A sense of society: entheseal change as an indicator of physical activity in the Post-Medieval Low Countries: potential and limitations

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Activity Reconstruction of Post-Medieval Dutch Rural Villagers from Upper Limb Osteoarthritis and Entheseal Changes

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Abstract

The first objective of this study is to reconstruct levels and types of physical activity and associated sexual and social differences using human skeletal remains from the predominately 19th century Dutch cemetery of Middenbeemster. For most individuals, life in the Beemster centred around dairy farming and was heavily based on manual labor, with a purported higher class of wealthier individuals performing less manual labor. Two skeletal markers of activity are examined in the upper limb of late young adult and middle-aged adults of both sexes (26–49 years, n= 69): osteoarthritis (OA) and entheseal changes (EC). Results support the hypothesis that the majority of the population engaged in high levels of physical activity; however, a group with a clearly lower or different pattern of activity, possibly representing a higher, less active class, was not discernible. This may be due to a low number of less active individuals in the analysed sample and/or the heterogeneity of occupations and activities. A gendered division of labour was evident in the EC data with males having more pronounced muscle attachments in almost all sites, especially the biceps brachii, used primarily in lifting. Females had more pronounced triceps brachii, which may be due to activities that required pushing or pulling with the elbow in a flexed position. The prevalence and severity of OA did not differ between the sexes. While this could be interpreted to indicate men and women engaged in a similar level of strenuous activity, hormonal and anatomical differences limit the strength of the comparison. The second objective of this study is to evaluate the concordance of OA and EC as activity markers. The correlation between OA and EC is very low, illustrating their variable and complex etiologies. Etiological factors need further research for OA and EC to become more reliable activity markers.

2.1 Introduction

The reconstruction of the levels and types of physical activity from individual skeletal markers is a popular yet controversial area of bioarchaeology. Many skeletal traits have been evaluated for use as activity markers with varying success. Two markers which are commonly used as indicators of activity-related stress on the human skeleton are osteoarthritis (OA) and entheseal changes (EC). OA is a disease occurring in synovial joints that is affected by physical activity (Pearson & Buikstra, 2006; 215–217; Waldron, 2009; 28; Molnar *et al.*, 2011). It has been used in activity reconstructions since the 1960s, when Angel (1966) used OA to infer specific activities such as spear-throwing. In a more recent example, Ubelaker & Newson (2002) examined sex differences in OA patterns in an agricultural society and distinguished a gendered division of labour. EC, also called enthesopathies or musculoskeletal stress markers, are the attachment sites of muscle onto bone, whose morphology is thought to correlate with muscle use and by expansion, physical activity (Churchill & Morris, 1998). New interest into the use of EC was instigated in the 1980s with a study by Dutour (1986) on Neolithic Saharan populations. In a recent example, Havelkovà *et al.*, (2011), established social differentiation between castle inhabitants and farmers in a Medieval agricultural population from Great Moravia using EC. Other recent studies have used skeletal collections of known age, sex and occupation to assess the correlation between EC and inferred physical activity levels. For example, Milella *et al.*, (2012) examined the Frassetto collection from early 20th century Sassari (Sardinia) and found a strong correlation between age, sex and EC, yet no clear connection between EC and activity. Alternatively, Villotte *et al.*, (2010) examined four identified skeletal collections (Christ Church Spitalfields, the Coimbra collection, and the Sassari and Bologna collections) and found a correlation between some EC and physical activity.

In the present study, OA and EC are examined in individuals from the Dutch post-medieval cemetery site of Middenbeemster for two purposes. The first goal is to evaluate whether OA and EC can provide information on physical activity in order to better understand how activity patterns varied according to social status and gender in this society. This research hypothesizes that working class individuals are more likely to have been highly active, resulting in higher EC and OA scores. It is important to assess the effects of such cultural practices on the Middenbeemster skeletons because they stem from a population that, according to historical sources, engaged in non-industrialized agriculture well into the 1800s (Drukker & Tassenaar, 1997; de Jong *et al.*, 1998). Osteological information can be used to assess historical accounts and provide new information about past lifeways, often on everyday activities of 'common' people who are underrepresented in historical accounts. More specifically, osteological activity markers can help discern whether the Middenbeemster population lived by 'traditional' labour divisions, wherein the elite did little physical work while the working class (e.g. field farmers) carried out most physical labour, and wherein there was a gendered division of labour, with men generally performing more strenuous tasks.

