0.97$, $p<0.001$). The archaeological sample consists of 83 females of which 9 are adults of indeterminate age, 50 old adults and 24 young adults. Table 1 lists the divisions by site and period.

Within individual bilateral asymmetry was calculated for each feature.

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[38] Salega et al., "Cambios Entesiales," 137-144.

[39] Cynthia Wilczak, Valentina Mariotti, Doris Pany-Kucera, Sébastien Villotte, and Charlotte Y. Henderson, "Training and Interobserver Reliability in Qualitative Scoring of Skeletal Samples," in *Journal of Archaeological Science: Reports* 11 (2017): 69-79.

[40] Louis M. Rea and Richard A. Parker, *Designing and Conducting Survey Research: A Comprehensive Guide* (San Francisco: Jossey-Bass, 1992).

[41] Jacob Cohen, *Statistical Power Analysis for the Behavioral Sciences* (Hillsdale: Lawrence Erlbaum Associates, 1988).

Descriptive statistics were used to test whether there was an effect of age (chronological) in the identified collection (Table 2). The difference in median age for individuals with equal (left and right sides having the same scores) and those with asymmetry ranged between 0.5 years and 43 years (median 16.5, sd 9.7). The results of the Kruskal-Wallis test indicate that these are statistically significant differences in age, and epsilon-squared indicates that these are moderate to relatively strong effects. The post hoc Mann-Whitney U tests showed that the differences lay predominantly between equal scores and those with higher scores on the left side (difference of one score) and occasionally the same for the right side. No statistically significant differences were found for those differing by two scores in either direction.

Within individual asymmetry between muscles working together was calculated for each feature. Descriptive statistics were also used to test whether there was an effect of age (chronological) in the identified collection (Table 3). On both sides, the difference in median age between equal scores and those with asymmetry ranged between 0 and 42 years. The median age on the left side was 17 (sd 9.3) and on the right 18.8 (sd 10.2). Predominantly the differences meeting the requirements for the statistical analysis were those involving bone formation (both zones) and erosions (both zones). The results of the Kruskal-Wallis test indicate that these are statistically significant differences in age, and epsilon-squared indicates that these are moderate to relatively strong effects. The post hoc Mann-Whitney U tests showed that the differences lay mostly between equal scores and those with an asymmetry scoring one. No differences were found in median age between those with higher scores in one muscle than the other.

Table 4 presents the descriptive statistics for raw scores of each feature by enthesis and side for data pooled as absent/present. When compared by feature, the identified skeletal collection has the higher frequency for all features on the left side, compared to the earlier time periods. However, on the right side, bone formation in both zones has higher frequencies in the earlier time periods. When compared by enthesis, all entheses have higher frequencies in the identified collection compared to the earlier time periods. When comparing the early modern and mediaeval periods, all entheses have equal textural change frequencies (all 0) and fine porosity (excepting the left triceps brachii, which has a higher frequency in the earlier period). Most features, apart from bone formation in zone one and macropores occur more commonly in the mediaeval compared to the early modern period (once equal frequencies, typically where all scores are zero, are removed). Bone formation in zone two occurs equally frequently in both periods. When considered by enthesis, frequencies are typically higher in the early modern than the mediaeval periods, except for the common flexor origin and infra- and supraspinatus on the left side and the subscapularis on the right side. Figure 1 presents the frequencies by enthesis and period for four features: bone formation and erosions in both zones. This shows high frequencies for the infra- and supraspinatus enthesis on the right side in the early modern period but note the small sample size (n=4) as shown in Table 4.

Odds ratios were calculated to compare frequencies between periods (Table 5). No differences were found between periods for textural change and only one for fine porosity (triceps brachii between the mediaeval and identified collection). Textural change and fine porosity show little difference between periods, in contrast, erosions in zone two and bone formation in both zones show more differences. Biceps brachii on both sides has the most differences of all the entheses. Fisher's exact test found no statistically significant group differences except for bone formation in zone two of the left triceps brachii insertion ($p < 0.001$). On the right side, statistically significant differences were found for bone formation in zone two of both the biceps brachii ($p = 0.032$) and triceps brachii ($p = 0.002$) insertions. These statistically significant differences are all due to the differences between the identified collection and the early modern sites, as can be seen from the odds ratios (Table 5).

Comparisons of the frequencies of bilateral asymmetry between groups, entheses and features found very few asymmetries in the postmediaeval period and more in the mediaeval, whereas in the twentieth century identified collection asymmetries in most features were in greater evidence (Table 6). Most scores were equal on the left and right sides. While most entheses have few asymmetries in the early modern and mediaeval periods, the triceps brachii has a greater range of features with asymmetries than any other. Where asymmetries were found, higher scores occurred more on the left compared to the right side in all periods. Fisher's exact test was used to compare those entheses and features which showed differences. Statistically significant differences were found for: bone formation in zone one at the common extensor origin ($p = 0.004$, Cramer's V 0.249) and erosions in zone one at the triceps brachii insertion ($p = 0.017$, Cramer's V 0.269). No other results were statistically significantly different, and Cramer's V was under 0.2 for all other comparisons, thus the effect size was small for all bilateral asymmetries.

Comparisons of the frequencies of asymmetries between muscle groups by side and feature found that most scores were equal. Some enthesis comparisons, such as the left common extensor minus the flexor origin had no asymmetry in the late-mediaeval period, in contrast to the right side although these were single cases except for bone formation in zone two which had a difference in score in two individuals (Table 7). Also, in this period the infra- and supraspinatus minus the subscapularis insertions had no negative scores on the right side and no positive scores on the left side. For all other periods, asymmetries existed for at least some features. In general, the right side exhibited more differences than the left, but there was considerable variability by enthesis and by feature. Fisher's exact test results showed differences between the chronological group for bone formation in zone one in the infra- and supraspinatus minus subscapularis on the right side ($p=0.026$, Cramer's V 0.239). Differences in textural change for biceps brachii minus triceps brachii on the left side were also found ($p<0.001$, Cramer's V 0.238). No other results were statistically significantly different, and Cramer's V was consistently below 0.3 for all tests, showing that this was only a small effect.

