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

Palmer, J.L.A.

Author: Palmer, J.L.A.
Title: A sense of society: entheseal change as an indicator of physical activity in the Post-Medieval Low Countries: potential and limitations
Issue Date: 2019-03-20

A SENSE OF SOCIETY

ENTHESEAL CHANGE AS AN INDICATOR OF PHYSICAL ACTIVITY IN THE POST-MEDIEVAL LOW COUNTRIES: POTENTIAL AND LIMITATIONS

A SENSE OF SOCIETY

ENTHESEAL CHANGE AS AN INDICATOR OF PHYSICAL ACTIVITY IN THE POST-MEDIEVAL LOW COUNTRIES: POTENTIAL AND LIMITATIONS

Proefschrift

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus prof. mr. C.J.J.M. Stolker,
volgens besluit van het College voor Promoties
te verdedigen op woensdag 20 maart 2018
klokke 11.15 uur

door

Jessica Lisbeth Antonia Palmer

geboren te Gent
in 1988

Promotor
Dr. M. L. P. Hoogland

Co-promotor
Dr. A. Waters-Rist

Committee
Prof. dr. J. Kolen (voorzitter, Universiteit Leiden)
Prof. dr. M. Soressi (secretaris, Universiteit Leiden)
Prof. dr. W. De Clercq (Universiteit Gent)
Prof. dr. E. Weiss (San Jose State University)
Dr. A. E. van der Merwe (Universiteit van Amsterdam)
Dr. S. A. Schrader (Universiteit Leiden)
Dr. L. Llorente Rodriguez (Universiteit Leiden)
Prof. dr. M.C. de Ruiter (Universiteit Leiden)

Imprint: Krijn Boom
Layout and cover design: Krijn Boom
Illustration cover: Map of Aalst (Belgium) by Braun and Hogenberg
Humerus by Krijn Boom

De totstandkoming van dit proefschrift is financieel ondersteund door de Stichting Nederlands Museum voor Anthropologie en Praehistorie (SNMAP)

S·N·M·A·P

"The story is in the soil keep your ear to the ground"

- Conor Oberst

Acknowledgements

A PhD is a strange journey. It twists, turns, rattles, and, occasionally, derails, to finally culminate in a body of work which bears one individual name. However, behind this individualistic-looking book hides a small army of people who have, in some way or another, made it all possible. I will try to do them justice.

I want to thank my supervisors, Dr. Menno Hoogland and Dr. Andrea Waters-Rist. Andrea, your support and enthusiasm have guided me ever since I started my MSc in 2011. Without you I would never have realized there were academic options for me past a master's degree. I'm still not sure whether that was a blessing or a curse, but it led me to do what I love these past five years and for that I am forever grateful. Menno, you have helped me and fought for me at every turn. Without you none of this would have been possible.

I'd also like to thank the colleagues and friends who have been with me through these years. My osteocrew; Sarah Inskip, Rachel Schats, Sarah Schrader, Felicia Fricke, Femke Reidsma, and Esther 't Gilde. I'm sorry for all the puns. Well, a little. Well, I know I should be sorry. Still, our office lunches, emergency whisky breaks, and occasional exasperated ranting sessions have added so much fun to my daily life. My climbing crew; for giving me a way to spend all the pent-up energy desk work gives me- I've thought long and hard about this. The Johnfoxes, for being amazing housemates.

To the friends back home- thanks for never feeling far away. I can't list all of you without filling too many pages but, to use a worn-out cliché: you know who you are. A few special mentions. Valerie, from now on you can tease me for being *Doctor* Bones. Hah! Elke, your common sense perspective on life has helped me keep my priorities straight more often than you know.

My parents, of course, deserve a place of honor in this list. Ingrid and Albert, you were in the acknowledgements of my BA, MA, and MSc theses, and now you're in the acknowledgements of my PhD. I think we can take this as evidence of some pretty solid (and enduring) parenting. I'd like to add my grandparents, as well, Antoine and Agnes, for always supporting me, and asking about my work, no matter how weird it may seem to you. Merci.

Maria Walgraeve, you have run this mental marathon with me, start to finish. I truly could not have done any of this without you.

And finally, Krijn; now we're both doctors! I'm so happy we found each other in time to share this experience, and I can't wait to continue to level up together.

Contents

1

Introduction and outline

Humans have long had an ambiguous relationship with physical activity. From the Greek idolization of the young athlete, over the long-lived condescending attitudes towards manual labor, to our present-day Olympic performers who push their bodies beyond all natural, healthy limits in a global competition for prestige. As early as AD 1025, a physician called Avicenna stated that moderate exercise ("until you succeed in panting") is healthy, whereas immoderate exercise leads to overload, causing the body to age before its time (cited in Shephard 2012). Today, the belief that a certain amount of physical activity is beneficial is ubiquitous (de Hollander and Staatsen 2003), and is widely supported by contemporary medicine.

This fascination with how we use our bodies is apparent when scientists study the current world, but also extends into the questions we ask about the lives of people in past societies. Archaeologists aim to reconstruct the past human experience in all its multifaceted complexity, down to the daily activities in which past peoples engaged. Within the field of archaeology, bioarchaeologists studying human skeletons have the unique advantage of being able to directly observe the physical remains of individuals from the past. As such, bioarchaeological research includes the identification and study of the traces that physical activity leaves on our bones. These skeletal indicators of physical activity are generally regarded as evidence of hardships faced by an individual during his or her lifetime, often linked to lower socioeconomic status. As such, intra-population differences in patterns of osteologically assessed physical activity are frequently used to study social differentiation in past societies.

To achieve these societal analyses based on human skeletal remains, bioarchaeologists rely on the anatomy and plasticity of the human body. The skeleton is a dynamic organ during life, and undergoes constant morphological adaptation in response to environmental factors, specifically changing in shape and size in response to physical activity (Larsen and Walker 2010). Thus, the skeleton provides a record of the physical activity in which an individual engaged during his or her life and is ideally suited for researching activity patterns. Bioarchaeologists have used many different skeletal indicators of physical activity (Capasso *et al.*, 1999). Markers such as dental wear related to specific crafts (Mickelburgh

2007, Waters-Rist *et al.*, 2010), osteoarthritis as a result of joint (over-)use (Molnar *et al.*, 2011), or even exposure to chemicals related to certain professions (Littleton 1999) have been used. This wealth of skeletal indicators of activity is in part due to the many different ways in which our body can react to physical activity, but also in part to the absence, as yet, of a single consistently utilizable activity marker. As such, activity reconstruction from human remains has been called the 'holy grail' of bioarchaeological research (Jurmain *et al.*, 2012).

Within the field of skeletal activity marker research, recent studies have focused on changes occurring at the attachment sites of muscles and ligaments to bone, known as entheses. Entheses act as the zone of force transmission from muscle or ligament to bone during muscle use (Lu and Thomopoulos 2013). Anatomically, they can be divided into two main types, i.e., fibrous and fibrocartilaginous entheses. This distinction in types of muscle/ligament attachment site to bone is important in EC research, as recent studies have found fibrocartilaginous entheses to be more reflective of physical activity (Henderson *et al.*, 2016).

Fibrous entheses, as the name suggests, attach directly to bone through fibrous tissue, usually in the form of a tendon. Fibrocartilaginous entheses, on the other hand, attach to bone through an intermediary layer of fibrocartilage (Apostolakos *et al.*, 2014). Fibrous entheses can usually be found on the shaft of long bones (figure 1) and tend to have larger surface sizes. They are more diffuse and can be challenging to delineate. Fibrocartilaginous entheses are usually located at the metaphysis and epiphysis of the bone and tend to mimic joint surfaces in their appearance.

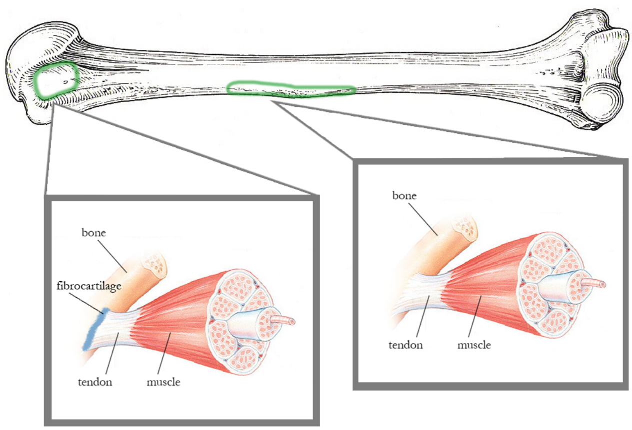


Figure 1: Right humerus with the M. subscapularis attachment (left) indicated as an example of a fibrocartilaginous attachment, and the M. deltoideus attachment (right) indicated as an example of a fibrous attachment, with a close-up of their anatomical make up.

The basic premise of entheseal change (EC) research harks back to Wolff's law of bone remodeling (Wolff 1892) which states that bone, being a plastic tissue, reacts to the strain put upon it. Thus, when a lot of muscle strain is placed on the skeleton, bones will reflect this through osseous changes occurring to accommodate this tension. Bones can effectively only react in two ways to stimuli; by the formation of new bone tissue or the resorption of existing material (Liedert *et al.*, 2005). In reality, these two types of changes can be subdivided based on how bone is resorbed or formed. At entheses, osseous change can be observed in the form of osteophyte formation, osteolytic lesions and cavitations, rugosity, texture change, and irregularity of the cortical surface, micro-and macroporosity, and robusticity of the attachment site (Hawkey and Merbs 1995, Mariotti *et al.*, 2004, 2007, Henderson *et al.*, 2016) (e.g., figure 2).

Figure 2: Four examples of EC at the M. biceps brachii attachment site on the proximal diaphysis of the radius (fibrocartilaginous attachment site) (from Palmer et al.*, 2016).*

Entheseal changes have been observed on the human skeleton and linked to activity since the 19th century (see Lane 1888 for an early study), yet the topic only truly gained momentum in the field of bioarchaeology following the study by Hawkey and Merbs (1995) of an Inuit population. In the decades that followed, entheseal changes (commonly referred to as musculoskeletal stress markers until ca. 2012) were analyzed in a host of different geographical and temporal contexts, such as prehistoric Alaska (Steen and Lane 1998), pre-contact California (Weiss 2007), Holocene Siberia (Lieverse *et al.*, 2009), Ancient Sudan (Schrader 2015), and early Medieval Serbia (Djukic *et al.*, 2018).

Although at first most scientists used the recording method created by Hawkey and

Merbs (1995), over time, new methods to observe and record EC were developed (e.g., Robb 1998, Wilczak 1998, Mariotti *et al.*, 2004, 2007, Villotte 2006, and Henderson *et al.*, 2016), while some research did not use a recording method as such but rather focused on one trait of EC (e.g., Milella *et al.*, 2015). One fundamental distinction between these recording methods is which entheses they can be applied to. For instance, where the initial Hawkey and Merbs (1995) method could be applied to all entheses, the Mariotti (2007) method was devised for 23 specific post-cranial entheses, and the Henderson *et al.*, (2016) method can only be applied to one anatomical type of entheses, namely fibrocartilaginous entheses.

All of these methods aim to present a reproducible standardized recording system, whether through measurements, 3D imaging, or macroscopic evaluation of different traits (Weiss 2015). However, the existence of different methods, applicable to different muscle and ligament attachment sites, inevitably generates different datasets which cannot be directly compared, thus limiting inter-study comparison which is crucial when evaluating activity patterns in and between populations. The most recent method, named the Coimbra method (Henderson *et al.*, 2016) was created as a collaboration between several prominent EC researchers, including the abovementioned Villotte, Mariotti and Wilczak, and aims to be the final, universally used, method for the analysis of all EC at fibrocartilaginous entheses. The Coimbra method divides the entheses into two zones for observation, zone 1 which is the outside edge of the entheses where the muscle fibers attach most obliquely, and zone 2 encompassing the rest of the attachment area. In zone 1 bone formation and erosion (i.e., osteolytic lesions in earlier methods) are scored, and in zone 2 textural change, bone formation, erosion, fine porosity, microporosity, macroporosity and cavitations are scored. These traits are scored as zero when absent, and 1 or 2 based on the extent of change when present (Henderson *et al.*, 2016).

Even with the creation of a standardized scoring method, EC research remains a somewhat contentious field. One reason for this is the multifactorial etiology of EC (Rhode 2013). Not only activity, but also other factors such as age (Henderson *et al.*, 2017), sex, body size (Weiss *et al.*, 2012), pathology (Henderson 2008), and genetics (Schlecht 2012, Mazza 2018) are known to affect enthesis morphology. Because activity is not the only factor causing EC, reconstructing physical activity from the skeleton is not a straightforward process. The growing awareness of these limitations has led EC researchers to re-evaluate the relationship between EC and activity through experimental research (e.g., Zumwalt 2006 using sheep and Wallace *et al.*, 2012 using mice) and analysis of identified skeletal collections (e.g., Alves Cardoso and Henderson 2010, Milella *et al.*, 2012, Villotte *et al.*, 2010), while other researchers continue to use EC as an activity marker without taking into account the critiques and limitations (e.g., Baldoni *et al.*, 2016).

