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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Entheseal change in osteoarchaeology: uses, limitations, and future perspectives

Physical activity is a complex and dynamic aspect of human society. Both the way physical activity is perceived and the way we use our bodies varies. Osteoarchaeology offers an excellent opportunity to analyze the diverse patterns of physical activity in past societies by using the direct traces they leave on the skeleton. The current dissertation focused on one such osseous trace of activity, entheseal change (EC).

This thesis assessed the use of EC as a marker of physical activity within osteoarchaeology on four fronts. First, this research evaluated how EC relates to other osteological markers of physical activity, and second, assessed if and how the different EC recording methods can be reconciled. Third, this thesis provided a standardized system to instigate the study of EC in growing individuals, and fourth, gauged whether EC, which are regularly used as a proxy for social differentiation, actually reflect such socio-economic divisions. Thus, this thesis has assessed the application of EC, tackled and filled certain lacunae in our knowledge, and contributed constructive new research tools. In doing so, it fulfilled the overarching goal voiced in chapter 1, to provide the reader with a comprehensive study of the potential and limitations of EC.

7.1 Activity marker research

The recurring conclusion throughout this four-tiered study is that EC are not a clear-cut direct indicator of physical activity. From the research presented here, as well as the myriad of other studies using EC cited throughout this thesis (and those listed in appendix E), it is clear that the morphology of muscle and ligament attachment sites shows a broad range of variation between individuals. What is not clear is exactly why EC are formed, and what the impact of the different contributing factors is in their formation. Weiss (2015) gives an overview of the etiological factors which have been identified in clinical and anthropological research. Crucially, she highlights how these factors also interact with each other. Thus, for instance, age, a factor which is generally accepted as having an impact on EC, interacts with hormone levels which influence EC, but will also have an effect on which activities a person does, and thus age will both directly and indirectly influence muscle marker mor-

phology. This also means that age will have a different effect on EC in different societies, depending on the extent to which a society imposes a division of labor based on age. Thus, EC are a result of an interaction of different factors. The key point is that EC are unlikely, in any given context, to be a result solely of physical activity, and thus any study trying to use EC as an isolated marker of activity without taking into account context is doomed to failure. This does not mean that EC cannot be used to assess patterns of physical activity in the past, but rather that researchers need to be acutely aware of all of the factors involved, and that research questions need to be developed with a realistic perspective of what EC can, and cannot, tell us about past individuals and societies.

In addition to these general findings, each of the four lines of research included in this thesis provided its own unique contributions to the body of knowledge on EC.

7.2 EC and other activity markers

Chapter two found a low correlation between osteoarthritis and EC. Thus, although these are both commonly used activity markers, there are differences in their etiology and/or the way they reflect the physical activity performed by an individual during their lifetime. This outcome implies that the activity marker used will define how the activity pattern is reconstructed, and evidences that activity markers on human bone cannot be used interchangeably. The second main finding from this study is that there is a significant difference in EC between men and women in post-medieval Middenbeemster. Given the context of this town, a Dutch rural settlement focused on dairy farming, it is likely that this points to a gendered division of labor. Further information on socio-economic differentiation was not attained from either the osteoarthritis or EC data, meaning that either socio-economic differentiation in this community was not extensive enough to show up in osseous markers, or that these osseous markers are not a valid proxy for this type of research question. This paper formed the ideal starting point for the current thesis as it shows the complexity of EC research as well as providing a tantalizing glimpse into the information it can provide.

7.3 Study comparability

Having established that certain different activity markers cannot be directly compared, the next step in the research was to assess whether the different existing methods for recording the one activity marker focused on in this thesis, EC, can provide data that can be compared. Being able to compare and contrast data from different populations with different expected physical activity loads is crucial for the further development of EC research. Fortunately, the current study ascertained that the two most prominent methods to systematically score EC are largely compatible. Thus, this second paper ensures that studies predating the new scoring method do not become obsolete.