Discussion

Archaeologists have widely studied the sexual as well as the gendered and other social division of labour in past societies, as such, it has also been an important goal of bioarchaeologists. One of the main methods to study this has been the use of entheseal changes, formerly called "musculoskeletal stress markers".[42] However, these analyses have faltered due to the known impact of ageing,[43] as well as differences in EC expression due to biological differences.[44] Thus differentiating biological factors from socio-cultural ones has been problematic. One of the biggest problems lies with the identified collections used to develop and test methods for recording EC (and other activity markers as well as other osteological methods). These typically have limited documentary data on female activities, compared to males. Even where data exist to study individuals activities through time, as in an identified skeletal sample from North Yorkshire (UK) which includes death certificates, census records and a diary, there is significantly greater detail on male activities than females ones.[45] In some of the most widely used identified collections for testing EC recording methods, (i.e. collections in Coimbra and Lisbon), there are few females which are not listed as "domésticas," a job description which provides no detail on the variability of activities performed by individuals.[46] There is also no occupation category which overlaps completely with males in terms of activities performed: thus, differentiating biological from socio-cultural changes in EC is unrealistic in many identified skeletal collections. This paper, therefore, takes a different approach to this topic. By comparing trends in EC frequency

[42] Jurmain et al., "Bioarchaeology's Holy Grail," 531-542.

[43] Cardoso and Henderson, "The Categorisation of Occupation," 186-196; Milella et al., "The Effect," 379-388; Henderson and Nikita, "Accounting for Multiple Effects," 805-817; Michopoulou et al., "Evaluating the Efficiency," 557-568; Michopoulou et al., "A Test of the Effectiveness," 409-417.

[44] Sébastien Villotte and Christopher J. Knüsel, "Understanding Entheseal Changes: Definition and Life Course Changes," in *International Journal of Osteoarchaeology* 23, 2 (2013): 135-146.

[45] Henderson et al., "Occupational Mobility," 197-210.

[46] Cardoso, "Lives Not Written in Bones," 151-168.

through time and using within body asymmetries, changes in lifestyle may be elucidated. Where trends differ only in one time period or geographic location, this may indicate a change in activity and these differences can then be compared to males. Biological differences cannot be completely removed, but previous research has shown that this approach can point to socio-cultural differences in activity patterns.[47]

The aim of this paper was to compare trends through time from the mediaeval period to the twentieth century in females in Portugal. Specifically, trends in feature frequency through time were compared as were within body asymmetries: bilateral and between muscle groups which work together. The hypotheses were that within body asymmetries would reduce the impact of ageing, that the identified skeletons would have the highest frequency of EC compared to earlier time periods, and that right-side frequencies would be higher than the left side. However, a notable and important limitation of this approach is that variability in activities within and between sites cannot be compared: only broad patterns through time.

The first aim of this study was to use within body asymmetry to reduce the impact of ageing, thereby enabling comparison of entheses from different periods including those for whom age cannot be assessed accurately. The study of the females in the identified skeletal collection demonstrated that both bilateral asymmetry and muscle group asymmetries were affected by ageing. However, there is very limited asymmetry and the statistically significant differences all lay between those without asymmetry and those with asymmetry. This indicates that the comparison of the asymmetries themselves is unlikely to be affected by ageing. However, it is clear that this approach does not fully reduce the impact of ageing. These results reflect those also found in the males in this sample and this is an effect of both the way in which asymmetry is measured and the large number of individuals without EC: thus, most asymmetry scores are equal (i.e. there is no asymmetry).[48] While within body asymmetry scores do not completely reduce the impact of ageing, both the oldest and youngest are more likely to have equal scores. Tentative comparisons between other populations may, therefore, be appropriate without taking into account age. However, using within body asymmetries impacts on the size of the available dataset, this is a significant drawback. Both entheses have to be present to provide an asymmetry score and differential preservation is a significant problem. For example, in the males in the identified skeletal collection over 78% of individuals had missing data in zone one of the common

[47] Villotte and Knüsel, "I Sing of Arms," 168-174; Henderson, "Opposites React".
[48] Henderson, "Do Muscle Attachments Change".

flexor origin.[49] This is a well-preserved sample thus, as found in this paper, the impact of this is even greater in archaeological samples. This in turn makes controlling for age even harder as sample sizes are already reduced and sample sizes become too small for meaningful comparisons of differences. This is a significant limitation of this approach especially for archaeological sites which typically have small sample sizes.[50]

Differences between chronological periods could be seen in the frequencies and in the odds ratios. For these bone formation (in both zones) and erosions in zone two were the ones to differ most and these are also some of the most common features to be found. While the aetiology of erosions is unclear, bone formation does seem to be a response to biomechanics, but it is also significantly affected by ageing.[51] Statistically significant differences were found and, in all cases, these reflected differences between the mediaeval period and the twentieth century. No doubt sample size plays a role in this, as there are few individuals in the early modern sample. Nevertheless, odds ratios do point to differences between periods, in some cases large, but these are also affected by sample size. These results cannot be directly compared to other published data, due to the differences in recording methods. However, the overall trend, as in previous studies, is to have more EC in more recent times.[52] Studies have also shown higher frequencies in more sedentary populations, which may indicate that lack of use rather than repetitive use is a factor in the aetiology of these changes.[53] However, without longitudinal in vivo studies, the aetiology of these changes when not associated with disease processes, such as the seronegative spondyloarthropathies is hard to elucidate and is currently poorly understood.[54] This makes interpreting the frequencies of the various features scored difficult. However, those found to differ through time, are also those most associated with ageing.[55]