In addition to these intrinsic challenges, all current EC methodology and subsequent research focuses solely on adult (18+ years) individuals. Due to intrinsic differences in how soft tissue attaches to developing bone, as compared to how it attaches to adult bone, the methods developed for adult bone cannot be used in nonadults (<18 years). Although some researchers have included later adolescents in their research, and noted the difference in their EC compared to adults (Castex 1980, Stirland 1996, Mariotti *et al.*, 2004, Vilotte and Knüsel 2013), this has as yet only been used as an argument to exclude growing individuals from EC research.

The current dissertation aims to address the obstacles in the field of EC research in regard to the validity of using EC as an indicator for activity, method compatibility, and nonadult entheseal change. The applicability of EC as an indicator of physical activity and its correlation with another commonly used activity markers, namely osteoarthritis, is assessed in chapter 2. The use of EC as a proxy for social differentiation is assessed in two archaeological contexts (chapters 2, 5, and 6), the compatibility between the two dominant recording methods is assessed in a well-defined skeletal collection (chapter 3), and a method is developed for the observation and analysis of nonadult entheses (chapter 4).

1.1 Archaeological context

To meet these aims, four skeletal collections from the post-medieval Low Countries are used. The Low Countries is the area geographically delineated as current-day Belgium and The Netherlands in Northwestern Europe (figure 3). For EC research, excellent skeletal preservation is key, as EC can be quite subtle and are observed on the cortical surface of the bone. Thus, the first criterium for the selection of materials was the state of preservation. Following this, collections were selected for their ideal suitability in terms of having well-defined historical and archaeological contexts. This led to the selection of one skeletal collection from Middenbeemster, The Netherlands, and three collections from Aalst, Belgium. The collections date to the post-medieval period, and range in date from the 15th to 19th century.

The collection from Middenbeemster was chosen because it represents a well-researched, well-documented archaeological population. The site was excavated in 2011 by the Laboratory for Human Osteoarchaeology of the University of Leiden, and the remains subsequently housed in this laboratory. The excavation encompassed the cemetery next to the town church of the post-medieval settlement, and unearthed a total of ca. 450 individuals, thus providing an ample sample for the current research.

The town of Middenbeemster was founded in AD 1613. To create a community here, settlers drained and elevated the land (figure 4), which used to be a marshy lake (the Beemster Lake), between 1609 and 1613 (Griffioen 2011, Klooster 2008). The church was built between 1618-1623 (Rijksdienst voor Cultureel Erfgoed), with an adjacent cemetery that remained in use until 1866 (Falger *et al.*, 2012). Thus, all the individuals buried here can be dated to the post-medieval period. The town was a rural community, with a population of 2971 in 1840 (Falger *et al.*, 2012), and an economy centered around dairy farming (Jong *et al.*, 1998). Modernization and mechanization of agricultural production processes came somewhat late to Middenbeemster, as exemplified by the introduction of steam-powered water pumps in 1877 (Jong *et al.*, 1998). Thus, for the sample that is analyzed traditional manual labor was used and physical activity levels were likely quite high, at least for most individuals. Based on historical sources, a group of elite farmers titled 'herenboeren' ('gentleman farmers') who owned farms but hired workers to do the manual labor, gradually emerged, especially from the second half of the 18th century onwards (Van der Wiel 2012), yet overall social stratification was probably relatively limited. With this rich historical and archaeological context, Middenbeemster forms an excellent population for the first step of the research plan (chapter 2), which is to compare EC to another osseous activity marker (osteoarthritis), and evaluate whether we can observe social differentiation and divisions of labor in this community.

Figure 3: Map of Europe with Middenbeemster (top) and Aalst (bottom) indicated by black dots. The Low Countries are delineated by a solid black line and the border between Belgium and the Netherlands by a dashed line.

In addition to the rich historical background of this skeletal community, the town of Middenbeemster also has archival records for the cemetery. From these records, it was possible to identify a number of the excavated individuals by linking the burial plots to an entry in the burial register. Thus, there exists a subset of individuals from Middenbeemster for which we have known age-at-death, sex, and name. Having identified individuals is exceptionally valuable for many areas of osteoarchaeological research. For the current study, having nonadults of known age and sex was crucial (chapter 4).

Thus, Middenbeemster forms an ideal skeletal collection on which to conduct fundamental and methodological EC research. To accommodate the research aims regarding the validity of using EC as a proxy for social differentiation, as well as for further methodological research, another context is added. Three skeletal collections from Aalst represent a unique opportunity to research distinct socio-economic groups within one well-defined geographic and temporal context (Figure 5). As in Middenbeemster, the skeletal material from Aalst is embedded in a solid historical and archaeological framework which allows us to contextualize the EC data and limit, insofar as possible, any unknown confounding factors. These Aalst collections are described in detail in chapter five, so less background information is provided here. Together, they offer a window into life and death in a post-medieval town. The three collections originate from (1) the main city church, the Saint-Martin's church (high class individuals), (2) the cloister garth and alleys of the male Carmelite monastery (middle class individuals and clerics) (Hopmarkt site), and (3) the general cemetery of the female Theresian convent (lower class individuals) (Louis D'haeseleerstraat site). All excavated skeletons date between AD 1492 and 1797AD.

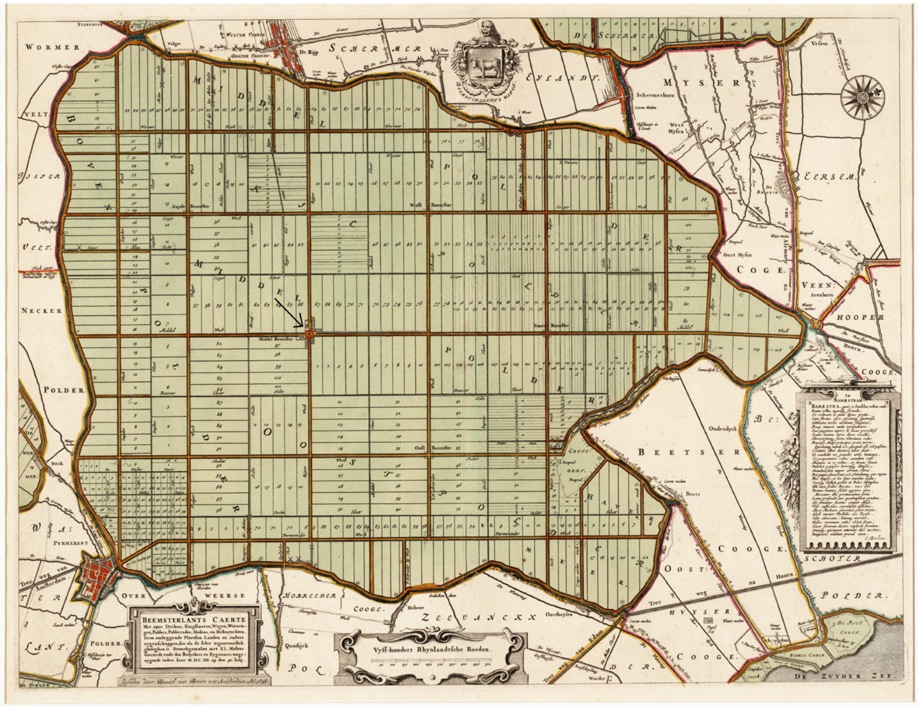


Figure 4: AD 1658 map of the reclaimed Beemsterpolder (now a UNESCO world heritage site), which encompasses nearly the exact area of the former Beemster Lake. The town of Middenbeemster is indicated with an arrow. The church and cemetery were located at the center of the town, at the intersection of the two perpendicular lines on the map. The grid pattern of rectangular farmland surrounding the town illustrates the planned nature of the settlement.

The Saint Martin's church sample was excavated in the winter of 1997-1998, as a four-week rescue excavation because an area of ground in the church was collapsing. The approximately 70 excavated skeletons were submitted to a limited general osteological assessment in 1999 (De Groote and Moens 1999). Some of the excavated skeletons were from the previous outside cemetery, which had been built over by a later church phase, while others were originally buried inside the church. Only the thirteen adult individuals deliberately buried inside the church are included in this current research. Based on the surrounding archaeological features and historically known building phases of the church, these individuals date to AD 1655 to 1782 (De Groote and Moens 1999). The Saint-Martin's church (Sint-Martinuskerk in Flemish) is the main church of Aalst, located at the heart of the city. It was the only parish church of the town until 1873 (Robijns 1976), making it the religious center of Aalst and a prestigious place to be buried.

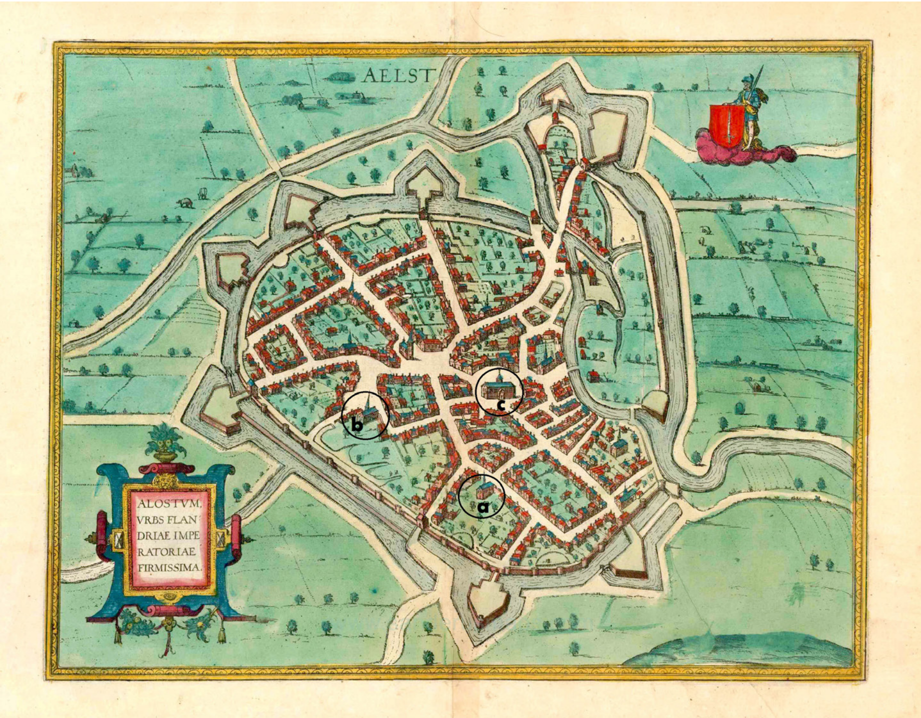


Figure 5: AD 1588 map of Aalst with the three sites circled; a= Louis D'haeseleerstraat convent, b= Hopmarkt monastery, c=Saint Martin's church.

The Carmelite monastery, located under the modern Hopmarkt, was excavated in two phases, in 2004-2005 and in 2011, with a total of approximately 350 individuals excavated. The skeletal remains from the second phase have not been previously analyzed (for a general osteological assessment of the first phase see De Groote *et al.*, 2011, for a dietary isotope study of the first phase see Quintelier *et al.*, 2014). The individuals were predominantly interred in the cloister garth and garden of the monastery. A subsection of individuals from the first excavation phase were originally interred in the monastery church. All skeletal remains are dated between the building of the monastery in AD 1497 and its termination as a result of the French Revolution in AD 1797 (De Groote *et al.*, 2011).

The last skeletal collection from Aalst, from the Louis D'haeseleerstraat, represents a part of the former convent located behind the current Theresian convent (founded in 1836). The area was excavated in 2016 and the human remains are analyzed as part of the current thesis. A convent was first constructed in this location in about AD 1450 by the Franciscan nuns. After destruction by the Geuzen in the 16th century AD, this convent was rebuilt by the sisters of the order of the Annunciation in 1667, who resided there until 1797 when, just as at the Carmelite monastery, the convent was dissolved as a result of the French revolution. The excavated human remains are dated between approximately AD 1450 and 1797.

1.2 Thesis outline

This thesis is organized into seven chapters, followed by a references cited section, the addenda, and appendices. The current chapter (chapter 1) provides a general introduction to EC in bioarchaeology, highlighting the evolution of the field, its challenges, and the existing lacunae in the research. It also provides an overview of the structure of the thesis, as well as detailing which skeletal collections are used and why.

The subsequent five chapters (chapters 2-6) take the form of research articles. Four of these chapters are published or under review in peer-reviewed, scientific journals, while one (chapter 5) is accepted as a chapter in a peer-reviewed, edited scientific book. Chapter 7 will contextualize and combine the findings from these research papers into constructive conclusions for EC research.