The second goal is to assess the correlation between OA and EC to evaluate their effectiveness and reliability for activity reconstruction. In osteoarchaeology, these osteological indicators are regarded as markers of activity, but their level of specificity and discernment, as well as the relative importance of various etiological factors, is not well understood. The concordance between these activity markers has not yet been widely studied (although see Alves Cardoso, 2008; Molnar *et al.*, 2011 and Villotte, 2008). A low correlation between OA and EC could have many causes but may imply that OA and EC do not form from the same type and/or level (i.e. intensity or severity) of physical activity. This study hypothesizes that if OA and EC have a low correlation, this would support the idea that they are the result of different activity-related phenomena and that researchers should be cautious not to oversimplify the concept of 'activity'. Overall, this study contributes to our knowledge of osteological activity markers in bioarchaeology and adds new information about a rural post-Medieval Dutch population.

2.2 Materials

Activity marker research is conducted on skeletons from the Dutch cemetery site of Middenbeemster, where all inhabitants of the surrounding Beemsterpolder who died between 1613 and 1866AD were interred (Falger *et al.*, 2012). Archival sources date most individuals used in this study to the last phase of cemetery use: between 1829 and 1866AD. At this time, we do not have individual archive-based information about the age, sex and/or occupation of skeletons. During this period, the Beemsterpolder formed a relatively small community centred around dairy farming. They had not yet truly been affected by the industrial revolution; therefore, most labour was manual (Drukker & Tassenaar, 1997). Sex of the skeletons was estimated using the Workshop for European Anthropologists methods (Ferembach *et al.*, 1980), Phenice traits (Phenice, 1969) and relevant metric measurements. Age was estimated by evaluating age-related changes to the pubic symphysis (Suchey & Brooks, 1990), auricular surface (Buckberry & Chamberlain, 2002), sternal rib ends (Işcan *et al.*, 1984), cranial sutures (Meindl & Lovejoy, 1985) and dental attrition (Maat, 2001).

For the evaluation of OA and EC, only late young adults (26–35 years) and middle adults (36–49 years) are used. The goal was to create a limited age range sample in order to better evaluate the two main research questions. Two age categories were necessary to achieve an acceptable sample size. Younger individuals are excluded as they may not have had sufficient time to develop these activity markers, whereas older individuals are excluded due to the accumulative nature of bony changes. Possible differences in EC related to activity become obscured in old individuals (Villotte *et al.*, 2010; Milella *et al.*, 2012). Insufficiently preserved skeletons, specimens with pathological conditions that could have interfered with physical activity (e.g. severe scoliosis, tuberculosis, residual rickets/osteomalacia) or interfered with the diagnosis of OA and EC (e.g. diffuse idiopathic skeletal hypertrophy (DISH)), were excluded. These requirements were fulfilled for 69 specimens: 32 late young adults, of which 19 are female and 13 are male, and 37 middle adults, of which 20 are female and 17 are male.

OA and EC evaluation is limited to the upper limb to best examine non-locomotion-related activities. The upper and lower limb can exhibit quite distinct activity patterns; therefore, in light of the proposed research questions, it was deemed best to limit research to one category. The effects of locomotion on the lower limb can obscure detection of other activities, a complication which is absent in the upper limb, making it better suited for the current study.

2.3 Methods

For OA, the acromioclavicular, shoulder and elbow joints are examined. Included skeletal elements are the acromial end of the clavicle, the acromion, the glenoid surface, the humeral head, the capitulum and trochlea, the radial head and all articular surfaces of the proximal ulna. For EC, four sites are scored on the humerus: the latissimus dorsii/teres major, deltoid, brachioradialis and pectoralis major. The latissimus dorsii and teres major were scored together because their attachment sites are often indistinguishable. On the radius, the biceps brachii attachment on the radial tuberosity is examined, and on the ulnar head the triceps brachii attachment.

Both activity markers are scored by macroscopic observation. For OA, a simple score of absent, mild, moderate or severe is given based on the criteria described by Waldron (2009): osteophyte formation (e.g. lipping), eburnation, joint contour deformation and porosity/pitting on the joint surface. At least two of these criteria need to be present for OA to be diagnosed, except for eburnation which is regarded as a determining criterion even in the absence of other signs of OA. This measure was taken to avoid over-diagnosis. A joint would be given a score of ‘mild’ if two osteoarthritic changes were just clearly visible, e.g. limited porosity and pitting and formation of a few osteophytes. For a moderate score, changes must be pronounced, whereas for a score of ‘severe’ the joint must be strongly deformed (Figure 1).