The results of bilateral asymmetry contrast with those of the males found in the identified skeletal collection. In males, there was typically a higher frequency of changes on the right compared to the left in all entheses except the biceps brachii insertion for which the pattern was reversed for all features.[56]

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[49] Ibid.
[50] Henderson and Nikita, "Accounting for Multiple Effects," 805-817.
[51] Henderson et al., "The New Coimbra Method," 140-149.
[52] Henderson, "Subsistence Strategy Changes," 491-508.
[53] Maria A. Acosta, Charlotte Y. Henderson, and Eugénia Cunha, "The Effect of Terrain on Entheseal Changes in the Lower Limbs," in *International Journal of Osteoarchaeology* 27, 5 (2017): 828-838.
[54] Villotte et al. "In Search of Consensus," 49-55; Henderson et al., "The New Coimbra Method," 140-149.
[55] Henderson et al., "The New Coimbra Method," 140-149.
[56] Henderson, "Do Muscle Attachments Change".

This pattern is not seen in labourers in an identified collection in Geneva,[57] indicating that these asymmetries may indeed represent lifestyle differences. In the identified females in this study, changes typically occurred more on the left than on the right side, when differences were found (most individuals had equal scores, as they did in the males). This trend was reflected in all periods, but the early modern period had the lowest number of asymmetries overall, presumably due to the small sample size (Table 1). Differences between periods were dominated by bone formation but only in zone one and erosions in zone two. These features are the most commonly occurring and the most associated with ageing. Overall, the bilateral asymmetry contrasts with most published studies and, where it does occur, there is no pattern in terms of activity, geographic location or time period. However, unlike the previous studies, this study reported within body asymmetries rather than overall patterns. Therefore, this trend may be found elsewhere. However, the difference between this and the males does indicate that either biological or sociocultural factors affecting activities may play a role in this finding. This warrants further investigation.

Comparisons between muscle groups have been less well studied. Differences have been found in the frequency of changes between the common extensor and flexor origins in males, but none have been found in females.[58] The results of this study show that there are differences through time, but that in general, the effect sizes are small. In contrast to bilateral asymmetry and the EC scores themselves, the textural change was found to show differences through time on the left side in the biceps and triceps brachii insertion comparison. However, in general, most differences were seen between bone formation and erosions. This appears to be the general trend and, as discussed above, is likely to reflect that they are more common. The impact of ageing on their formation even for this asymmetry data cannot be ignored, as seen in the results from the identified collection.

In general, the results, apart from the bilateral asymmetry, reflect the expectations, but the small sample sizes, particularly in the early modern period, are a problem. Within the body, asymmetry does not completely control for age, but the advantage of this approach is that the small sample sizes for age categories were avoided. Ageing itself is a problem and creating categories based on late fusing epiphyses or degeneration cannot control for differences in skeletal maturity or differential ageing.[59] As EC are often considered

[57] Charlotte Y. Henderson, Valentina Mariotti, Doris Pany-Kucera, Sébastien Villotte, and Cynthia Wilczak, "Recording Specific Entheseal Changes of Fibrocartilaginous Entheses: Initial Tests Using the Coimbra Method," in *International Journal of Osteoarchaeology* 23, 2 (2013): 152-162.
[58] Villotte and Knüsel, "I Sing of Arms," 168-174.
[59] Jo Buckberry, "The (Mis)use of Adult Age Estimates in Osteology," in *Annals of Human Biology*

degenerative, using degenerative changes to age individuals may risk pooling those whose bodies "degenerate" faster into older categories conflating the impact of chronological and biological age on EC formation. At the moment, within body asymmetries are probably the best approach to taking into account ageing in non-identified skeletal samples, but interpretations must be made with caution by acknowledging the fact that this does not avoid the problem of ageing completely.

Placing this research in the wider context of gender, it does seem that differences in EC frequency and asymmetries occur through time. These differences may reflect biological components: differences in ageing patterns as well as differences caused by access to resources needed to develop, although the latter would also imply a socio-cultural component (differential access to food quality and quantity).[60] This is a particular problem when interpreting the differences seen in bone formation (both zones) as this is the change most associated with ageing. However, other features also show differences: ones that are less associated with the ageing process, such as macropores. These changes may reflect a response to injury (due to accident or an increase in riskier activities) and the fact that these appear to differ through time, albeit on a limited scale, may reflect socio-cultural differences. The fact that the results differ from those found in males indicates that socio-cultural differences caused by biological sex can be explored, albeit tentatively, and may lead to new ways to consider gendered lifeways.[61]

Conclusions

There has been a lot of research on the relationship between male activities and EC presence but there has been considerably less in females. Women have been neglected because documented collections provide less detail about their lives than those of men. Thus, trying to study differences in activity patterns in females has been virtually impossible using identified skeletal collections alone. The aim of this study was therefore to determine whether there are different patterns through time in EC frequency which may point to changes in activity. To achieve these, raw frequencies as well as within body asymmetries were compared between mediaeval, early modern and modern periods. The latter period was represented by individuals in an identified skeletal collection who died in the early twentieth century. These

42, 4 (2015): 323-331.

[60] Velissaria Vanna, "Sex and Gender Related Health Status Differences in Ancient and Contemporary Skeletal Populations," in *Papers from the Institute of Archaeology* 18 (2007): 114-147.