The first research paper (chapter 2), combines EC analysis with another marker commonly used for activity research, i.e., osteoarthritis, to analyze labor division in the Dutch post-medieval skeletal population of Middenbeemster. The goal of this study, which forms the first stage of the current thesis, is to evaluate the utility of EC on a well-defined skeletal collection to assess whether any patterns of social differentiation occur in the EC data, and whether EC data correlate with osteoarthritis data. This research was done in 2013, at a time when major transformations were occurring in the field of EC research (see the special issue on EC research of the International Journal of Osteoarchaeology, which was published in March/April 2013). EC data for this article were collected using the Mariotti (2004, 2007) method, which was, at the time, the most suitable method for inter-study comparisons and the most easily applicable system for obtaining EC data. The research shows a low correlation between EC and osteoarthritis, which suggests that, if both are markers of physical activity on the human skeleton, they do not provide a reflection of the same activities. The data do, however, show a potentially gendered division of labor, with males scoring higher in five of the analyzed entheses, and females scoring higher in one entheses, namely the triceps brachii on the proximal ulna. Thus, this study functioned as a critical exploration of EC as an activity marker, demonstrating both that activity reconstruction is not a straightforward process, as evidenced by the low correlation between the two activity markers, and that EC can highlight societal divisions, as evidenced by the differences between males and females.

The second research paper (chapter 3), was necessary as result of the rapid transformations in EC research. Two important developments occurred. The first is that the distinction between two anatomical types of entheses (first distinguished in Vilotte 2006) became important to EC studies, with one type of entheses proving to be more reliable and useful for activity research than the other. Specifically, fibrocartilaginous entheses, in which muscle attaches to the bone via a patch of cartilage, were proven to be more appropriate than fibrous entheses, in which muscle attaches to the bone via muscle and tendon fibers (Vilotte *et al.*, 2016). After 2013 this finding led most studies to exclude fibrous entheses, which prior to these findings formed the largest group of entheses used for study. The second development is that of a new, standardized, and biologically appropriate scoring method, created specifically for these fibrocartilaginous entheses (the Coimbra method). The first prototype of the method was presented as a poster in 2010 (Henderson *et al.*, 2010), with the complete version first published online in 2015 (Henderson *et al.*, 2016).

As these developments presented fundamental changes to how and which entheses could be analyzed, research from the previous years and decades was at risk of becoming obsolete. As such, the second research paper aims to counter this by comparing data gathered using an older EC method to data using the new Coimbra method. The older method used is that created by Mariotti and colleagues (2007). This method is a more structured, updated version of the first method for EC recording which was broadly applied, namely the Hawkey and Merbs (1995) method, and essentially organizes the same traits of EC put forward by the 1995 paper but with more explanation per enthesis and photographic examples. It can therefore safely be implied that research done using the Hawkey and Merbs (1995) method is highly correlated with the Mariotti method. Thus, using the Mariotti method in this new comparison will ultimately allow researchers to compare EC patterns from the majority of previously conducted studies to EC patterns established using the new Coimbra method. The results of this research paper show a high correlation between EC data obtained with the older and new method, with some nuances. The main product of this research paper is therefore that new studies using the most recent Coimbra method can be compared to older studies that used the other common EC methods.

The third research paper (chapter 4) addresses a lacuna in current EC research; entheses in growing individuals. There has, as yet, been no EC research targeted specifically at how EC presents in nonadults. In order to address this issue in a structured, scientific, and reproducible manner, a standardized system for observing nonadult EC is necessary. Therefore, this paper presents all osseous variations observed in a skeletal sample of individuals aged 2-17 years, and structures those observations into a functional scoring method which can be used by future researchers. The archivally identified nonadult sample from Middenbeemster assures that an accurate overview of osseous changes in all ages and both sexes is achieved. The method is developed for 16 nonadult entheses, and incorporates eight traits of EC which are scored as absent or present. The method had minimal intra-observer error and satisfactory inter-observer agreement. Thus, this method can be used to assess EC in future research from any forensic or archaeological context, and will allow scientists to analyze the relationship between nonadult EC, growth, development, activity, and other factors influencing entheses morphology.

The fourth and fifth research papers (chapters 5 and 6) are two phases of one study of a post-medieval population from Aalst (Belgium). They present an assessment of EC as a proxy for social differentiation. First, chapter five provides a detailed context for the three Aalst skeletal collections, with unequivocal historical and osteological data demonstrating that the three skeletal collections contain individuals of different socio-economic status. As noted, the three skeletal collections originate from a male monastery, a female convent, and the main town church. All skeletons were subjected to a full osteobiographical analysis to create a reliable and balanced sample for EC research. Additionally, dietary isotope research was done to evaluate the socio-economic statuses that had been established through historical sources. These stable isotope ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) showed that the individuals in the general cemetery of the female convent had the 'poorest' diet, thus supporting that this was the lower-class burial area. This chapter also provides some extra information on this previously unstudied skeletal collection, by identifying the high-ranking nuns who were buried in a separate area of the cemetery and ate more fish (elevated $\delta^{15}N$ values), and highlighting some unusual pathologies that were found. Thus, this chapter provides a more in-depth context to the osteoarchaeology of Aalst.

Thereafter, chapter six uses the collections described and contextualized in chapter five, with the established socio-economic statuses of the three burial locations, and gages whether EC data are correlated with this social differentiation. Entheseal change is regularly used as an indicator for socio-economic status. The general hypothesis is that richer people would engage in less strenuous physical labor and therefore exhibit lower levels of EC. Indeed, chapter 2 tried to identify low-versus higher class individuals based on EC change at the Dutch Middenbeemster site, but failed to do so. In that case, it is possible that EC showed no evidence of socio-economic groups because there was insufficient social differentiation in the sample. In the current case, however, there is confirmed social differentiation. Thus, the current two-phase chapter provides an exceptional context in which to evaluate whether EC reflect socio-economic status. Sixteen entheses are tested for correlation with socio-economic status, but no clear evidence of social division is apparent. Only two of 16 entheses show any correlation with burial site, and in these cases, it is in fact the higher-class individuals that have higher levels of EC, which would imply that they performed more strenuous physical activity. Thus, this study shows that EC are not a reliable proxy for socio-economic status in this post-medieval Belgian town, and presents a cautionary tale for research into social status and EC.

Following this four-tiered study of EC, through combination with another activity marker (chapter 2), comparison of two recording methods to increase study compatibility (chapter 3), creation of a system for the observation of nonadult entheses (chapter 4), and assessment of EC as an indicator of social differentiation (chapters 4 and 5), chapter seven will combine the results of the research papers and use them to present a balanced appraisal of EC research as it currently stands. This chapter will highlight both the value of EC research for osteology and archaeology and its limitations, as well as offering some future perspectives.

The ultimate goal of this dissertation is to provide the reader with a comprehensive study of the potential and limitations of EC research, using case studies from the post-medieval Low Countries, and with the addition of new previously unexplored research into subadult entheseal changes. In doing so, the current research presents an exceptional glimpse into the lives of people in these past communities. This new understanding of physical activity in the past in turn provides future researchers with a deeper temporal foundation for the study of physical activity in our current-day society. As always, the past is the key to understanding the present, and a doorway to the future.

2

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

International Journal of Osteoarchaeology

DOI: 10.1002/oa.2397

Authors:
J. L. A. Palmer
M. H. L. Hoogland
A. L. Waters-Rist

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.

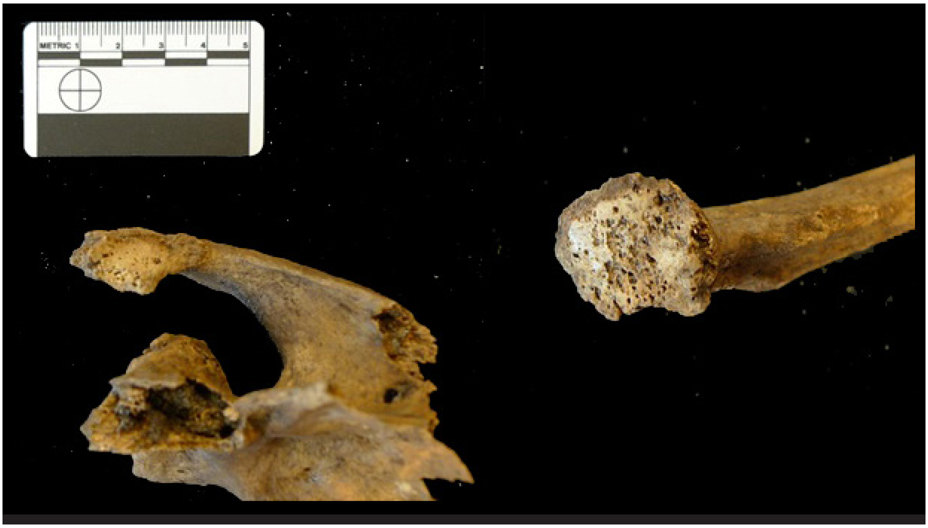


Figure 1. Example of severe acromioclavicular OA. All criteria are present.

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).

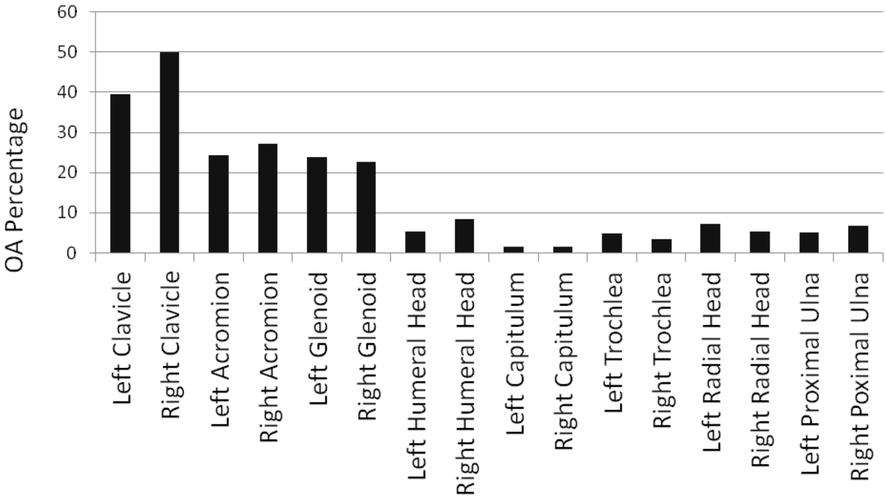


Figure 3. Percentage of specimens with OA per joint surface in the Middenbeemster collection, sexes and ages combined.

		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.

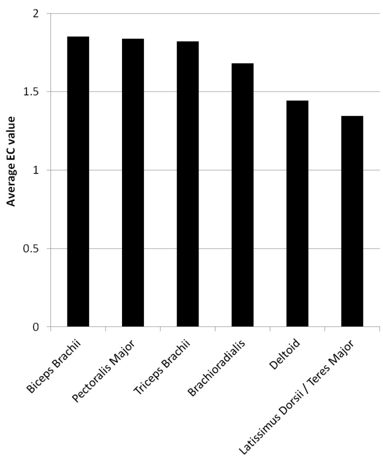


Figure 4. Ranked mean EC scores per muscle attachment site for the Middenbeemster collec-tion, sides sexes and ages combined.

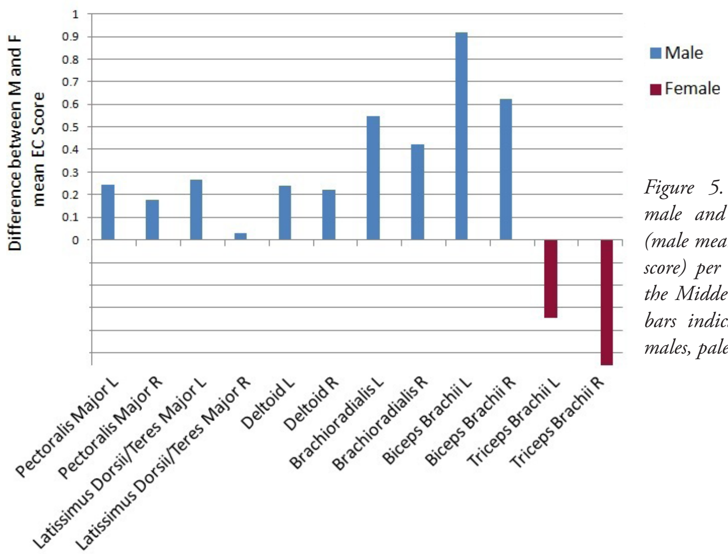


Figure 5. Differences between the male and female mean EC scores (male mean score minus female mean score) per muscle attachment site in the Middenbeemster collection. Dark bars indicate higher mean score in males, pale bars in females.

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).