For EC, the method created by Mariotti *et al.*, (2004, 2007) is used. This method was deemed the most straightforward and reproducible of all currently available methods. It incorporates muscle attachment robusticity (Figure 2), osteophyte formation and osteolytic lesions in a comprehensive standardized form, with descriptions and pictures to aid robusticity scoring. It is well suited to comparisons between sexes, as the inherent higher male robusticity is not a confounding factor: the scoring system regards robusticity relative to the bone rather than to an abstract standard and evaluates surface markings rather than entheses dimension. Mariotti *et al.*, (2007) also combined the latissimus dorsii and teres major into one element for scoring. Thus, per individual, scores are given for robusticity, osteophyte formation and osteolytic lesions. These scores are then combined for each muscle attachment site (the lowest possible cumulative value is 1, the highest possible cumulative value is 9). Average EC scores per muscle attachment site for the entire sample are then calculated. Osteophyte formation, robusticity and osteolytic lesions react differently to age, yet given the limited age bracket of this study it was deemed acceptable to combine them. For another example of a study which combines new bone formation and bone resorption in one score, see Villotte (2013). It must be noted that this method does not incorporate the difference between fibrocartilaginous and fibrous entheses. Recent studies have suggested that fibrocartilaginous entheses provide more reliable results (Weiss, 2012; Villotte & Knüsel, 2013). Yet, Niinimäki *et al.*, (2013) have shown that not accounting for the difference between fibrous and fibrocartilaginous entheses does not greatly bias the results and have successfully used both joint types together (Niinimäki & Baiges Sotos, 2013). Thus, while we follow the method of Mariotti *et al.*, (2004, 2007) which combines both entheses types, we analyse the data in two ways: first with all fibrous entheses included and second with only the fibrocartilaginous entheses. In this way, we can assess if using only fibrocartilaginous entheses influences the results.

EC patterning is evaluated to assess the existence of sex- or age-based correlation, both through statistical tests and through a simple calculation of male mean score minus female mean score per muscle attachment site. The presence of distinct data groups is examined to see if there are different activity level groups (high vs. low activity) that could infer social differences. OA and EC data are also examined for left and right limb to assess handedness and physical stress level. For example, a lack of asymmetry could indicate higher physical stress, yet so could left-side dominance, as in many farming activities the right hand guides the movement while the left hand provides the brunt of the force. Asymmetry was expressed following Milella *et al.*, (2012) as (Left score / Right score) × 100, values <100 indicate right-side dominance. Differences between males and females as well as late young adults and middle adults for both OA and EC are tested using Mann–Whitney U tests. The final step in the analysis is the correlation between OA and EC, which is tested using Spearman's Rho test. Statistical significance is set at $p<0.05$. The coefficient of determination statistic is also performed to quantify the correlation between OA and EC. Statistical analyses are conducted using SPSS 17.0.

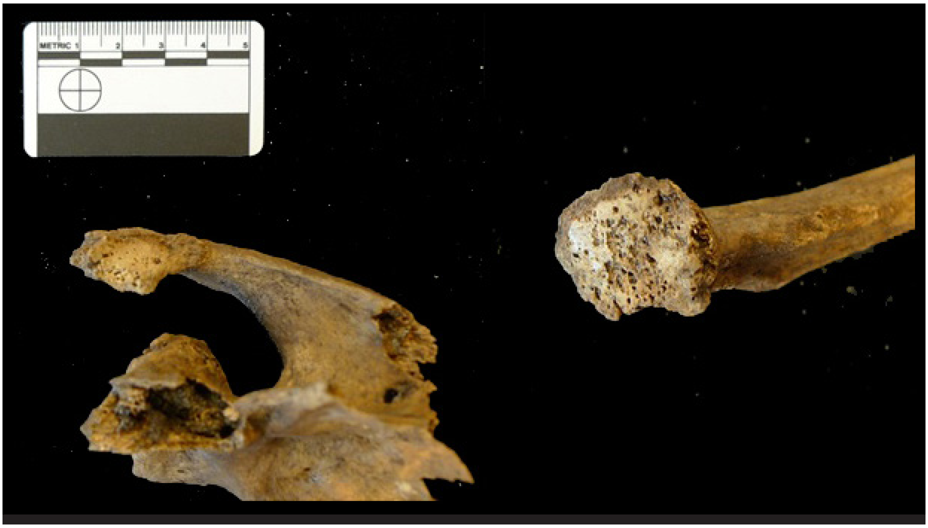

Figure 1. Example of severe acromioclavicular OA. All criteria are present.