[61] Joanna Sofaer, "Bioarchaeological Approaches to the Gendered Body," in *A Companion to Gender Prehistory*, Ed. Diane Bolger (Hoboken: John Wiley & Sons, 2014), 226-243.

individuals were also used to test whether within body asymmetries could be used to reduce the impact of ageing on EC frequency as ageing is the main factor in EC presence. This approach was not wholly successful. Overall differences between periods were found, but these were in the most common features and those most associated with ageing. Sample sizes were also small in the archaeological collections once within body asymmetries were calculated. However, the bilateral asymmetry showed a surprising trend: in contrast to males and where asymmetries occurred (most individuals had no side asymmetry) more females showed higher frequencies of EC on the left than the right side. This was unexpected and a contrast to previous studies using this recording method. The finding may indicate that within body asymmetries can be used to study gendered lifeways, but first more studies are needed to determine whether this difference is wholly biomechanical or related to biological sex differences.

Broad Chronology	Site	N	Young adult		Older adult		Adult	
			n	%	n	%	n	%
Mediaeval	Rua dos Barcos	31	15	48,4%	14	45,2%	2	6,5%
	São Jorge	2	0	0,0%	2	100,0%	0	0,0%
	Convento São Francisco	21	5	23,8%	14	66,7%	2	9,5%
	Monte da Nora	7	0	0,0%	6	85,7%	1	14,3%
	TOTAL	61	20	32,8%	36	59,0%	5	8,2%
Early modern	Alcacer do Sal	3	0	0,0%	2	66,7%	1	33,3%
	Largo Candido dos Reis	9	1	11,1%	7	77,8%	1	11,1%
	Rabaçal	1	0	0,0%	1	100,0%	0	0,0%
	Sousa Bastos	9	3	33,3%	4	44,4%	2	22,2%
	TOTAL	22	4	18,2%	14	63,6%	4	18,2%
Twentieth century	Coimbra identified skeletal collection	173	18	10,4%	153	88,4%	2	1,2%

Table 1. List of sites by period with sample sizes.

Enthesis	Feature	Asymmetry score	n	sd	median	mad	min	max	range	Kruskall-Wallis	df	p	Epsilon-squared
Infra- and supraspinatus	BFZ1	equal	119	17,52	45	17,79	19	89	70	13,29	2	0,001	0,10
		-1	10	10,97	64,5	12,6	46	77	31				
		1	5	12,68	65	4,45	54	88	34				
	ERZ2	equal	105	17,33	43	17,79	17	89	72	17,51	3	0,001	0,12
		-1	31	14,55	57	17,79	30	88	58				
		1	11	16,87	63	16,31	28	87	59				
		-2	3	20,5	73	1,48	38	74	36				
Subscapularis	ERZ1	equal	128	16,59	44,5	17,05	17	88	71	26,24	4	<0.001	0,18
		-1	7	11,14	65	17,79	52	79	27				

		1	7	9,94	72	11,86	62	89	27				
		-2	2	1,41	75	1,48	74	76	2				
		2	1	NA	74	0	74	74	0				
Common extensor origin	BFZ1	equal	84	15,86	40	14,83	19	88	69	28,11	3	<0.001	0,25
		-1	24	13,32	62	16,31	39	87	48				
		1	1	NA	72	0	72	72	0				
		-2	3	10,5	64	14,83	53	74	21				
	BFZ2	equal	118	17,92	42,5	17,79	17	89	72	20,97	3	<0.001	0,15
		-1	17	11,07	62	11,86	45	87	42				
		1	5	12,19	58	7,41	42	75	33				
		-2	1	NA	23	0	23	23	0				
	ERZ2	equal	106	17,39	39	17,79	17	89	72	27,61	3	<0.001	0,20
		-1	21	13,73	59	10,38	34	88	54				
		1	10	14,2	57,5	22,24	42	74	32				
		-2	3	3,61	71	2,97	69	76	7				
Common flexor origin	BFZ1	equal	79	15,98	39	16,31	17	82	65	17,83	2	<0.001	0,20
		-1	9	12,5	73	20,76	54	88	34				
		1	3	11,5	53	16,31	42	65	23				
	ERZ2	equal	110	17,8	44	20,76	17	88	71	10,99	2	0,004	0,09
		-1	8	12,09	64,5	14,83	50	87	37				
		1	2	10,61	66,5	11,12	59	74	15				
Biceps brachii	BFZ1	equal	103	18,45	40	17,79	17	88	71	13,14	4	0,011	0,11
		-1	6	9,5	58,5	4,45	37	63	26				
		1	14	14,82	61,5	15,57	40	89	49				
		-2	1	NA	66	0	66	66	0				
		2	1	NA	50	0	50	50	0				
Triceps brachii	BFZ1	equal	107	18,06	45	19,27	17	89	72	15,19	3	0,002	0,06

-1	14	14,91	62	17,05	37	87	50
1	4	6,76	65	3,71	60	76	16
-2	1	NA	42	0	42	42	0

Table 2. Descriptive statistics for bilateral asymmetry and age in the identified skeletal collection for those entheses and features which have statistically significant differences in median age by asymmetry.

Score	n	sd	median	mad	min	max	Kruskall-Wallis	df	p	Epsilon-squared
equal	99	16,54	40	16,31	19	88	40,23	3	<0.001	0,30
-1	30	11,98	65	14,83	45	82				
1	5	6,58	53	4,45	50	66				
-2	3	14,57	66	5,93	62	89				
equal	121	17,73	45	19,27	19	89	13,08	4	0,011	0,10
-1	9	12,69	66	16,31	46	79				
1	4	16,03	62	14,83	39	74				
-2	1	NA	76	0	76	76				
2	1	NA	62	0	62	62				
equal	72	15,42	38	14,08	19	87	27,08	4	<0.001	0,29
-1	6	11,67	60,5	9,64	50	82				
1	13	12,16	63	13,34	45	88				
-2	2	22,63	58	23,72	42	74				
2	1	NA	73	0	73	73				
equal	108	17,68	40	17,05	19	88	14,14	4	0,007	0,12
-1	2	16,26	53,5	17,05	42	65				
1	13	13,56	63	13,34	28	80				
-2	1	NA	74	0	74	74				
2	1	NA	58	0	58	58				
equal	99	16,3	39	16,31	19	87	31,01	3	<0.001	0,25