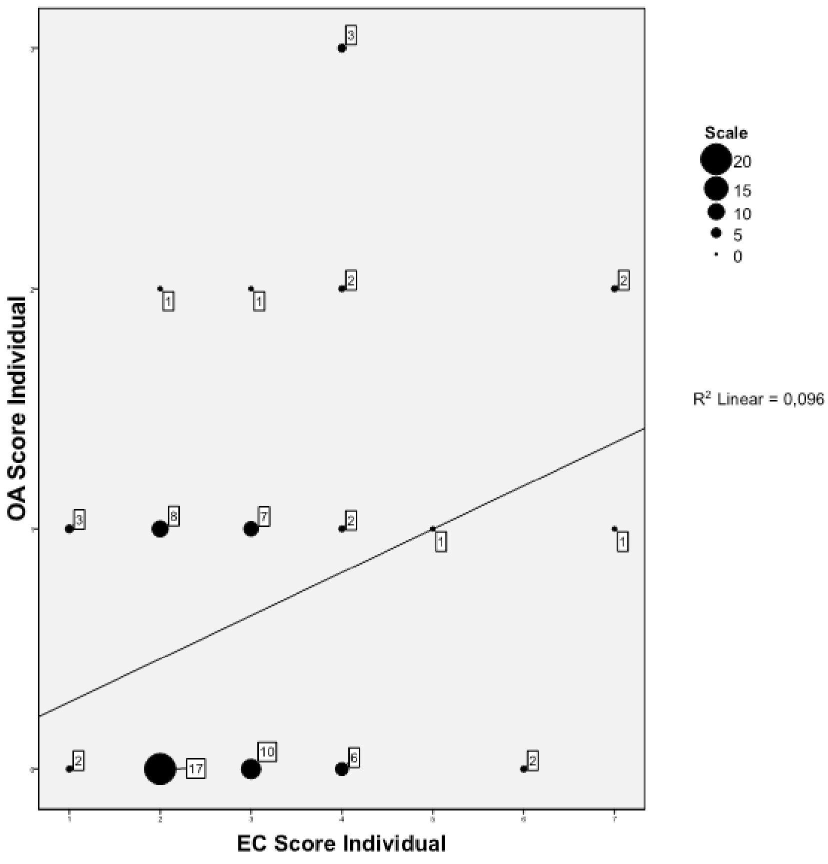


Figure 6. Scatter plot showing all individual EC scores on the x-axis and all individual OA scores on the y-axis for the Middenbeemster collection. The number tag indicates the exact number of individuals (n = 69).

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

The authors would like to thank the volunteers of the Historisch Genootschap Beemster for their help in cleaning the skeletons of the Middenbeemster collection and Prof. Dr. George J. R. Maat for his suggestions on possible activities which would exercise the triceps brachii.

3

A comparison of two methods for recording entheseal change on a post-medieval urban skeletal collection from Aalst (Belgium)

Archaeometry

Published by John Wiley & Sons Ltd.
on behalf of University of Oxford

DOI: 10.1111/arcm.12409

Authors:
J. L. A. Palmer
K. Quintelier
S. Inskip
A. L. Waters-Rist

Abstract

This research compares two current methods for recording bony changes at muscle attachment sites called entheseal changes (EC); the Mariotti *et al.*, (2004, 2007), and the Coimbra method (Henderson *et al.*, 2010, 2013, 2016), to evaluate the concordance and comparability of results in a Post-Medieval skeletal collection from Aalst, Belgium (n=116). For both methods EC scores produce broadly similar patterns, are symmetrical, and differ between age groups. Statistical differences between upper and lower limb and the lower limb of males and females only occur in the Mariotti method. With careful consideration of the influence of different EC score ranges, the results from the two methods can be generally compared.

3.1 Introduction

Research into entheseal changes (EC) has evolved rapidly in the past few years as a means to reconstruct aspects of the activity patterns of past populations (Weiss 2015). Osteoarchaeologists have long noted the development and morphological variation of bony attachment sites of muscles and tendons (e.g. Angel 1945, Wells 1963), however, structured studies of EC only commenced in the eighties (see Dutour (1986) for an early example) and gained momentum with the creation of a broadly applicable scoring method by Hawkey and Merbs (1995). Although several other methods have been created since (see for example Robb 1998 and Wilczak 1998), most studies have used the method suggested by Hawkey and Merbs (1995) (Acosta *et al.*, 2017), or the updated version thereof designed by Mariotti *et al.*, (2004, 2007). Entheses are divided into two types based on direct or indirect bony attachment, namely fibrous and fibrocartilaginous entheses (Weiss 2015). While the methods listed above can be applied to all entheses, recently, the focus of EC research has been on fibrocartilaginous entheses (Jurmain *et al.*, 2012). The main reason being that a normal, 'no entheseal change' baseline for fibrous entheses has not been established (Villotte *et al.*, 2016), whereas it has been ascertained for fibrocartilaginous entheses. This development has improved understanding of the nature of EC's and their usefulness in activity reconstruction. It went hand in hand with the creation of new scoring methods, such as Villotte's (2006) system which incorporates the difference between fibrocartilaginous and fibrous entheses, or the later version focusing exclusively on fibrocartilaginous attachment sites (Villotte *et al.*, 2010). More recently, a group of scientists, including Mariotti and Villotte, united in the Coimbra group, and set out to create a standard scoring method, which, because of the limitations of fibrous entheses mentioned above, focused only on fibrocartilaginous entheses (Henderson *et al.*, 2010, 2013, 2016). Although a more standardized scoring method is certainly desirable to enable inter-study comparison (Henderson 2013), it does not address issues of comparability of previous and future studies using different methods. Given the considerable amount of research already conducted with different methods, and the likelihood that some researchers will continue to use different methods in the future, it is important to establish the extent to which results from different methods can and cannot be compared. Such an assessment must begin by examining the patterning of EC results generated by the different methods as applied to the same skeletons. If the older Mariotti (2004, 2007) method and the new Coimbra method (Henderson *et al.*, 2010, 2013, 2016) can be shown to produce sufficiently similar result patterns, this can allow inter-study comparisons and thereby greatly enlarge the utilizable dataset on entheseal change in different regions, contexts, and time periods.

Therefore, this paper will compare EC results obtained with the Coimbra method (Henderson *et al.*, 2010, 2013, 2016) to those obtained with the Mariotti *et al.*, (2004, 2007) method, to 1) evaluate the concordance of resulting EC patterns, 2) assess implications for inter-study comparison, and 3) point out the practical advantages and limitations of each method.

3.2 Materials and methods

The sample of human skeletons for this methodological study was taken from the post-medieval Belgian Carmelite friary of Aalst, excavated in the current Hopmarkt. This site was excavated in two phases, the first in 2004-2005, and the second in 2011. The collection was chosen for its good preservation, skeletal completeness, and potential for further research. The cemetery population is recorded as containing monks as well as lay people who were buried between 1497 and 1797 AD (De Groote *et al.*, 2011). Both sexes and all age groups are represented. Sex was estimated through traits on the pelvis, cranium, and mandible, following the Workshop for European Archaeologists guideline (Ferembach *et al.*, 1980), the Phenice (1969) pubic traits, and metrics (McCormick *et al.*, 1991, Stewart 1979, and Steyn and Işcan 1999). For this research, only adults were selected, as entheses can develop and change differently in the growing skeleton (Villotte 2006, see also Palmer *et al.*, 2017 for an explorative study). The 116 analyzable individuals were divided into four age categories; early young adult (18-25 years), late young adult (26-35 years), middle adult (36-49 years), and old adult (50+ years) (Table 1). Age was estimated using the morphology of the pubic symphysis (Suchey and Brooks 1990), auricular surface (Buckberry and Chamberlain 2002), and sternal rib end (Işcan *et al.*, 1984), as well as dental attrition (Maat 2001), cranial suture closure (Meindl and Lovejoy 1985), and the fusion state of late fusing epiphyses (i.e. the sternal end of the clavicle, spheno-occipital synchondrosis, iliac crest, and ischial tuberosities) (Schaefer *et al.*, 2009).

			Sex	Total
		Female	**Male**	
Age	Early young adult	8	9	17
	Late young adult	16	26	42
	Middle adult	14	26	40
	Old adult	6	11	17
	Total	44	72	16

Table 1: Age-at-death and sex distribution of the Aalst Hopmarkt sample.

The most consistent result in EC research is the positive correlation between the development of changes at muscle attachment sites and age (e.g Weiss 2007, Molnar *et al.*, 2011, and Michopoulou *et al.*, 2017 on collections with osteologically assessed age-at-death, and Alves Cardoso and Henderson 2010, Henderson *et al.*, 2012, 2017, Milella *et al.*, 2012, and Villotte *et al.*, 2010 on collections with known age-at-death). It is mainly new bone formation being related to ageing (Henderson *et al.*, 2012, 2017). Although old adults have been shown to be less reliable for activity reconstruction (Niinimäki *et al.*, 2013), they are included here to evaluate scoring method result differences. Statistical tests are run both with the entire sample (n=116) and without the old adults (n=99) to evaluate their influence on the sample.

Only the entheses that could be scored with both methods are used in this study. As such, only the fibrocartilaginous entheses (listed by Villotte *et al.*, 2010) which were included in the Mariotti (2004, 2007) method are used, namely the M. triceps brachii and M. brachialis attachments on the ulna, the M. biceps brachii on the radius, the M. iliopsoas on the femur, the M. quadriceps femoris and M. popliteus on the tibia, the M. quadriceps femoris on the patella, and the tendo calcaneus (Achilles tendon, attaches the M. plantaris, M. gastrocnemius and M. soleus to the heel) on the calcaneus. An enthesis is only included if all traits included in both methods (described below) could be scored. The surface area of the enthesis was identified and delineated based on anatomical textbooks (Gray 1977, Paulsen and Walschke 2011) prior to EC scoring. Enthesis delineation can be challenging (more so for fibrous than fibrocartilaginous entheses), and thus a source of inter- and intraobserver error. Furthermore, it can be a cause for deviation between recording results not related to the actual method used. To limit error, all entheses were scored solely by the first author, whose recording process was to delineate the entheses and then score it using both methods, before moving on to the next entheses.

The two methods this study compares use different criteria for observation and recording. The Mariotti (2004, 2007) method uses three criteria for EC, namely robusticity, osteophyte formation, and osteolytic lesions. The method was developed for twenty-three fibrous and fibrocartilaginous entheses, with a specific description and pictures for robusticity scores for each enthesis. These descriptions and pictures were added to incorporate the unique changes seen at each attachment site and to attempt to limit inter-observer error, a main problem in the Hawkey and Merbs (1995) method (Davis *et al.*, 2013). Robusticity is scored between one and three, with score one subdivided into three stages, a, b, and c, whereas the other two markers are scored between zero and three. Per enthesis, three individual scores are obtained. Mariotti *et al.*, (2007) allow researchers to decide how many categories to incorporate for robusticity based on the specifics of the collection under study (e.g. sample size, research question). For the current study, robusticity was scored as one, two, or three, as recommended in the method paper (Mariotti *et al.*, 2007), thus omitting the subdivisions possible for score one as including them would produce a dataset which is mathematically difficult to synthesize.

The Coimbra group method (Henderson *et al.*, 2010, 2013, 2016) will be used it in the way it was presented at the 18th European Meeting of the Paleopathology Association (Henderson *et al.*, 2010). For this method, the fibrocartilaginous entheses are divided into two zones: zone 1 being the edge of the enthesis surface, at an obtuse angle to where the tendon fibers attach (i.e. the rim the furthest away from the direction in which the muscle/tendon pulls) and zone 2 being the rest of the surface (i.e. the majority of the entheseal surface). For zone 1, two traits are evaluated: bone formation and erosion. For zone 2, bone formation, erosion, fine porosity, macro-porosity, and cavitation are analyzed. Thus, per enthesis, seven individual scores are obtained. The final version of the Coimbra method (2016), also includes the factor of textural change for zone 2. As data collection for this research was completed prior to that publication this factor is not incorporated. The largest difference between the Coimbra method and the Mariotti method is that the Coimbra method does not include robusticity as a trait, but includes more possible changes occurring at the enthesis site.

Ten individuals were re-analyzed using both methods two weeks after the original analysis to test for intra-observer variation. In all cases for both methods, the composite score deviation per enthesis was maximally 1 unit of measurement different from the original score. Per method, intra-observer error percentages were calculated for the composite score per individual. The thus obtained percentages from the ten individuals were then combined into an average. The average error percentage for the 10 individuals was 6% difference for the Mariotti method and 4% difference for the Coimbra method. No specific enthesis was more sensitive to intra-observer error.

Neither method, as yet, includes a way to synthesize the data for statistical analysis. More research into the relative importance of the different entheseal changes (i.e. porosity, lytic lesions, new bone formation, etc.) is necessary to provide the data to create an appropriate system of data synthesis, potentially giving different weights to different EC traits. For the purpose of this study, all scores are tallied per enthesis in the same manner for both methods to create a composite score. For the Mariotti (2004, 2007) method this means each entheses obtains a score between 1 and 9, whereas Coimbra method scores can range from 0 to 18. An average score is calculated for the left and right upper limb and lower limb and these results are shown in bar charts. Thus, the Mariotti and Coimbra EC averages cannot be directly compared due to their different scoring parameters but the overall trends and patterns in the results can be compared at a more general level. It must be noted that creating average scores based on ordinal data is, from a purely mathematical perspective, inappropriate. However, for EC scoring, the ordinal data system represents an artificial approach to organizing the underlying continuous spectrum of human variation at entheses. Therefore, reframing this type of ordinal data into averages for analysis is an acceptable way to elucidate patterns (as noted by Robb 1998 based on Weisberg 1992). For some individuals, not all entheses of the upper and lower limb could be scored. Individuals were included when more than half of the entheses under study were present and omitted when less than half were present.