Figure 2. Examples of EC robusticity scores of the triceps brachii on the ulnar head. From left to right: 1, 2 and 3.

2.4 Results

2.4.1 OA

All 69 individuals could be evaluated for (a-)symmetry in OA (appendix A1). OA data are symmetrical in 59 individuals, while eight individuals have a higher OA score for the right side, and two individuals exhibited a higher OA score for the left side. All differences between left and right were only one point.

OA prevalence is 44.9% in the shoulder and 8.7% in the elbow. These percentages indicate the presence of OA on at least one joint surface, not its severity. The high prevalence of shoulder OA was mainly due to OA in the acromioclavicular joint (Figure 3). Most cases of OA are mild. For example, in the right clavicle (acromial end), the joint with the highest OA prevalence, the affliction was severe in only one out of 44 individuals. Six others had a moderate case, and 15 a mild case.

OA prevalence rates in the late young adult and middle adult age categories are not significantly different (U= 530.00, p= 0.404), although the joint affliction is more likely to be severe in the older age category (Table 1). The difference between male and female OA is not statistically significant (U= 570.50, p= 0.844) (Figure 4).

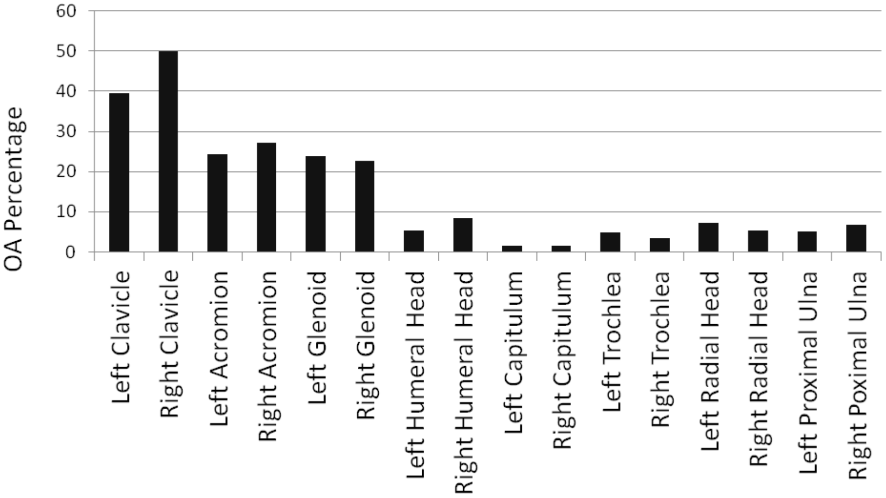

Figure 3. Percentage of specimens with OA per joint surface in the Middenbeemster collection, sexes and ages combined.

		OA Score Individual				
		0	**1**	**2**	**3**	**Total**
Age	Late young adult	18	13	1	0	32
	Middle adult	20	9	5	3	37
	Total	38	22	6	3	69

Table 1. Distribution of osteoarthritis scores for late young adults (26–35) and middle adults (36–49) from the Middenbeemster collection, sexes combined. Score 0 = absent, 1 = mild, 2 = moderate, 3 = severe.

2.4.2 EC

EC was symmetrical in 32 of the 58 individuals which could be evaluated (appendix A2). Thirteen individuals had more pronounced EC on the left (on average by 89.7%). The remaining 13 had more pronounced EC on the right (on average by 47.8%). When all data are pooled including symmetrical data, this leads to overall slight left side dominance (left side larger by 15.7%).

There is a significant difference between late young adults and middle adults for the total EC score (U= 384.00, p= 0.009), as well as when only fibrocartilaginous entheses are analysed (U=388.5, p= 0.023), with higher EC scores for middle adults. The difference between males and females for the total EC score does not reach statistical significance at the 0.05 level (U= 450.500, p= 0.09). Fibrocartilaginous entheses do not reach statistically significant differences between males and females either (U= 447.5; p= 0.166). However, the low p-value for all entheses combined invoked further analysis. When individual muscle attachments were compared, males had more pronounced EC for all muscles except the triceps brachii (Figure 5). The triceps brachii was more pronounced in females. The biggest sex difference was in the biceps brachii EC, which explains why the correlation test on only fibrocartilaginous entheses yielded such a weak association. When male and female data are pooled, as shown in Figure 4, the biceps brachii is the most pronounced EC, whereas the deltoid is the second least pronounced EC. As illustrated above, this ranking obscures intra-sample variation, yet having a samplewide overview is a useful aid for comparison with other studies.