-1	5	13,18	74	13,34	55	88				
1	17	11,61	63	16,31	42	82				
2	4	13,78	69,5	14,08	54	87				
equal	94	17,53	43	17,79	17	89	17,83	4	0,001	0,15
-1	8	18,72	50	11,12	37	87				
1	13	15,7	66	11,86	27	80				
-2	2	21,92	57,5	22,98	42	73				
2	5	8,66	64	2,97	60	82				
equal	127	17,25	45	19,27	17	88	15,58	3	0,001	0,11
-1	8	12,86	57	8,15	51	82				
1	9	19,26	70	23,72	28	89				
2	1	NA	66	0	66	66				
equal	121	17,05	44	17,79	17	88	16,80	3	0,001	0,12
-1	15	13,02	66	11,86	39	89				
1	2	2,83	56	2,97	54	58				
2	1	NA	53	0	53	53				
equal	126	16,78	45	17,79	17	88	13,70	2	0,001	0,10
-1	9	12,37	72	11,86	46	89				
1	4	18,57	61,5	8,15	28	69				
equal	72	15,42	38	14,08	19	87	27,08	4	<0.001	0,29
-1	6	11,67	60,5	9,64	50	82				
1	13	12,16	63	13,34	45	88				
-2	2	22,63	58	23,72	42	74				
2	1	NA	73	0	73	73				
equal	108	17,68	40	17,05	19	88	14,14	4	0,007	0,11
-1	2	16,26	53,5	17,05	42	65				
1	13	13,56	63	13,34	28	80				
-2	1	NA	74	0	74	74				

2	1	NA	58	0	58	58				
equal	99	16,3	39	16,31	19	87	31,01	3	<0.001	0,25
-1	5	13,18	74	13,34	55	88				
1	17	11,61	63	16,31	42	82				
2	4	13,78	69,5	14,08	54	87				
equal	86	17,5	40	17,05	17	88	23,59	3	<0.001	0,21
-1	4	11,63	69	8,15	50	76				
1	17	11,98	62	13,34	42	89				
2	5	9,1	70	11,86	62	82				
equal	119	16,64	45	17,79	17	88	22,65	2	<0.001	0,09
-1	8	13,09	64	18,53	50	82				
1	9	12,31	74	11,86	50	89				
equal	111	17,06	45	19,27	17	89	19,67	4	0,001	0,15
-1	11	19,02	50	20,76	24	88				
1	7	6,9	74	8,9	64	82				
-2	4	10,21	63,5	6,67	56	80				
2	3	14,74	53	8,9	47	75				

Table 3. Descriptive statistics for asymmetry between entheses and age in the identified skeletal collection for those entheses and features which have statistically significant differences in median age by asymmetry.

			BFZ1		ERZ1		BFZ2		ERZ2		FPO		MPO		CA		TC	
Side	**Period**	**Enthesis**	**n**	**freq**	**n**	**freq**	**n**	**freq**	**n**	**freq**	**n**	**freq**	**n**	**freq**	**n**	**freq**	**n**	**freq**
	20thC	Biceps brachii	145	0,23	145	0,01	156	0,06	155	0,06	156	0,02	156	0,03	156	0,01	156	0,37
	Early modern	Biceps brachii	15	0,13	15	0,00	13	0,15	13	0,00	13	0,00	13	0,08	13	0,08	13	0,00
Left	Mediaeval	Biceps brachii	39	0,13	39	0,03	38	0,11	38	0,03	38	0,00	38	0,00	38	0,00	38	0,00
	20th Century	Common extensor origin	141	0,43	141	0,03	156	0,24	155	0,26	156	0,03	156	0,03	156	0,01	155	0,00
	Early modern	Common extensor origin	8	0,13	8	0,00	22	0,00	9	0,11	9	0,00	9	0,00	9	0,00	9	0,00