Comparability of the methods is gauged both by assessing how similar are their separate results and by testing their correlation. For each method separately Wilcoxon signed ranked tests are used to assess the difference between left and right side and the upper and lower limb. Similarly, for each method separately, the Kruskal-Wallis test is used to examine if there are significant differences in EC score by age and the Mann-Whitney U test for differences between the sexes. The comparability of the methods can then be gauged by the similarities and differences in statistical significance with the parameters of side (left vs. right), limb (upper vs. lower), age (EYA, LYA, MA, OA) and sex (male vs. female). Next, the results are assessed for correlation between the methods, with a Spearman's rho correlation test, based on the concordance of the two datasets per individual.

All statistical test are performed using IBM SPSS 23 (IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp). Statistical significance is set at $p \leq 0.05$.

3.3 Results

An overview of all statistical test results is provided in table 2. This table provides specific n-values for each test done with each method, the test statistic value, and the p-values.

3.3.1 Left and right side

There is no statistically significant evidence of asymmetry or side dominance in EC scores for either method (Wilcoxon signed rank tests; Mariotti p=0.960, Coimbra p=0.771). This

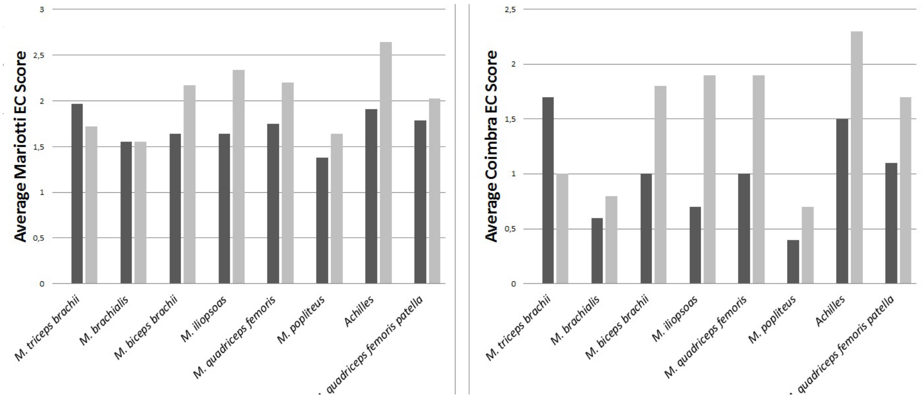


Figure 1: Average EC score per muscle attachment site for left and right side. Left side in dark grey, right side in light grey (n=116).

Variables	*Mariotti method*			*Coimbra method*		
	P value	**factor**	**n**	**P value**	**factor**	**n**
Upper vs Lower limb[a]	**p=0.044**	**Z=-2.010**	97	p=0.878	Z=-0.153	92
Age[b]	**p<0.001**	**χ2(2) = 34.381**	116	**p<0.001**	**χ2(2) = 23.324**	115
Upper Limb Age[b]	**p<0.001**	**χ2(2) = 24.893**	111	**p=0.001**	**χ2(2) =15.441**	107
Lower Limb Age[b]	**p<0.001**	**χ2(2) = 27.881**	102	**p<0.001**	**χ2(2) =18.813**	100
Age without Old Adults[b]	**p<0.001**	**χ2(2) =24.860**		**p<0.001**	**χ2(2) =19.298**	99
Upper Limb Age with-out Old Adults[b]	**p<0.001**	**χ2(2) =16.527**	95	**p=0.009**	**χ2(2) =9.369**	92
Lower Limb Age Without Old Adults[b]	**p<0.001**	**χ2(2) =21.379**	89	**p=0.002**	**χ2(2) =12.975**	88
Sex[c]	**p=0.007**	**U=2099.00**	116	**p=0.100**	**U=1276.5**	115
Upper Limb Sex[c]	p=0.168	U=1235.00	111	**p=0.571**	**U=1265.00**	107
Lower Limb Sex[c]	**p=0.006**	**U=857.00**	102	p=0.075	U=956.00	100
L vs R[a]	p=0.960	Z=-0.050	104	p=0.771	Z=-0.292	109
L Upper vs. R Upper[a]	p=0.397	Z=-0.847	83	p=0.917	Z=-0.104	77
L Lower vs. R Lower[a]	p=0.448	Z=-0.758	84	p=0.991	Z=-0.011	80

	P value	**factor**	
Mariotti vs. Coimbra[d]	**p<0.001**	**ϱ=0.764**	116
Mariotti vs. Coimbra Upper Limb[d]	**p<0.001**	**ϱ=0.651**	111
Mariotti vs. Coimbra Lower Limb[d]	**p<0.001**	**ϱ=0.791**	100

Table 2: All tests run for each method. Statistically significant results indicated in bold. n-value indicated in far right column. Wilcoxon signed rank[a], Kruskal Wallis[b], Mann-Whitney U[c], Spearman's rho[d].

attachment site, the pattern of scores is similar for both methods for the M. triceps brachii and M. brachialis of the upper limb, and the M. iliopsoas and M. quadriceps femoris on the patella in the lower limb, and only slightly different for the other four entheses under study (see figure 1). In the M. popliteus entheses especially, differences in score patterns are

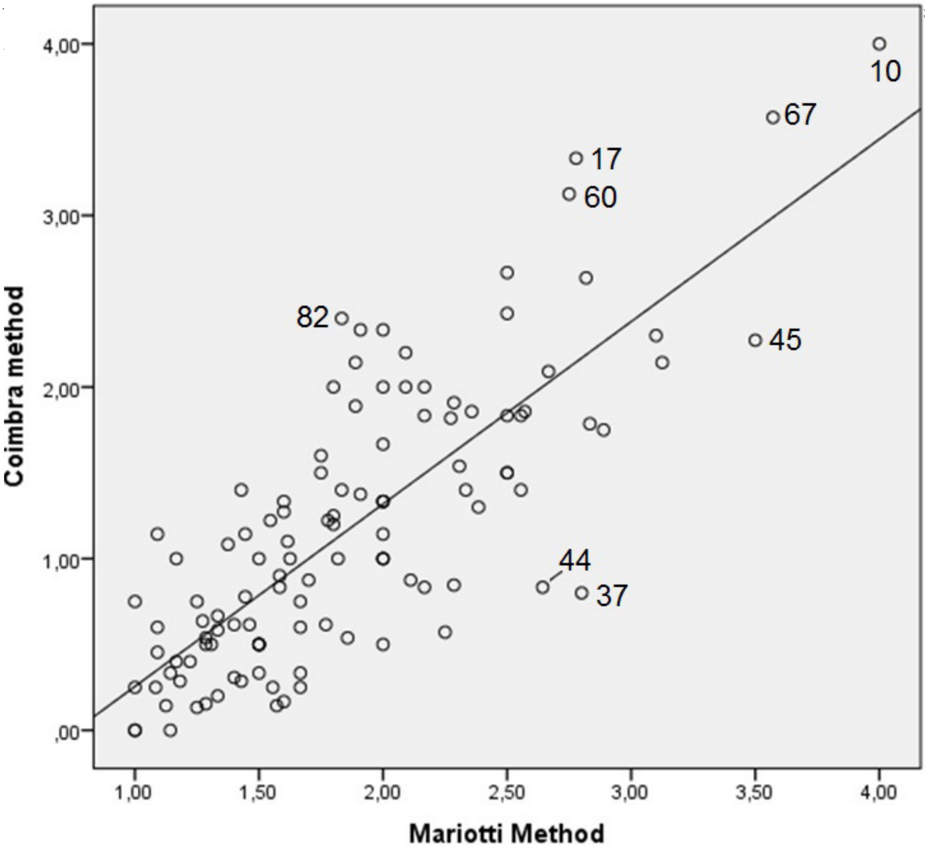


Figure 2: Scatterplot showing the data from both methods with a fit line. Outliers are labelled and discussed in the text (n=116, R^2 Linear = 0.615).

3.3.2 Comparing the methods

A Spearman's rho correlation test shows a statistically significant positive correlation in scores between the methods ($p<0.001$, $\varrho=0.764$) when all entheses are combined, as well as for the upper and lower limb individually (upper limb $p<0.001$, $\varrho=0.651$, lower limb $p<0.001$, $\varrho=0.791$). A scatterplot of all scored individuals shows that while results do cluster around the fit line, there is still a noteworthy amount of diversion (figure 4). The most diverging individuals have been labelled in the figure. Individuals 17 (an old adult male), 60 (also an old adult male), and 82 (a late young adult female) score notably higher in the Coimbra then Mariotti method. Individuals 45 (an old adult female), 37 (a late young adult male), and 44 (an old adult female) score higher in the Mariotti Method compared to the Coimbra method. Individuals 67 and 10 are both old adult males, and score high in both methods, if more so in the Coimbra method.

3.3.3 Upper and lower limb

Wilcoxon signed rank tests show a significant difference in EC scores between the upper and lower limbs in the Mariotti method (p=0.044), with a mean EC score for the upper limb of 1.81 and for the lower limb of 1.95. For the Coimbra method, there is no significant difference between upper and lower limb (p=0.878), with the mean EC score for the upper limb being 1.18 and 1.16 for the lower limb.

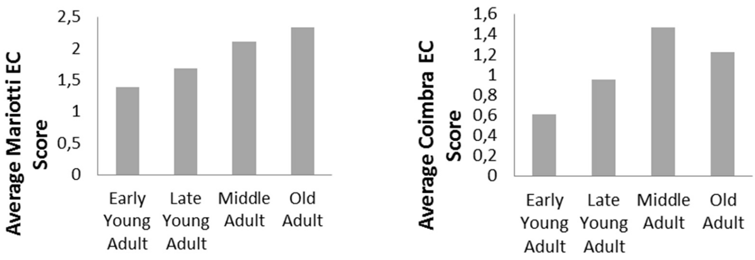


Figure 3: Average EC score per age category for upper and lower limb combined (n=116).

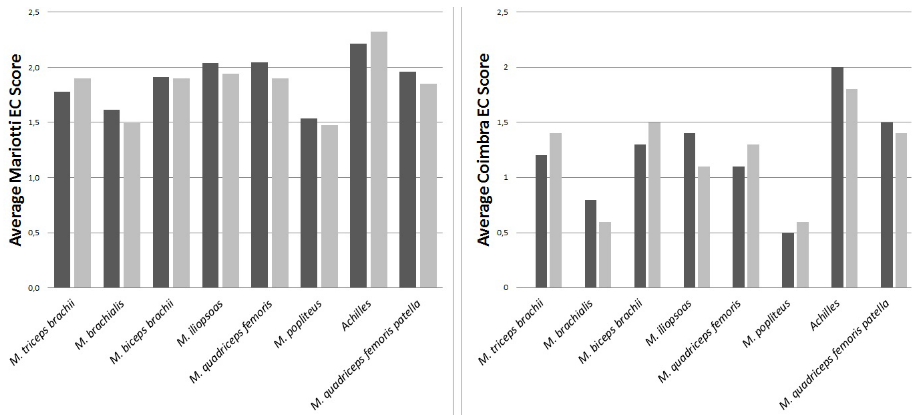


Figure 4: Average EC score per muscle attachment site for males and females. Females in dark grey, males in pale grey (n=116). Left and right side data pooled.

3.3.4 Age

Both methods show a significant difference in EC scores between age groups using the Kruskal-Wallis tests (Mariotti method: p<0.001, Coimbra method p<0.001) for all EC combined as well as for the upper and lower limb separately (Mariotti: Upper limb p<0.0001, lower limb p<0.0001, Coimbra: Upper limb p=0.001, lower limb p<0.001) (for test statistics see table 2) (see also Figure 3).

3.3.5 Sex

According to a Mann-Whitney U test, when all EC scores are combined, the Mariotti method shows a significant difference between the EC scores of the sexes (p=0.007), whereas this significant difference is absent in the Coimbra method (p=0.100). When the upper and lower limb EC scores from the Mariotti method are analyzed separately, the upper limb shows no statistically significant difference between the sexes (p=0.168) whereas the lower limb does (p=0.006). In the lower limb, the male EC scores are consistently higher than the female EC scores, whereas in the upper limb, males score higher for the M. biceps brachii attachments, but females score higher for the M. triceps brachii. For the Coimbra data, neither upper nor lower limb show a statistically significant difference between the sexes at the 0.05 level (upper p=0.571, lower limb p=0.075). However, when the muscle attachment score averages are regarded per muscle, even though statistical significance is not reached, the pattern is similar to that of the Mariotti method: greater lower limb scores for males, and in the upper limb higher male scores for the M. brachialis and M. biceps brachii attachments, but higher female scores for the M. triceps brachii (see figure 3).

3.4 Discussion

This paper aimed to assess whether the Coimbra method and the Mariotti method produce sufficiently similar results to permit the comparison of past (and possible future) research that used the different methods. Therefore, the concordance of results was analyzed, and the implications for inter-study comparisons are now appraised along with consideration of the practical advantages and limitations of each method, together with some additional findings.