7.4 EC in nonadults

Given the decades of research into muscle markings, it is remarkable that nonadult individuals have largely been ignored. As their physiology is intrinsically different, a distinct system is necessary for the observation of EC in this segment of society. Chapter four addressed this gap in the current body of research by presenting a standardized method for the recording of nonadult EC. This chapter also presents the first in-depth study of EC in growing individuals, and illustrates the amount of variation observable in these nonadult remains. As an exploratory aspect of this study, the correlation between age, sex, and EC was tested. These tests found no significant patterns of correlation between EC and age and sex, which indicates that EC are influenced by other factors, possibly including activity. The proposed method is applicable to nonadult remains from any archaeological, medical, or forensic context, and will help researchers study this unexplored aspect of the nonadult skeleton. As such, the method facilitates studies on EC as a potential activity marker in growing individuals, but also studies of how EC interacts with growth and development of the human body, making it a uniquely valuable addition to the scientific field.

7.5 EC as an indicator of social differentiation

As addressed in chapters two and six, bioarchaeologists have repeatedly used activity patterns inferred from EC as a proxy for social differentiation in archaeological populations. Chapters five and six tested whether EC can actually be a used in this fashion. Chapter five first provided unequivocal historical and osteological evidence of the three socio-economic groups represented by the three skeletal collections from post-medieval Aalst, and chapter six then tested whether EC reflected these established social groups in this context. The results showed that where historical data and dietary stable isotopes could identify socio-economic status, EC data did not differ significantly between the three groups. Although results from this specific context are not necessarily relevant to all skeletal research, they are undeniably relevant to osteoarchaeological studies which use post-medieval European collections. The outcomes of this study infer that our assumptions about the lives of past peoples likely over-simplify their daily reality. The lack of correlation between EC and status could mean that the differences in activity patterns between the groups are not as big as we think they are. Thus, this study illustrates the caution necessary when trying to assess socio-economic status from EC, and highlights the intrinsic problems of using EC to answer this research question.

7.6 Osteoarchaeological contribution

On a more general level, the current research illustrates the unique value of human osteological research. This thesis provides new information about life and death in the post-medieval communities of Middenbeemster and Aalst. For Aalst, in particular, the current

thesis provides a unique contribution. It combined material from three contemporaneous post-medieval skeletal collections from this town into one study, thus providing valuable insights into life in this urban environment. The dietary differences between the social classes, with individuals buried in the monastery at the Hopmarkt eating a diet richer in animal protein than the individuals buried outside the convent at the Louis D'haeseleer-straat, clearly substantiate the social differences in burial preferences within Aalst. These dietary differences, as attested by the stable isotope analysis of carbon and nitrogen, additionally allowed the identification of a subgroup of older females buried in a separate area at the Louis D'haeseleerstraat as nuns, as they were eating considerably more fish than the general population. Moreover, the differences in other osteological and paleopathological matters which are partially touched upon in chapter five provide incentive for further research into the osteoarchaeology of this vibrant town. This future research can then, in turn, potentially elucidate additional aspects of the EC patterns discussed in the current thesis.

7.7 Future research

The current research focused on EC in the post-medieval Low Countries, and used skeletal populations from the towns of Middenbeemster and Aalst as test communities to assess the value and best application of EC as an activity marker. As this research has proven the importance of analyzing EC within a well-defined historical setting, more studies on skeletal populations for which the contextual information is similarly rich would be beneficial. Specifically, populations from very different contexts need to be researched, to then compare to the studies such as the current thesis and assess the impact of the social and cultural environment on EC. Key aspects to these future studies should be obtaining a solid understanding of the different social tiers present in the skeletal collection, and aiming for a robust sample size for statistical analyses. Thus, the different etiological factors can become better understood and the weight of activity in the formation of EC determined.

At a more fundamental level, more research is needed into the different ways entheses can change, and whether these different osseous changes are indicative of different things. The Coimbra method is specifically designed to allow this type of research, and some preliminary steps in this direction have been taken (Henderson *et al.*, 2013), but much more is needed.