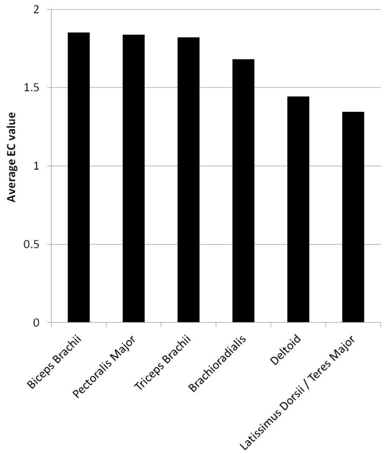

Figure 4. Ranked mean EC scores per muscle attachment site for the Middenbeemster collec-tion, sides sexes and ages combined.

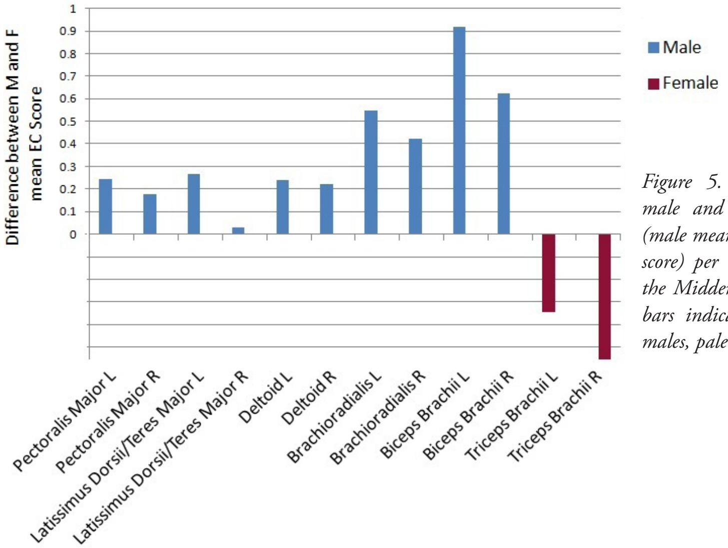

Figure 5. Differences between the male and female mean EC scores (male mean score minus female mean score) per muscle attachment site in the Middenbeemster collection. Dark bars indicate higher mean score in males, pale bars in females.

2.4.3 Correlation of OA and EC data

One hypothesis of this study is that low positive correlation between OA and EC supports the supposition that they are markers of different types of activity. The correlation coefficient between OA and EC in the Middenbeemster collection is r = 0.242 (p = 0.045) when using all EC, and r = 0.265 (p = 0.031) when using only fibrocartilaginous EC. While these values are indeed positive and reach statistical significance, the correlation coefficients are quite low (it does not reach the moderate range which begins at r≥0.300). The coefficient of determination between OA and EC is also very low (R2 = 0.096) (Figure 6), indicating that the predictive value of each activity marker towards the other is low, further illustrating what is to be expected given their low correlation.

As visible in Figure 6, no clearly demarcated physical activity level groups are evident. The most distinct individuals are the two late young adult females who had no signs of OA (score 0) and whose highest EC score was 1 (i.e. the lowest possible score).