3.4.1 Concordance of results between methods

Given that both methods, for a large part, rely on the same traits (i.e. bone formation and lytic activity) as evidence of EC, it could be expected that they would deliver similar results. At a general level this is shown to be true; the methods give broadly concurring patterns of results as seen in figures 2 and 3. However, relative sex differences appear larger when using the Coimbra method (figure 2). The explanation for this is purely methodological: in the Mariotti method all individuals have a minimum score of one, whereas in the Coimbra method a score of zero is possible, making differences between individuals with little or no EC and individuals with EC seem larger. As well, in figure 3 the relative left-right differences are different between methods, although there is no clear explanation for this. There is a positive correlation between the methods, and this correlation reaches very high statistical significance, yet when all data are pooled in a scatterplot, the underlying variation within this overall picture of similarity between methods is illustrated (figure 4). No single explanation emerges to explain the outliers in this graph, and no single entheses, group of entheses, or trait can be singled out as creating intermethod inconsistency. It is noteworthy that four of the individuals diverging the farthest from the fit line are old adults, and that of these four old adults the higher Coimbra scores are males where the higher Mariotti scores are female. Future research into which entheseal change traits are more common in which sex and age group can perhaps explain this. It is unsurprising that the highest scoring individuals are both old adults given the correlation between age and EC (discussed above).

Both methods demonstrate no statistical difference between left and right and significant differences in EC among age groups. However, only the Mariotti data demonstrate a significant difference between the upper and lower limb, a difference in part driven by a statistically significant difference in EC between the lower limbs of males and females. Thus, there is perhaps more difference between the methods' results than expected. Some of these differences could lead researchers to different conclusions. For example, if the ECs were scored using the Mariotti method one would conclude there was a significant difference between the lower limb ECs, and hence activity patterns, of males and females, whereas one would likely conclude no such difference existed if the data were generated using the Coimbra method. In the former scenario it might have been concluded that males were more mobile than females; in the latter scenario that they were not.

As with most archaeological studies, it must be borne in mind that limited sample size will impact the statistical results (see Henderson and Nikita 2016 for a discussion of the effect of sample size on EC), however, as sample sizes are highly similar for both methods (table 2) it can be assumed, at least for concordance between methods, that the impact of sample size was limited.

3.4.2 Implications for inter-study comparison

Comparison between studies and populations is key to achieving a better understanding of how changes in morphology of muscle attachment should be interpreted. As both the Mariotti *et al.*, (2007) method and Coimbra method (Henderson *et al.*, 2010, 2013, 2016) aim to register the changes at muscle attachment sites to analyze physical activity, the differences between results obtained via the two methods are an important finding, further highlighting the complexity of entheseal change research. Michopoulou *et al.*, (2017) tested the correlation between the Coimbra method and bone cross-sectional geometry, an activity marker with proven reliability. They found that EC can at least be partially caused by activity when observed via the Coimbra method. In an earlier study (Michopoulou *et al.*, 2015) they conducted the same test upon the Mariotti (2004) method and found no correlations between activity as construed via cross-sectional geometry and EC as observed via osteolytic and osteophytic lesions. However, as that study did not use the Mariotti *et al.*, (2007) method, nor incorporated robusticity as described in Mariotti *et al.*, (2007), these results do not offer any conclusive outcomes for our current study. For pre-industrial populations, we are forced to rely mainly on archaeological materials to answer questions about if and to what extent ECs are related to activity. Further testing of both methods on skeletal collections of known activity can elucidate their respective validity, however given the complicated nature of activity throughout a person's life, which is much wider than one's registered occupation, this still holds limitations.

The results from this research suggest that general usage of studies conducted with these two different EC recording methods is suitable only when comparing the same muscle attachment sites, and, bearing in mind the intrinsic properties of each method as these may sometimes lead to different statistical outcomes. The largest differences are seen in the lower limb, where sex differences are statistically significant in the Mariotti but not the Coimbra method, a difference which is also reflected in the statistically significant difference between the upper and lower limb in the Mariotti but not the Coimbra method. Researchers must remain aware of the larger range of scores possible in the Coimbra method, which can make intra-and inter-individual differences appear larger than in the Mariotti method simply as a result of the scoring system. Yet, the number of similarities in results between methods outweighs the number of differences and we argue that when the discernment of broad patterns is the goal of using studies that employed the different methods this can be acceptably achieved with careful consideration of the results and the aforementioned factors.

3.4.3 Advantages and limitations of each method

For fibrocartilaginous entheses, the Coimbra method, which uses seven traits per EC, is the most detailed, giving a very accurate overview of the osseous changes occurring at an entheses (except for changes in robusticity). Although there has been anatomical research which has improved our understanding of EC, we are still not yet fully knowledgeable about the relationship between a muscle and its bony attachment site. Therefore, this level of detail in recording is desirable, to allow for in-depth analysis of the occurring osseous changes. Due to the more complex nature of this method, it ideally requires training by someone proficient in the field to learn to distinguish between the two zones and the different traits. For fibrous entheses, which cannot be analyzed in the Coimbra method, the Mariotti method can be retained. The issue remains, however, that we do not yet have a normal, 'no entheseal change' baseline for fibrous entheses (Villotte *et al.*, 2016). The Mariotti (2004, 2007) method does not provide a solution to this, so as of now it is a factor to be kept in mind. However, as fibrous attachment sites change in a less complex manner (i.e. not as prone to porosity, no two distinguishable physiological zones) the Mariotti method, with its three scored traits, robusticity, osteolytic lesions, and osteophyte formation, is also intrinsically well-suited to the analysis of fibrous entheses. Given its more limited terminology, relative simplicity, detailed descriptions and pictures per enthesis, it can be learned more rapidly and auto-didactically, if a sufficiently large reference collection with variation in entheseal changes is available for training. A recent study by Milella *et al.*, (2015) used only the factor of robusticity to analyze activity, with considerable success. However, recording bone formation and bone resorption, two major types of bony change used in all areas of osteoarchaeology, adds extra information which any well-trained osteologist is capable of observing correctly. Therefore it can be suggested that these two other traits scored in the Mariotti (2004, 2007) method should be reserved for more general studies of EC. Based on all the above, it can be suggested that the best course of action is to implement the Coimbra method for fibrocartilaginous entheses while reserving the Mariotti method for fibrous entheses.

3.4.4 Further findings

In both methods, it is noteworthy that the visualization (figure 2) of the male and female M. triceps brachii, M. brachialis, and M. biceps brachii shows a sex difference which is obscured when the three muscle scores are grouped. The M. triceps brachii score is higher in females and the other two entheses score higher in males. This highlights the necessity of observing not only muscle groups, but also each muscle separately.

With the factor osteophyte formation, researchers must take into account that some entheses, such as the Achilles on the calcaneus, the M. quadriceps femoris on the patella, and the M. triceps brachii on the ulna, are potentially more prone to new bone formation than other entheses. This has been noted by Villotte (2006), who grouped these three entheses as 'group 2' in his scoring method, identifying them as entheses that show enthesophyte formation at their edges frequently, and osteolytic lesions infrequently and very rarely in combination with osteophyte formation. Figure 4 shows how average EC scores for the Achilles on the calcaneus and the M. quadriceps femoris on the patella are relatively higher than for other entheses, but this must not be interpreted solely as evidence of more extensive use of these muscles. Physiological factors such as the existent bursae, location on the bone, and the angle of pull will influence EC scores regardless of the method used. Further research is necessary to evaluate the extent of differences, establish if and how this can be corrected for, and how to incorporate this when interpreting data. Both the sex differences in EC scores and bone formation differences between different entheses indicate that comparison between studies is only possible when the same muscle attachment sites are analyzed.

3.5 Conclusion

In the current study, while some differences in EC results exist, the Mariotti and Coimbra EC recording methods show broadly similar enough results to allow for comparison of general EC patterns between studies on the same entheseal sites using the different methods, but only when the intrinsic differences in score range, and hence possible differences in statistical significance, are taken into account. We argue that with careful consideration a trend seen in a given sample using one method can be used to discuss trends seen in another sample using the other method. Although more studies on different populations are necessary to bolster these findings, these results are very promising, as inter-method comparability would facilitate continuity within EC research. The general comparability shown by the current study serves as an extra boost to the positive impulse generated by the new Coimbra method for the field of EC research. EC research has already delivered tantalizing results (see for example Eshed *et al.*, 2004, Havelkovà *et al.*, 2013, Lieverse *et al.*, 2009, and Palmer *et al.*, 2014), making it an important field for future osteoarchaeological research. However, given the remaining lacunae in our knowledge, fundamental research and larger datasets are necessary before solid conclusions about past activities can be made from EC. By striving towards a standardized system of observation and scoring, larger comparisons which can allow solid activity-related patterns to emerge become possible. Future research should develop a standardized method to synthesize the EC data for statistical analyses, with an ideal analytical tool being one that limits or removes the effect of the score range thereby permitting a more valid comparison of results generated from different methods.

Acknowledgements

The authors would like to thank Wouter De Maeyer and Stijn Van Cauwenbergh at Solva archaeology for granting permission to use this skeletal collection, and the anonymous reviewers for their valuable feedback.

4

A recording method for sixteen nonadult muscle entheses

HOMO Journal of Comparative Human Biology

Under review

Authors:
J. L. A. Palmer
A. R. Lieverse
M. L. P. Hoogland
A. L. Waters-Rist

Abstract

Bioarchaeology lacks a system for recording the morphology of muscle and ligament attachment sites, called entheses, in growing individuals. Therefore, a new method is necessary to analyze this in nonadult individuals. Such information could eventually be useful in investigating factors that affect bone growth and development, including sex, age, puberty, pathology, and activity. To begin the creation of such a recording system this pilot study on 29 individuals of known age and sex (a) assesses the range of osseous changes of 16 entheses in the upper and lower limbs of growing individuals, and (b) presents a scoring method based on these findings that can be used by other researchers. The pilot results show no unidirectional relation between entheseal change (EC) and age, nor a clear relationship with sex. Ultimately, this method will allow researchers to evaluate if and how EC correlates with growth and development and factors that may affect those processes in nonadult remains from any archaeological or forensic context.

4.1 Introduction

Children provide a unique window into past cultures and societies. The way a society treats those who are, to a certain extent, dependent upon help, offers invaluable insights into the workings of humanity in a certain era and area. Bioarcheology can add unique data to our understanding of the life of growing individuals by analyzing the lesions and anatomical variations occurring in their skeleton. Currently, bioarchaeological research into individuals who have not yet reached skeletal maturity is often limited to the estimation of age-at-death, growth patterns, diet, and the assessment of pathology. The reasons for this are largely methodological. As the growing, developing skeleton has distinct physiological properties, many osteological methods, developed on adult human remains, cannot be applied (Ruff *et al.*, 2013). Additionally, osseous changes which take a long time to develop, or that emerge because of puberty, will not commonly occur in younger individuals. Furthermore, there has been a persistent misconception in osteoarchaeology that nonadult (<18 years) skeletal material is always more susceptible to taphonomic damage and less likely to preserve than adult material (e.g. Gordon and Buikstra 1981, Walker *et al* 1988). While this is true in some cases and soil conditions, in many cases it is not a problem. In past osteoarchaeology research this perception has led to an underrepresentation of studies of nonadults.

In the last two decades, there has been a major impetus in the study of nonadult remains, supported by the creation of well-structured manuals and books (i.e., Baker *et al.*, 2005; Scheuer and Black 2000; Schaefer *et al.*, 2009, Lewis 2017). Methods for estimating age-at-death (e.g., Primeau *et al.*, 2016) and sex (e.g., Stull *et al.*, 2017) of nonadults are being actively refined. In addition, aspects of childhood pathology and diet are becoming increasingly well-understood (e.g., Novak *et al.*, 2017, Stark 2014, Reitsema *et al.*, 2016, Tsutaja *et al.*, 2015). Less has been done in regard to investigating patterns of nonadult activity, in contrast to the vast amount of research on adult activity patterns (e.g., Hawkey and Merbs 1995, Henderson *et al.*, 2016, Eshed *et al.*, 2004, Milella *et al.*, 2015). Such knowledge will be important to gain for an improved understanding of factors related to nonadult growth but also of the development of entheseal changes (EC) in adults.

The current research aims to add to our growing osteological understanding of the lives of nonadults by analyzing and creating a method to assess variation in entheses within growing individuals. This is done using 29 known age and sex nonadult remains from a Dutch post-medieval cemetery, ranging in age from two to 17 years, free from macroscopic signs of skeletal pathology or abnormality. Assessment of intra- and inter-observer consistency in scoring is conducted. These results are critical in demonstrating this method that can be adopted by untrained osteoarchaeology researchers working on skeletal material from any spatiotemporal context. The EC results will also be assessed for correlation with age and sex. Our primary aim is to provide a standardized recording system which can be used by osteoarchaeologists to study how nonadult EC relates to growth and development, which in turn may be affected by variables such as sex, age, puberty, pathology, and physical activity. Until a standardized method for recording nonadult EC is established for osteoarchaeology we are missing out on a potentially valuable data source that could improve our understanding of biological and sociocultural variation during nonadulthood.

This article is structured to follow the method creation process as it occurred. This is done to allow readers to assess all decisions made in the method creation process and provide maximum transparency on the steps that led to the final proposed method.