In addition to this necessary fundamental research on adults, this thesis has paved the way for future scientists to start evaluating EC in growing individuals. Studies of EC in nonadults using the proposed standardized scoring method will shed light on how muscle and bone interact in a developing individual, and if and how physical activity changes the morphology of the entheses. The proposed method is set up in such a way that the different morphological changes (i.e.., types of new bone formation or bone resorption) can be scored separately, and their relative significance evaluated. As this topic is as yet virtually

unexplored, an extensive amount of new research is necessary.

Finally, we must also look to other disciplines to increase our understanding of the impact of physical activity on the skeleton. Osteoarchaeologists are currently researching EC in animals using controlled activity and known activity (e.g. Binde *et al.*, 2018, Niinimäki *et al.*, 2018, Niskanen 2018), and more research in this field will certainly offer valuable insights. However, animal models will never be an ideal proxy for the omnivorous, bipedal and culturally complex species that is our own. Therefore, more intense collaborations with the subfields of modern medicine which are interested in musculoskeletal interactions are necessary. Specifically, research collaborations with scientists in sports medicine and physiotherapy would be mutually beneficial, with osteoarchaeologists having access to a much larger amount of dry human bones, and modern medicine having access to a much more detailed background for their patients.

7.8 In conclusion

Osteoarchaeologists research every observable morphological variation on the human skeleton. These variations help scientists discover a large amount of information about the life of the individual represented by the skeleton on their laboratory table. Discrete morphological differences allow researchers to estimate the sex of an individual, his or her age-at-death, which diseases and afflictions they bore, some markers of genetic ancestry, and the activities in which the individual commonly engaged. Thus, every distinct osseous change is studied to tell us more about the lives of people in the past. However, where some changes are easy to identify and interpret (e.g., a broken and badly healed bone), others are more complicated.

It is an undeniable fact that entheses present a spectrum of morphological variations in muscle attachment sites both between individuals and populations. This obvious observable diversity has led researchers to use EC as a marker of muscle use. While it is likely that physical activity is a formative factor for EC, it is increasingly clear that other etiological factors are also at play. The current thesis has shown that EC do vary, and can tell us something about the lives of past peoples. However, the current thesis has also provided evidence that we are not necessarily asking the right questions of EC data. Assessing social status from EC simplifies the lives of people in the past, and ignores the individual agency of humans, who use their bodies for more than just their profession or occupation. Assuming that different activity markers would correlate over-simplifies human physiology, and the way different osseous elements respond to stress and strain. Regardless of the individual or population under study, context is always key in EC research. Obtaining the maximum amount of information possible about the person/population's physical status (i.e., pathology, body size, sex, age, diet) and the societal setting (i.e., time period, geographic location, environment, societal structure, common occupations) is key to designing appropriate re-

search questions to which EC can provide an answer.

By pinpointing research questions to which EC cannot provide the answer, as well as contributing new results which demonstrate how EC can be used, the current study provides a framework for the conception of future EC research questions. It showed that while we cannot use EC as a proxy for social differentiation, at least not in all societal contexts, we can sometimes identify gendered divisions of labor. Additionally, it proved that results obtained using different methods can be compatible and thus comparative research is possible. In this way, this thesis offers a new impulse to this highly active yet controversial field of research. Finally, this dissertation provides osteoarchaeology with a new research avenue by presenting a method to analyze nonadult EC.

Thus, this thesis provides valuable tools for the study of physical activity in the human body, tools which can be applied to any skeletal material, be it forensic or archaeological. It also offers new insights into the lives of people in the past, by reconstructing aspects of the daily experiences of people living in the towns of Middenbeemster and Aalst. As such, this research contributes to our understanding of the daily reality in these post-medieval societies, as well as facilitating future research using the unique skeletal marker that is entheseal change.

The results presented in this dissertation, combined with the possibilities for future research it creates, add to and will continue to refine our growing understanding of the impact of society on individuals in the past. This temporal perspective, in turn, provides scientists with invaluable insights into the implications of physical activity for our body in the present. Knowledge of how activity affects people is highly relevant to our current society, with its increasing focus on sedentary labor. Consequently, the data presented in this thesis can be a valuable tool for policy-making in our rapidly evolving globalizing world. Understanding how humans behaved in the past and how this impacted their bodies thus enables us to improve our physical well-being, now, and for future generations.