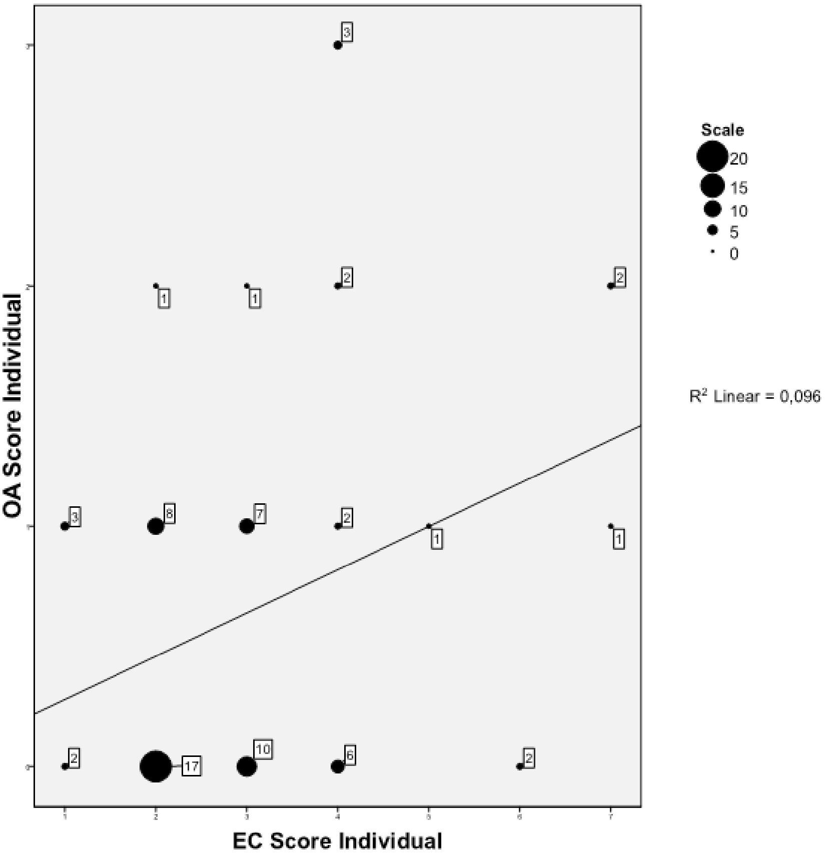

Figure 6. Scatter plot showing all individual EC scores on the x-axis and all individual OA scores on the y-axis for the Middenbeemster collection. The number tag indicates the exact number of individuals (n = 69).

2.5 Discussion

It is always difficult to interpret OA frequency in past populations because of its inherent multifactorial etiology and because comparisons to the results of other researchers are complicated by the use of different recording methods. However, the prevalence of OA in the shoulder and elbow of the Middenbeemster sample is much higher than in contemporaneous Dutch populations, suggesting that Middenbeemster inhabitants engaged in generally strenuous labour. For example, in a contemporary urban population from Alkmaar Sint-Laurenskerk, dated to the 17th century through 1830 AD, OA prevalence was 2% in the shoulder and 5% in the elbow (Baetsen, 2001). Although the frequent occurrence of OA in the Middenbeemster sample is thought to be partially due to strenuous physical activity, its markedly higher prevalence compared to Alkmaar also suggests differences in recording methods. However, the Alkmaar study does not specify their recording method so no further comparison is possible. This illustrates the need for a standardized OA recording method. In another study, a population of citizens of the Dutch city of Dordrecht interred between 1275 and 1572AD had an OA prevalence of 8% in the shoulder and 4% in the elbow (Maat *et al.*, 1998). Percentages may be lower in that sample because individuals of all ages (including subadults in whom OA is rare) were included; however, most specimens were adults. From these low prevalences, Maat *et al.*, (1998) concluded that the population was of high socioeconomic status, engaging in minimal manual labour. If their conclusion is correct, it supports the hypothesis of strenuous physical labour in the Middenbeemster sample.

Comparison to a totally different sample, that of African slaves, shows that other factors besides methodological differences are also present. Wilczak *et al.*, (2004) used a similar scoring method to that of this study and found 13% of individuals had moderate to severe OA in the shoulder. This difference in prevalence rates between the Middenbeemster population and the African slaves could be a result of different physical activities; however, there is currently no way of knowing how large a role genetics, environmental factors, body mass, etc. played. The complex multifactorial nature of OA (Weiss, 2005; Weiss & Jurmain, 2007; Waldron, 2009) thereby further muddles any attempt to derive information on physical activity.

Another comparison can be made between the Middenbeemster OA data and 22 canons (male religious order) buried in the Sint-Servaas church in the Dutch city of Maastricht (Jansen & Maat, 2002) between 1070 and 1521 AD. These canons were wealthy men over 40 years of age who were unlikely to have engaged in strenuous physical activity. However, the prevalence of shoulder OA was 19% and elbow OA 46%. This example further illustrates the complexity of OA as an activity marker. The high prevalence rate could indicate that age and genetics played a large role in OA etiology in this instance. Also, all canons were afflicted by DISH, a disease which causes proliferative bone formation, and thus could contribute to OA development. In our study, individuals with DISH were excluded partly for this reason. Furthermore, the canons presumably had a higher body mass, although Weiss (2006) suggests that this will not greatly influence OA prevalence. Of course, the different relative distribution of OA in the Maastricht sample, with elbow OA being more prevalent than shoulder OA, could be evidence of different activities; however, further hypothesizing would be mere speculation given our limited knowledge.