	Mediaeval	Common extensor origin	31	0,26	31	0,00	34	0,12	34	0,06	34	0,00	34	0,00	34	0,00	34	0,00
	20th Century	Common flexor origin	116	0,22	117	0,00	140	0,12	139	0,14	140	0,01	140	0,01	140	0,00	140	0,01
	Early modern	Common flexor origin	22	0,00	8	0,00	22	0,00	11	0,00	11	0,00	11	0,00	11	0,00	11	0,00
	Mediaeval	Common flexor origin	37	0,08	37	0,00	43	0,07	43	0,02	43	0,00	43	0,00	43	0,00	43	0,00
	20th Century	Infra- and supraspinatus	145	0,12	145	0,08	154	0,17	154	0,39	154	0,33	154	0,01	154	0,03	154	0,00
	Early modern	Infra- and supraspinatus	22	0,00	5	0,00	22	0,00	5	0,00	22	0,00	5	0,00	5	0,00	5	0,00
	Mediaeval	Infra- and supraspinatus	15	0,07	15	0,13	18	0,11	18	0,11	18	0,00	18	0,06	18	0,06	18	0,00
	20th Century	Subscapularis	153	0,32	152	0,10	169	0,43	169	0,34	169	0,30	169	0,09	169	0,12	169	0,01
	Early modern	Subscapularis	5	0,40	2	0,00	6	0,33	6	0,67	6	0,00	6	0,00	6	0,33	6	0,00
	Mediaeval	Subscapularis	16	0,19	16	0,00	17	0,18	17	0,35	17	0,00	17	0,00	17	0,06	17	0,00
	20th Century	Triceps brachii	145	0,18	145	0,02	161	0,05	161	0,09	161	0,03	161	0,01	161	0,00	161	0,07
	Early modern	Triceps brachii	10	0,50	10	0,00	10	0,50	10	0,10	10	0,00	10	0,00	10	0,00	10	0,00
	Mediaeval	Triceps brachii	40	0,15	40	0,03	40	0,10	40	0,05	40	0,03	40	0,00	40	0,03	40	0,00
Right	20th Century	Biceps brachii	135	0,24	135	0,01	148	0,06	148	0,07	148	0,03	148	0,01	148	0,02	147	0,45
	Early modern	Biceps brachii	16	0,06	16	0,00	17	0,18	17	0,00	17	0,00	17	0,06	17	0,00	17	0,00
	Mediaeval	Biceps brachii	39	0,10	39	0,03	42	0,00	42	0,02	42	0,00	42	0,00	42	0,07	42	0,00
	20th Century	Common extensor origin	125	0,22	125	0,02	147	0,15	147	0,20	147	0,01	147	0,05	147	0,01	146	0,00
	Early modern	Common extensor origin	7	0,14	7	0,00	9	0,22	9	0,00	9	0,00	9	0,11	9	0,00	9	0,00
	Mediaeval	Common extensor origin	32	0,28	32	0,00	36	0,17	36	0,06	36	0,00	36	0,00	36	0,00	36	0,00
	20th Century	Common flexor origin	112	0,17	113	0,01	135	0,05	135	0,09	135	0,00	135	0,01	135	0,00	135	0,00
	Early modern	Common flexor origin	11	0,18	11	0,09	14	0,00	14	0,07	14	0,00	14	0,00	14	0,00	14	0,00
	Mediaeval	Common flexor origin	33	0,09	33	0,00	40	0,10	40	0,00	40	0,00	40	0,00	40	0,00	40	0,00
	20th Century	Infra and supraspinatus	151	0,07	151	0,05	164	0,11	165	0,29	164	0,27	164	0,02	165	0,02	165	0,01
	Early modern	Infra and supraspinatus	4	0,50	4	0,00	4	0,00	4	0,75	4	0,00	4	0,00	4	0,00	4	0,00
	Mediaeval	Infra and supraspinatus	21	0,10	21	0,00	23	0,04	23	0,17	23	0,00	23	0,00	23	0,13	23	0,00
	20th Century	Subscapularis	154	0,18	155	0,08	167	0,35	165	0,41	166	0,34	166	0,07	166	0,06	166	0,00
	Early modern	Subscapularis	5	0,20	5	0,00	6	0,00	6	0,17	6	0,00	6	0,00	6	0,00	6	0,00

Mediaeval	Subscapularis	19	0,11	19	0,00	22	0,27	22	0,23	22	0,00	22	0,05	22	0,05	22	0,00
20th Century	Triceps brachii	138	0,10	137	0,01	160	0,06	160	0,11	160	0,06	160	0,04	160	0,00	160	0,11
Early modern	Triceps brachii	15	0,27	15	0,13	14	0,36	14	0,00	14	0,00	14	0,00	14	0,00	14	0,00
Mediaeval	Triceps brachii	42	0,14	42	0,00	43	0,14	43	0,09	43	0,00	61	0,00	43	0,00	43	0,00

Table 4. Sample sizes and frequencies of entheseal changes by enthesis and feature for each time period.

Side	Enthesis	Period comparison	BFZ1	ERZ1	BFZ2	ERZ2	FPO	MPO	CA	TC
Left	Biceps brachii	Early modern / 20th Century	0,52	0,00	2,65	0,00	0,00	3,30	12,92	0,00
		Mediaeval / Early modern	0,96	NA	0,65	NA	NA	0,00	0,00	NA
		Mediaeval / 20th Century	0,50	3,79	1,72	0,39	0,00	0,00	0,00	0,00
	Common extensor origin	Early modern / 20th Century	0,19	0,00	0,00	0,35	0,00	0,00	0,00	NA
		Mediaeval / Early modern	2,43	NA	NA	0,50	NA	NA	NA	NA
		Mediaeval / 20th Century	0,47	0,00	0,43	0,17	0,00	0,00	0,00	NA
	Common flexor origin	Early modern / 20th Century	0,00	NA	0,00	0,00	0,00	0,00	NA	0,00
		Mediaeval / Early modern	NA	NA	NA	NA	NA	NA	NA	NA
		Mediaeval / 20th Century	0,32	NA	0,54	0,15	0,00	0,00	NA	0,00
	Infra- and supraspinatus	Early modern / 20th Century	0,00	0,00	0,00	0,00	0,00	0,00	0,00	NA
		Mediaeval / Early modern	NA	NA	NA	NA	NA	NA	NA	NA
		Mediaeval / 20th Century	0,54	1,87	0,62	0,20	0,00	9,00	2,21	NA
	Subscapularis	Early modern / 20th Century	1,41	0,00	0,66	3,83	0,00	0,00	3,73	0,00
		Mediaeval / Early modern	0,35	NA	0,43	0,27	NA	NA	0,13	NA
		Mediaeval / 20th Century	0,49	0,00	0,28	1,04	0,00	0,00	0,47	0,00
	Triceps brachii	Early modern / 20th Century	4,58	0,00	**19,13**	1,17	0,00	0,00	NA	0,00
		Mediaeval / Early modern	0,18	NA	0,11	0,47	NA	NA	NA	NA
		Mediaeval / 20th Century	0,81	1,21	2,13	0,55	0,80	0,00	NA	0,00
Right	Biceps brachii	Early modern / 20th Century	0,21	0,00	**3,31**	0,00	0,00	9,19	0,00	0,00