4.2 Materials

The method is developed on the skeletal collection from the post-Medieval village of Middenbeemster, curated at the Human Osteology Laboratory of Leiden University. The collection is chosen for its good preservation, well understood historical (Falger *et al.*, 2012) and osteoarchaeological context (Griffioen *et al.*, 2012, Waters-Rist and Hoogland 2013, Lemmers *et al.*, 2013, Veselka *et al.*, 2015, Palmer *et al.*, 2016, Ziesemer *et al.*, 2015, Caroll *et al.*, 2016, Vikatou *et al.*, 2017), and the availability of individuals of known sex and age-at-death. Nonadults aged two to 17 years are used. Individuals younger than two years are omitted as the visible ECs are too subtle to be included in the same method. Individuals over 17 years are omitted because, even though full skeletal maturity is not yet reached, patterns of EC in these individuals better fit within existing adult methods (e.g. Hawkey and Merbs 1995, Henderson *et al.*, 2016, Mariotti *et al.*, 2004, Vilotte 2006). A total of 29 archivally identified individuals from the established age bracket, of sufficient completeness and good to excellent preservation, were available for analysis to assess the spectrum of EC (table1). This sample consists of seventeen girls and eleven boys.

	Archival age in years													
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**16**	**n**
Sex?			1											1
Female	1		4	1	1	1	2	3	1	1	1	1		17
Male		2	2	3	1		1					1	1	11
Total														29

Table 1: Individuals used for method creation, with their age and sex (n=29). For one 4-year old individual, sex is unknown.

4.3 Anatomy

An enthesis is a complex anatomical area where two different plastic and mobile tissues are made to connect to each other (Benjamin *et al.*, 2006). This junction poses inherent challenges to the body, which are further increased by force loading and force concentration (Benjamin *et al.*, 2006). The body accommodates these connections by creating a discrete site of attachment with a specific topography (Thomopoulos *et al.*, 2013), in the shape of tuberosities, processes, spines, ridges, crests, lines, fossæ, pits, depressions, grooves, furrows, fissures, or notches (Gray and Lewis 1918). Development of the entheses starts in utero in the embryonic stage (Zelzer *et al.*, 2014) and is completed when skeletal maturity is reached. Once an individual is fully grown, the entheses remains a plastic and changeable area, which can then be analyzed with the abovementioned adult methods.

Prior to skeletal maturation, bone and soft tissue interact in a specific fashion to allow for growth. Long bones in human nonadults, as well in the animals from which many bone growth models are created, increase in size and length primarily at the epiphyseal growth plates. Muscle and ligament attachment sites get dragged along this growing bone by the periosteum (Matyas *et al.*, 1990), thus ensuring that the attachment always stays at the same relative location, rather than being 'left behind' (Dörfl 1980a, b). The growing body maintains a fine balance of growth to allow for this precise maintenance of the relative location of tendon and ligament insertions (Stern *et al.*, 2015). The mechanical pull of muscles does not influence this isometric scaling system (Dörfl 1980b). This implies that, except in cases of premature closure of either the distal or proximal growth plate, or other developmental issues, nonadult muscles attach at the same locations on growing bone as they do in an adult skeleton (e.g., M. pectoralis major will always attach on the antero-lateral upper 1/3 of the humeral diaphysis).

Thus, although the location of an entheses is possible to find using adult anatomy handbooks, the actual appearance and variation visible at the entheseal site differs significantly between adults and nonadults. Both the underlying developmental process outlined above and the macroscopically visible enthesis on dry bone support this. Several osteoarchaeological researchers have observed how muscle and ligament attachments present differently in growing individuals; Castex (1980) noticed a high frequency of individuals aged 11-18 with attachments for the M. Pectoralis Major and M. Teres Major presenting in the shape of a fossa, as well as a higher frequency of hypotrochanteric fossa and rhomboid fossa in growing individuals from 5th to 6th Century AD Chalon-sur-Saône in France. These fossae have been interpreted as a result of an active phase of growth (Saunders 1978), and, in the case of the hypotrochanteric fossa and rhomboid fossa, recorded as non-metric traits when they are retained in adulthood (Finnegan 1978). Nonadults also frequently presented with fossae at entheseal sites in studies by Stirland (1996) and Mariotti and colleagues (2004). Villotte and Knüsel (2013: 141) stated that these fossae are "very common in immature human skeletons, in frequency but also in their distribution in the body". The current method aims to allow standardized observation of a selection of attachment sites for ligaments, fibrous muscle attachments, and fibrocartilaginous muscle attachment sites (see section 4.1), to further explore this attested phenomenon and to begin documenting the pattern of entheseal development at attachment sites.

4.4 Method creation

The initial development of this method occurred in four phases; selection of suitable entheses, observational analysis of entheses, draft method creation, and revised method creation. These phases are outlined in this section. The thus created method was then tested (section 6), and the results of these tests (section 7) were used to create the final method version (section 8).

4.4.1 Entheseal selection

Entheses were selected that would be most suited to analysis of their potential changes, based on the ability to distinguish and delineate them macroscopically on nonadult remains in the 2-17 year age range. Fibrous entheses predominately fulfilled these criteria, as fibrocartilaginous entheses are commonly close to the epiphyses of the bone and therefore obscured and complicated by the presence of the growth plates in a developing individual. This led to the selection of sixteen muscle and ligament attachment sites on seven bones (table 2).

Bone	Muscle/ligament	Tissue type at site of attachment
Scapula	Long head of M. triceps brachii	Fibrocartilaginous muscle attachment
Clavicle	Costoclavicular Conoid Trapezoid	Ligament attachment Ligament attachment Ligament attachment
Humerus	M. pectoralis major M. latissimus dorsii/M. teres major M. deltoideus	Fibrous muscle attachment site Fibrous muscle attachment site Fibrous muscle attachment site
Radius	M. pronator teres	Fibrous muscle attachment site
Ulna	M. pronator quadratus M. brachialis	Fibrous muscle attachment site Fibrocartilaginous muscle attachment
Femur	M. gluteus maximus M. vastus medialis M. pectineus M. gastrocnemius medial head M. gastrocnemius lateral head	Fibrous muscle attachment site Fibrous muscle attachment site Fibrous muscle attachment site Fibrocartilaginous muscle attachment Fibrocartilaginous muscle attachment
Tibia	M. soleus	Fibrocartilaginous muscle attachment

Table 2: overview of the ligament and muscle entheses used, the bone they are located on and their anatomical attachment type.

4.4.2 Observation

The selected entheses were described in detail in ten individuals to assess which osseous changes can occur at each enthesis and distill the range of possible traits at nonadult entheses. Then, the observable traits per enthesis from all ten individuals were compiled into a list to form a reflection of the spectrum of EC. Room was left for expansion of this list if dictated by the subsequent stages.

4.4.3 Draft method creation

From this list of possible EC, an ordinal scoring scale was created for each enthesis. The reasoning behind this was that, because each muscle has its own distinctive size and shape, each enthesis can change in its own unique manner due to intrinsic factors such as its size and location on the skeleton, the angle of the bone, the angle of the muscle, and whether it is an origin or insertion site. Thus, separate descriptions were deemed necessary per enthesis incorporated in this method. A graded score was created for each enthesis, ranging from stage zero, meaning no observable EC, to stage three, which describes maximal EC. The first version of this nonadult EC scoring method ascribes a stage zero to entheses where the attachment site either cannot be delineated, or where delineation is just possible, depending on the enthesis under study (see appendix B1).

When testing this first version of the scoring method, it became clear that it often caused the observer to be torn between two possible scores (e.g. score 1 or 2, or score 2 or 3), thus allowing for a lot of potential intra- and interobserver error (Palmer *et al.*, 2017). Scoring in this manner also does not allow researchers to record and assess the specific osseous characteristics of each enthesis. It was therefore decided to deconstruct the method back to the list of potential osseous characteristics. From this list, a scoring form was created allowing the researcher to score, per observed enthesis in an individual, all the occurring osseous traits. Thus, seven characteristics were retained: enthesis delineation, porosity, surface irregularity/rugosity, ridges, depression/sulcus, presence of a distinct tubercle, and enthesophytes (defined below).

4.4.4 Revised method creation

For the next step of the method creation process, for the seven retained characteristics, score categories were created. Some osseous characteristics were simply scored as present (score of 1) or absent (score of 0). Other characteristics were scored in tripartite, ranging between no expression of the trait (score 0), medium expression of the trait (score 1), to maximal expression of the trait (score 2). Distinct thresholds were described for each score category to ensure maximal reproducibility by other scholars and to decrease intra-observer error. Section five defines the seven entheseal osseous characteristics, with section 5.8 explaining how their range of variability was categorized in scores zero to two. The method was then tested in this form to evaluate which ECs occur per specific enthesis, and to explore the presence of correlations with age and sex presented itself (section 7). Following the intra-and inter-observer agreement testing (section 8), the method was re-revised to improve utility and repeatability and presented it in its final form (section 9).

4.5 Terminology and scoring of traits

This section will first define the traits as they are used throughout this paper and in all stages of method creation. Section 5.8 will then present the scoring system as it was used for testing of trait expression and inter-and intra-observer agreement.

4.5.1 Entheseal delineation

Entheseal delineation is defined as whether an entheses that can be delineated, by visual identification, bone contour, palpation, or any of the traits below. Note: if entheseal delineation is not possible, all other traits score zero by default.

4.5.2 Porosity

Porosity indicates that the cortical bone surface appears permeable rather than solid and compact. In adult bone, a distinction is usually made between macro- and microporosity when evaluating this trait (e.g. Buckberry and Chamberlain (2002) for auricular surface age estimation, Henderson *et al.*, 2016 for EC). For nonadult bone, which is consistently more porous than adult bone, this distinction is not useful. Therefore, porosity is identified as any texture change that causes the entheseal area to appear porous, be it as a small patch of pinprick holes, diffuse holes, or larger pores.

4.5.3 Surface irregularity/rugosity

Any rough bone formation visible or palpable on the entheseal surface that does not present distinct enthesophytes, ridges, or tubercles (see below).

4.5.4 Ridges

This is the formation of a longitudinal line of elevated bone, creating a distinct ridge. The ridge can present a sharp or rugose ‘peak’, or a blunt/rounded elevated line.

4.5.5 Depression/sulcus

This is any indentation or cavity in the entheseal area, of any shape, which causes the enthesis (or a portion of it) to present a lower plane than the surrounding bone.

4.5.6 Presence of a distinct tubercle

This is any observable distinct tubercle, independent of size but larger than an enthesophyte (i.e. ca. >2mm). The surface of the tubercle can be scored for the other characteristics.

4.5.7 Enthesophytes

Any new bone formation that is a distinct nodule, spur, or bony projection <2mm.

4.5.8 Scoring classification

Table 3 represents the scoring classification as it was implemented for inter-and intra-observer agreement testing, prior to the final method creation.

Entheseal delineation	0 = entheses cannot be delineated 1 = entheses can be delineated
Porosity	0 = porosity covers less than half of the surface 1 = covers more than half of the delineated entheses
Surface irregularity/rugosity	0 = absent 1 = covers less than half of the delineated entheses 2 = covers more than half of the entheses
Ridges	0 = absent 1 = ridge presents a blunt/rounded elevated line 2 = ridge presents a sharp or rugose 'peak'
Depression/Sulcus	0 = absent 1 = edges of the depression are rounded and smooth 2 = edges of the depression/sulcus are sharp
Tubercle	0 = absent 1 = present
Enthesophytes	0 = absent 1 = only 1 enthesophyte observed 2 = 2+ enthesophytes observed

Table 3: initial scoring classification

Note that porosity was scored for EC only if it is not inherent to the anatomical area. For some entheses, the attachment site is always porous, due to the intrinsic properties of the bone. Of the sixteen entheses included in the method, only the lateral and medial heads of the gastrocnemius are always porous. Therefore, for these two entheses, porosity was not included in the scored traits for method testing.

4.6 Method testing

As a first test of the method, the scorable EC traits were structured into a recording form and the method tested on the 29 individuals of known age and sex by the first author. When scoring was impossible due to missing elements or taphonomic damage, a dash was put on the form. All observations were done near a window using natural light, without magnification. This testing of the method was done to evaluate the expression of the defined traits in the individual entheses and to explore how the EC interacted with the archival age and sex data.

As a second test of the method, the data were re-analyzed by the same observer for intra-observer agreement assessment, and by two other researchers to assess inter-observer agreement. The researchers also provided feedback on their experience with the method prototype. These tests of the method were done to assess and improve method usability and repeatability. Only after these tests was the final method created (section 9).

4.7 Results

4.7.1 Trait expression per enthesis

To assess EC trait expression, left and right entheses were scored for all individuals. Thus, a maximum of 58 entheses could be scored per specific muscle attachment site, given our sample collection of 29 individuals. The number of individuals and entheses observed varies due to completeness and preservation, so "all individuals" in the entheses subsections refers to all individuals for whom the left, right, or both entheses could be observed. Exact numbers of observable entheses are given per subsection. For full detailed data, see appendix B2.