There was no statistically significant difference for OA and age in the Middenbeemster sample, as the prevalence of affected individuals did not differ between late young and middle adults. However, OA severity did increase with age, as demonstrated by the fact that only middle adults had severe scores. This trend may not be statistically discernible because of the low number of affected individuals. Given the limited age range included in the study, it is unclear how we should interpret this trend. Possibly, this suggests a strong genetic predisposition for OA. Genetics could (partly) dictate whether an individual will or will not develop OA when under physical stress. Then, the disease will progress with age in this individual. Shipley *et al.*, (2002) estimate genetic predisposition of OA at 35–65%, whereas Weiss & Jurmain (2007) point out that although some recent studies estimate genetics to cause OA in 50% of cases (e.g. Spector & MacGregor, 2004), other studies (e.g. Zhai *et al.*, 2004) find this to be an exaggeration. Thus, while it is clear there is a strong genetic component for OA, we cannot establish if this is the main reason for the apparent pattern of increased OA severity with age.

The lack of difference in OA between men and women in the Middenbeemster sample could mean they engaged in equally strenuous activities. However, other factors must be considered before this simplistic interpretation can be accepted. First, female predominant hormones can make women more susceptible to OA (Spector & MacGregor, 2004), which could effectively efface evidence of less strenuous physical activity for this sex. Although many studies have examined sex differences in OA, there is currently no consistent answer to the questions of influence and etiology (Weiss, 2005). Also, anatomical differences between male and female joints (Sizer & James, 2008) could influence OA. These confounding factors seem insurmountable with current knowledge and suggest that our OA data should not be interpreted to indicate the absence of gendered division of labour. The (a-)symmetry test revealed a slight right side dominance for OA. Further research into how OA (a-)symmetry relates to physical activity (i.e. type, duration, severity etc.) could be very useful to interpret this result.

The overview of EC in Figure 4 shows that the deltoid is the second least pronounced. This is surprising because it is an important multifunctional muscle that is usually amongst the most pronounced EC. For example, it was most pronounced in Eshed *et al.*,'s (2004) study of Natufian hunter–gatherers and Neolithic farmers in the Levant, and in Wilczak *et al.*,'s (2004) study of urban African slaves in New York. However, no other Dutch sites have been analysed for EC, limiting regional interpretations of this finding, and drawing attention to the need for EC research in Dutch skeletal collections. Indeed, the absence of comparative data is a major complicating factor in current EC research. Apart from the absence of spatiotemporally similar studies, the plethora of different scoring methods (e.g. Hawkey & Merbs, 1995; Robb, 1998; Wilczak, 1998; Villotte, 2006) and the various ways of organizing the resultant data limit comparisons. We argue that a more standardized recording procedure must be established for EC to become more useful activity markers. An international working group is currently creating this (Henderson & Alves Cardoso, 2013). As it is, it is impossible to interpret the relatively low development of the deltoid in Middenbeemster.

The significant difference in EC between age categories, with Middle adults showing more pronounced EC, concurs with the findings of other studies (e.g. Weiss, 2003, 2007) and supports the hypothesis that EC are accumulative in nature. Possibly, the combination of enthesophyte formation and osteolytic lesions in one score could partially obscure some age-related changes. A confounding factor of EC research which must be noted here is the concept of 'bone formers'. These are individuals who might have an inherent tendency towards proliferative bone formation (Waldron & Rogers, 1990). Little is known about the existence, prevalence and expression of this phenomenon. However, as EC evaluation is largely based on bone formation and resorption at entheses sites, a bone forming predisposition in part of a population could greatly influence results. As the prevalence of bone formers may be as high as 20% (Waldron, 2009), further research into the effect of this on EC data is necessary.

EC results suggest a gendered division of labour in the Middenbeemster population. Males were especially involved in activities exercising the biceps brachii as these showed the highest sexual dimorphism. Activities which exert the biceps brachii include the lifting of heavy objects. Males had more pronounced EC in all sites but the triceps brachii. This muscle is active in the extension of the lower arm, the adduction and extension of the arm, and the bracing of the elbow joint, for instance when pushing an object. It is also exercised when, starting from a flexed position of the elbow, one pulls or pushes something down. This may indicate that women were engaged in tasks such as milking cows or using a scrubbing board on laundry, activities which put repeated and sustained stress on the triceps brachii.