	Mediaeval / Early modern	1,71	NA	0,00	NA	NA	0,00	NA	NA
	Mediaeval / 20th Century	0,37	3,53	0,00	0,30	0,00	0,00	3,72	0,00
Common extensor origin	Early modern / 20th Century	0,60	0,00	1,62	0,00	0,00	2,50	0,00	NA
	Mediaeval / Early modern	2,35	NA	0,70	NA	NA	0,00	NA	NA
	Mediaeval / 20th Century	1,42	0,00	1,14	0,24	0,00	0,00	0,00	NA
Common flexor origin	Early modern / 20th Century	1,09	11,20	0,00	0,79	NA	0,00	NA	NA
	Mediaeval / Early modern	0,45	0,00	NA	0,00	NA	NA	NA	NA
	Mediaeval / 20th Century	0,49	0,00	2,03	0,00	NA	0,00	NA	NA
Infra- and supraspinatus	Early modern / 20th Century	14,10	0,00	0,00	7,31	0,00	0,00	0,00	0,00
	Mediaeval / Early modern	0,11	NA	NA	0,07	NA	NA	NA	NA
	Mediaeval / 20th Century	1,48	0,00	0,34	0,51	0,00	0,00	6,04	0,00
Subscapularis	Early modern / 20th Century	1,18	0,00	0,00	0,29	0,00	0,00	0,00	NA
	Mediaeval / Early modern	0,47	NA	NA	1,44	NA	NA	NA	NA
	Mediaeval / 20th Century	0,55	0,00	0,70	0,42	0,00	0,67	0,74	NA
Triceps brachii	Early modern / 20th Century	3,22	10,38	**9,32**	0,00	0,00	0,00	NA	0,00
	Mediaeval / Early modern	0,46	0,00	0,29	NA	NA	NA	NA	NA
	Mediaeval / 20th Century	1,48	0,00	2,72	0,81	0,00	0,00	NA	0,00

Table 5. Odds ratios comparing EC absence and presence by time period for each enthesis and feature. Bold indicates those comparisons which had statistically significant differences using Fisher's exact test.

Enthesis	Period	Score	BFZ1	ERZ1	BFZ2	ERZ2	FPO	MPO	CA	TC
Biceps brachii	20th C	left side higher	0,06	0,01	0,04	0,06	0,01	0,02	0,01	0,13
		right side higher	0,12	0,01	0,03	0,05	0,02	0,01	0,02	0,20
	Early modern	left side higher	0,08	0,00	0,00	0,00	0,00	0,09	0,00	0,00
		right side higher	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Mediaeval	left side higher	0,08	0,04	0,12	0,00	0,00	0,00	0,00	0,00

		right side higher	0,12	0,00	0,00	0,00	0,00	0,00	0,08	0,00
Common extensor origin	20^{th} C	left side higher	0,25	0,02	0,13	0,17	0,03	0,02	0,00	0,00
		right side higher	0,01	0,01	0,04	0,08	0,01	0,04	0,01	0,00
	Early modern	left side higher	0,25	0,00	0,40	0,00	0,00	0,00	0,00	0,00
		right side higher	0,25	0,00	0,60	0,00	0,00	0,20	0,00	0,00
	Mediaeval	left side higher	0,00	0,00	0,09	0,09	0,00	0,00	0,00	0,00
		right side higher	0,06	0,00	0,09	0,00	0,00	0,00	0,00	0,00
Common flexor origin	20^{th} C	left side higher	0,10	0,00	0,08	0,07	0,01	0,01	0,00	0,01
		right side higher	0,03	0,01	0,02	0,02	0,00	0,00	0,00	0,00
	Early modern	left side higher	0,00	0,00	0,00	0,11	0,00	0,00	0,00	0,00
		right side higher	0,00	0,00	0,00	0,11	0,00	0,00	0,00	0,00
	Mediaeval	left side higher	0,10	0,00	0,00	0,03	0,00	0,00	0,00	0,00
		right side higher	0,00	0,00	0,03	0,00	0,00	0,00	0,00	0,00
Infra and supraspinatus	20^{th} C	left side higher	0,07	0,04	0,11	0,23	0,21	0,01	0,02	0,00
		right side higher	0,04	0,01	0,05	0,07	0,15	0,03	0,02	0,01
	Early modern	left side higher	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
		right side higher	0,50	0,00	0,00	0,50	0,00	0,00	0,00	0,00
	Mediaeval	left side higher	0,00	0,13	0,09	0,09	0,00	0,00	0,00	0,00
		right side higher	0,13	0,00	0,00	0,09	0,00	0,00	0,09	0,00
Subscapularis	20^{th} C	left side higher	0,20	0,06	0,20	0,15	0,16	0,07	0,10	0,01
		right side higher	0,03	0,06	0,09	0,22	0,20	0,05	0,03	0,00
	Early modern	left side higher	0,00	0,00	0,00	0,33	0,00	0,00	0,33	0,00
		right side higher	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Mediaeval	left side higher	0,00	0,00	0,00	0,10	0,00	0,00	0,10	0,00
		right side higher	0,13	0,00	0,10	0,00	0,00	0,00	0,10	0,00
Triceps brachii	20^{th} C	left side higher	0,12	0,01	0,04	0,04	0,03	0,01	0,00	0,05
		right side higher	0,03	0,01	0,05	0,08	0,05	0,05	0,00	0,09

Early modern	left side higher	0,11	0,00	0,22	0,11	0,00	0,00	0,00	0,00
	right side higher	0,11	0,22	0,11	0,00	0,00	0,00	0,00	0,00
Mediaeval	left side higher	0,00	0,04	0,04	0,04	0,04	0,00	0,04	0,00
	right side higher	0,00	0,00	0,07	0,04	0,00	0,00	0,00	0,00

Table 6. Frequencies with bilateral asymmetries by enthesis and feature.