There is a slight left side dominance in EC. This could be consistent with strenuous physical activity,as the left side of the body would provide the brunt of the force while the right side would guide the movement in many agricultural activities such as using a shovel.

Interestingly, the OA data on (a-)symmetry do not concur with the EC data. This seeming contradiction could be caused by their different etiologies, illustrating that they should be viewed as markers of different components of physical activity. It must also be noted, however, that this study is based on a limited sample size of 69 individuals; therefore, low sample size could also be a confounding factor for all analyses.

The correlation between OA and EC was low, further reinforcing the hypothesis that they are markers of different types of physical activity, for example repeated low-strain activities versus short bursts of explosive activity. Their low correlation could also be caused by their complicated multifactorial etiologies, as their different relation to age illustrates. Also, as OA and EC are evaluated in anatomically different bone regions, there is an inherent difference in bone response. OA and EC both need extensive clinical study, specifically regarding their etiology. Furthermore, both need a clear, standardized recording method to make studies more comparable.

The Middenbeemster data showed no evidence of social differentiation at a population level. It was impossible to distinguish distinct groups based on the combination of these skeletal activity markers. It is possible that the level of socioeconomic division at Middenbeemster was too low to show up on the skeleton, or that the 'elite' engaged in a similar amount (if maybe different type) of physical activity. Another possible explanation is that the number of elite individuals was too low to be readily detected. For OA, it is likely that the individuals who were affected by this disease engaged in strenuous labour, yet these individuals represent only a part of the group which was physically highly active. It could be hypothesized that the two individuals who show no signs of OA and have an EC score of one (as seen in the bottom left corner of the chart in Figure 6) were in fact members of the elite. Interestingly, both these individuals were late young adult females. The positive correlation of EC with age could partially cause this, yet neither OA nor EC were influenced by sex in a way that would cause this pattern. Therefore, there could be a sexual difference in OA and/or EC that does not show up in these data. It could also be that young elite females were less active than young elite males. Interesting as these possibilities are, the pattern is not unambiguous enough to present certain conclusions.

Another possible explanation for the lack of visible social differentiation is found in the town council death records. These records note the professions of the 19th century inhabitants. Among the noted professions were workers, tailors, handmaidens, saddle makers, merchants, innkeepers, carpenters and preachers. Such diverse professions are bound to result in a diversity of activity marker expressions. The archival data thereby provide an explanation for the absence of a clear high status and low status group, as well as providing an excellent reminder of the complexity involved in studying past lifeways.

It is obvious from this study that both activity markers need further research. On a general methodological level, standardized recording and data processing methods are necessary. The age distribution of the OA data indicates a strong genetic factor, yet the extent of genetic influence on this joint affliction is still being studied. Likewise, while many other factors in OA etiology are known, their 'weight' is uncertain and needs to be better established. EC research has similar issues. There is insufficient clinical research on EC because they do not cause symptoms (Pearson & Buikstra, 2006), although the etiological factors are actively being studied from an osteoarchaeological perspective (e.g. Weiss, 2006; Weiss & Jurmain, 2007; Niinimäki, 2011). Experiments on animals are also being undertaken, for example in sheep (Zumwalt, 2006) and mice (Wallace *et al.*, 2012), although these are hampered by the absence of a non-weight bearing upper limb.

2.6 Conclusions

OA and EC analysis of the Middenbeemster sample found that this population likely engaged in strenuous physical labour, based on high OA prevalence, as well as the slight left side dominance in EC. The EC data suggest a gendered division of labour with men more often performing tasks that required heavy lifting and women performing more tasks associated with pushing or pulling at objects with a flexed elbow. On a population level, no social differentiation in activity was apparent, which could be due to a number of factors including a low number of 'elite' individuals and the diversity of professions. However, it may also indicate that there was little social differentiation in the community. Future research into age, sex and class based activity on the lower limb will aid in answering the remaining questions. There was a low correlation between OA and EC, supporting that there are differences in the etiologies of these activity markers. Both OA and EC need further etiological research if they are to become reliable markers of physical activity. Overall, this study added to our knowledge and understanding of the use of purported osseous markers of activity for the reconstruction of past lifeways.

Acknowledgements

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