Enthesis	Side	Period	Score	BFZ1	ERZ1	BFZ2	ERZ2	FPO	MPO	CA	TC
Biceps brachii minus triceps brachii	Left	20th C	negative	0,08	0,02	0,05	0,08	0,03	0,01	0,00	0,03
			positive	0,15	0,00	0,07	0,05	0,01	0,03	0,01	0,35
		Early modern	negative	0,38	0,00	0,25	0,00	0,00	0,00	0,00	0,00
			positive	0,13	0,00	0,00	0,00	0,00	0,13	0,13	0,00
		Mediaeval	negative	0,13	0,00	0,06	0,06	0,03	0,00	0,03	0,00
			positive	0,09	0,00	0,03	0,00	0,00	0,00	0,00	0,00
	Right	20th C	negative	0,04	0,01	0,06	0,11	0,04	0,04	0,00	0,00
			positive	0,19	0,00	0,07	0,07	0,01	0,01	0,01	0,37
		Early modern	negative	0,08	0,08	0,15	0,00	0,00	0,00	0,00	0,00
			positive	0,08	0,00	0,00	0,00	0,00	0,08	0,00	0,00
		Mediaeval	negative	0,03	0,00	0,11	0,09	0,00	0,00	0,00	0,00
			positive	0,03	1,00	0,00	0,00	0,00	0,00	0,09	0,00
Common extensor minus flexor origin	Left	20th C	negative	0,08	0,00	0,02	0,04	0,00	0,01	0,00	0,00
			positive	0,15	0,03	0,12	0,17	0,01	0,06	0,02	0,00
		Early modern	negative	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
			positive	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
		Mediaeval	negative	0,00	0,00	0,03	0,03	0,00	0,00	0,00	0,00
			positive	0,18	1,00	0,06	0,03	0,00	0,00	0,00	0,00
	Right	20th C	negative	0,08	0,00	0,02	0,04	0,00	0,01	0,00	0,00
			positive	0,15	0,03	0,12	0,17	0,01	0,06	0,02	0,00

		Early modern	negative	0,14	0,14	0,00	0,11	0,00	0,00	0,00	0,00
			positive	0,14	0,00	0,22	0,00	0,00	0,11	0,00	0,00
		Mediaeval	negative	0,00	0,00	0,03	0,00	0,00	0,00	0,00	0,00
			positive	0,29	1,00	0,09	0,06	0,00	0,00	0,00	0,00
Infra- & supraspinatus minus subscapularis	Left	20th C	positive	0,04	0,04	0,03	0,24	0,21	0,01	0,03	0,00
			negative	0,40	0,00	0,40	0,60	0,00	0,00	0,20	0,00
		Early modern	positive	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
			negative	0,09	0,18	0,07	0,20	0,00	0,00	0,00	0,00
		Mediaeval	positive	0,00	0,00	0,07	0,00	0,00	0,07	0,07	0,00
			negative	0,11	0,07	0,29	0,27	0,20	0,07	0,06	0,00
	Right	20th C	positive	0,02	0,03	0,04	0,13	0,14	0,03	0,02	0,01
			negative	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
		Early modern	positive	1,00	0,00	0,00	0,33	0,00	0,00	0,00	0,00
			negative	0,06	0,00	1,00	0,05	0,00	0,05	0,05	0,00
		Mediaeval	positive	0,06	0,00	0,00	0,10	0,00	0,00	0,15	0,00
			negative	0,25	0,07	0,32	0,16	0,20	0,09	0,13	0,01

Table 7. Frequencies with asymmetries (note most individuals have equal scores) between entheses by feature.

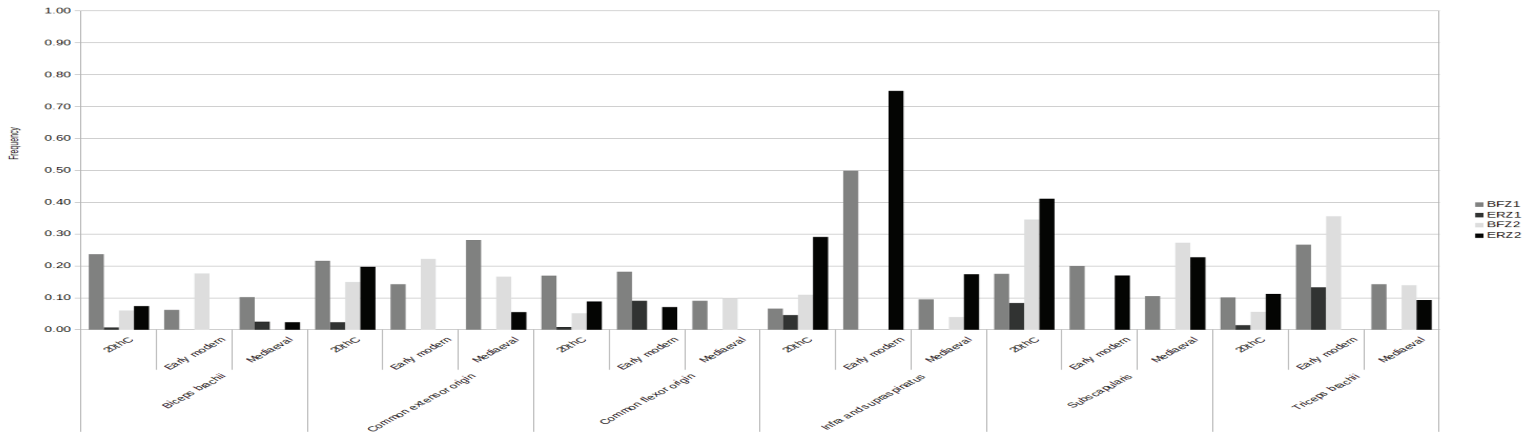

Fig. 1. Frequencies of the most common EC features by enthesis and period. Abbreviations: BFZ1 – bone formation in zone 1; ERZ1- erosion in zone1; BFZ2 – bone formation in zone 2; and ERZ2- erosion in zone 2.