The long head of the M. Triceps Brachii could always be delineated (n=19) with a total of 36 observable entheses. The enthesis was delineated based on the contour of the bone and its distinct location on the lateral edge of the scapular blade just below the glenoid. Porosity is common (53%), as is surface irregularity (69%). Tubercle formation (8%), depression (6%), and ridge formation (6%) were rarer.

The costoclavicular ligament attachment on the clavicle could be delineated in all but one individual, with a total of 39 scorable entheses (n=22). Porosity was present in 64% of the 39 observed entheses, surface irregularity in 44% and ridge formation in 18%. Depressions are relatively common (51%), often with sharp edges (31% of cases of depression). Tubercle formation was observed in one instance in a 5-year old boy (2.6%). Enthesophyte formation and surface flattening were not observed.

The conoid could always be delineated (n=19) with a total of 33 analyzable entheses. Thirty percent of entheses showed porosity. Surface irregularity is very common (79%) and tubercle formation is relatively common (27%). Ridge formation (6%), surface flattening (3%) and depressions (9%) were much less common.

The trapezoid could always be delineated (n=20) with a total of 36 analyzable entheses. Porosity is present in one third (33%) of observed entheses. Surface irregularity was observed in 44% of cases, and ridge formation in 14%. Depression is common (72%), usually in combination with porosity and/or surface irregularity. No enthesophyte formation or surface flattening was observed.

The M. Pectoralis Major could always be delineated (n=22), with a total of 42 analyzable entheses. Fifty-seven percent of entheses showed porosity. Surface irregularity (57%)

and ridge formation (50%) are common, whereas surface flattening and depression were both only observed in 9% of cases. No tubercle formation of enthesophyte formation was observed.

The M. Latissimus Dorsii/Teres Major could be delineated in all individuals (n=22) with a total of 38 analyzable entheses. In one individual, a 10-year old female, the enthesis could be delineated on the right but not on the left. Porosity was observed in 53% of entheses. Surface irregularity was less common (16%), as was ridge formation (8%). Surface flattening (32%) and depression formation (53%) are relatively more common at this enthesis.

The M. Deltoideus could be delineated in all analyzed individuals (n=22) with a total of 37 analyzable entheses. Porosity (46%) and surface irregularity (49%) were common, with some instances of ridge formation (30%) but only two instances of depression (5%).

The M. pronator teres could be delineated in all analyzed individuals (n=21), but only on one side in two cases (94% delineable). A total of 34 entheses could be analyzed. Surface flattening (74%) and porosity (50%) are common, and some individuals show depressions (26%). No ridge, tubercle, or enthesophyte formation was observed.

The M. pronator quadratus could be delineated in all analyzed individuals (n=18), with a total of 30 analyzable entheses. Entheseal change was subtle, with porosity and surface irregularity occurring most commonly.

The M. brachialis could be delineated in all analyzed individuals (n=20) with a total of 37 analyzable entheses. One third exhibit porosity (30%). Surface irregularity is less common (14%) than ridge formation (27%). Some instances of surface flattening were observed (14%) but depressions were more prevalent (54%). Enthesophyte formation was rare (5%) and no tubercle formation was observed.

The M. gluteus maximus could be delineated in all analyzed individuals (n=26) with a total of 38 analyzable entheses. Porosity was relatively uncommon (21%), while surface irregularity (39%) and ridge formation (61%) were observed more frequently. Surface flattening (8%) was observed less often than depression, which was observed relatively frequently (34%), sometimes with sharp edges (31% of depressions). Tubercle and enthesophyte formation were not observed.

Delineation of the M. vastus medialis was possible in 14 of 26 analyzable individuals (53%), although in 3 of these 14 nonadults, delineation was only possible on one side. At the 44 analyzable entheses, the only observed traits were porosity (5%) and depression (18%).

The M. pectineus could be delineated in all but two individuals (n=29; 93%), with a total of 41 analyzable entheses. Porosity was commonly observed (80%). In more rare instances, surface irregularity (17%) or ridge formation (2%) were observed. No other osseous characteristics were observed in these individuals.

The medial head of the M. gastrocnemius could be delineated in all individuals (n=26) with a total of 45 analyzable entheses. Porosity was not scored in these individuals as it was always present on the entire attachment area. Surface irregularity was common (78%), often covering more than half of the entheseal area (in 40% of cases). Depression formation was also common, sometimes with sharp edges (in 18% of cases). In some instances (9%), ridge formation was observed along the edge of the depression. Surface flattening, tubercle, and enthesophyte formation were not observed.

The lateral head of the M. gastrocnemius on the femur could be delineated in all analyzed individuals (n=25) with a total of 41 analyzable entheses. As with the medial head of the M. gastrocnemius, porosity was not scored. Surface irregularity was common (41%) sometimes covering more than half of the entheseal surface (24% of cases). Depressions were commonly observed (66%), with a sharp edge in one instance (4%). Ridge formation only occurred in one individual (2%), along the edge of the depression.

The M. Soleus entheses could be delineated on all individuals (n=25) with a total of 50 analyzable entheses. Porosity was the most commonly observed trait (88%), sometimes covering more than half of the attachment area (23% of cases). Depression formation was also common (66%), sometimes with sharp edges (12%). Some instances of surface irregularity (22%) and ridge formation (10%) were observed, but no tubercles or enthesophyte formation.

From these data it is clear that every enthesis has its own unique range of expression. Thus, it is not appropriate to compare results from different entheses to each other. For instance, the M. Pectineus will never show as much variation in new bone formation or lytic activity as the M. Pectoralis Major; therefore, a lower score on the first does not mean it was less developed or used than the latter. For this reason, expression of each entheses is discussed separately.

4.7.2 Entheseal changes, sex, and age

No clear pattern between EC results (in the form of a composite score) and sex appears for any of the 16 analyzed entheses, whether regarding the data or through statistical testing (appendix B3 and table 4). As physical maturation rates differ between boys and girls, establishing if and how EC relates with sex is going to take considerable research. The current preliminary EC data do not show a clear relationship with sex, but this needs more substantiation from future studies.

	Test statistic	**p**	**n**
Long head of M. triceps brachii	1.53	0.675	18
Costoclavicular	2.768	0.597	21
Conoid	2.057	0.561	18
Trapezoid	1.515	0.824	20

M. pectoralis major	0.924	0.82	21
M. latissimus dorsii/M. teres major	5.931	0.052	21
M. deltoideus	2.489	0.288	21
M. pronator teres	0.267	0.606	20
M. pronator quadratus	2.137	0.343	17
M. brachialis	5.964	0.113	19
M. gluteus maximus	7.051	0.133	25
M. vastus medialis	0.135	0.935	25
M. pectineus	5.741	0.125	24
M. gastrocnemius medial head	3.634	0.603	25
M. gastrocnemius lateral head	2.625	0.622	24
M. soleus	2.143	0.543	24

Table 4: Chi square tests for relation between sex and EC based on the composite score per enthesis.

In relation to age, for the specific EC osseous characteristics, only tubercle formation at the conoid ligament attachment on the clavicle stands out as appearing more common with increasing age (see appendix B3). Of all entheseal osseous characteristics this tubercle formation is the most likely to be related to the skeletal maturation process, as the formation of bone eminences is, at least in part, regulated by the expression of specific genes involved in growth and development (Zelzer *et al.*, 2014).

Pearson's correlation tests between age and EC did not reveal a consistent pattern of correlation between EC and age in the sample. The Long head of the M. triceps brachii, the conoid, and both gastrocnemius site showed a positive correlation with age, whereas the M. pectoralis major showed a negative correlation with age (table 5).

	Correlation factor	**p**	**n**
Long head of M. triceps brachii	.613	0.005	19
Costoclavicular	-0.183	0.416	22
Conoid	0.492	0.033	19
Trapezoid	0,07	0.762	21
M. pectoralis major	-5.27	0.012	22
M. latissimus dorsii/M. teres major	-0,.93	0.186	22
M. deltoideus	-0.288	0.194	22
M. pronator teres	-0.074	0.749	21
M. pronator quadratus	-0.362	0.14	18
M. brachialis	0.415	0.069	20
M. gluteus maximus	-0.233	0.253	26
M. vastus medialis	0.302	0.133	26
M. pectineus	-0.177	0.398	25
M. gastrocnemius medial head	0.552	0.003	26
M. gastrocnemius lateral head	0.483	0.014	25
M. soleus	0.222	0.286	25

Table 5: Pearson's correlation tests between age and EC based on the composite score per enthesis. Statistically significant correlations (p<0.05) highlighted in bold.

The inconsistency of the relation between age and EC suggests that at this point we do not yet comprehend sufficiently how EC interact with age and/or other etiological factors to accurately analyze relations in this way. The relatively small sample size, especially when divided up per enthesis, and the less than straightforward dataset of this exploratory study do not allow us to draw founded conclusions on correlation with age. As EC data are complex, and, in nonadults, not yet thoroughly understood, further research is necessary to understand the interaction between EC and age.

4.7.3 Inter-and intra-observer agreement

4.7.3.1 Intra-observer agreement

For intra-observer agreement assessment, nine individuals were re-analyzed by the same researcher a month after the original data collection. Individuals were selected for re-analysis based on their level of completeness, with a variety of ages. Data are presented as percentages of agreement per trait and per enthesis in table 6 . When an enthesis was deemed not recordable in one assessment yet scored in the other, this difference was not included in the percentage calculation because it represents the assessment of the entire enthesis rather than observation of the specific trait. The percentage of agreement as to whether an enthesis is scorable is calculated separately (row entitled Entheses Observable).

	Long head of triceps brachii	**Costaclavicular ligament**	**Conoid**	**Trapezoid ligament**	**M. pectoralis major**	**M. Latissimus dorsii/teres major**	**M. Deltoideus**	**M. pronator teres**	**M. Pronator quadratus**	**M. brachialis**	**M. Gluteus Maximus**	**Vastus Medialis**	**Pectineus**	**M. gastrocnemius, medial head**	**M. gastrocnemius, lateral head**	**M. Soleus**
Delineation possible	100	94	100	100	100	88	100	100	100	93	100	85	80	100	93	100
Porosity	86	81	71	76	71	75	69	55	70	93	92	100	53	/	/	83
Surface irregularity	43	94	86	76	65	88	75	82	60	71	62	100	93	94	93	83
Ridge formation	79	100	93	88	65	94	88	100	100	100	69	100	93	88	93	100
Surface flattening	100	100	100	94	88	75	100	73	100	71	62	77	100	100	100	94
Depression	100	88	100	71	82	88	100	73	100	64	38	69	100	94	87	83
Tubercle formation	93	100	93	88	100	100	100	100	100	100	100	100	100	100	100	100
Enthesophyte formation	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
n =	14	16	14	17	17	16	16	11	10	14	13	13	15	16	15	18
Entheses observable	94	94	94	100	100	94	94	83	94	94	89	89	94	100	94	100

Table 6: Percentage of intra-observer agreement when scoring the same enthesis with a one-month interval. All values are percentages except the n-values, which represent the number of entheses scored (9 re-analyzed individuals so a maximum n=18 entheses per ligament/muscle)

Intra-observer agreement was generally high, with 89% on average over all traits and entheses. It must be noted that this agreement percentage is inflated by traits that are highly unlikely to occur at particular entheses and therefore consistently scored as zero (e.g.

enthesophyte formation at the M. pectoralis major). This is a factor for the overall agreement percentage of all entheses discussed for intra-observer error. Inconsistencies where intra-observer agreement was lower than 75% are discussed. Therefore, per enthesis, the more divergent scores between the two moments of observation are discussed, i.e., where intra-observer agreement was less than 75% for a specific enthesis on all scored individuals.

For the long head of the M. triceps brachii on the scapula, there was inconsistency both as to the extent (score 1 or 2) and presence (score 0 or 1) of surface irregularity, y*et all* other traits showed minimal difference between the two scoring instances. On average for this enthesis, intra-observer agreement was 88%. On the clavicle, intra-observer agreement is high for the costoclavicular ligament, with average agreement reaching 94%. The conoid ligament attachment site has some discrepancy for porosity scores, mainly as to the severity (score 1 or 2), with an overall average agreement of 93%. For the trapezoid ligament, some discrepancies occurred for porosity, surface irregularity, and depression formation. Here, the average agreement was 88%. Of the three entheses analyzed on the humerus, the M. pectoralis major was the most prone to disagreement, with some observers scoring as surface irregularity what others scored as ridge formation (average agreement 86%). The M. latissimus dorsii/teres major showed higher consistency (average 89%), while the M. deltoideus showed some disagreement as to the presence of porosity (score 1 vs. 0) with an average agreement of 92%. For the M. pronator teres on the radius, porosity was the least consistently scored, with some instances of disagreement between depression formation and surface flattening. Overall agreement was 85%. On the ulna, some disagreement occurred as to the presence of porosity and surface irregularity of the M. pronator quadratus (average agreement 92%), whereas for the M. brachialis surface flattening and depression were interchanged at times, and surface irregularity only found in the second scoring round. Overall agreement for the M. brachialis was 87%. On the femur, the M. gluteus maximus showed the lowest intra-observer agreement (average 79%), with surface irregularity and ridge formation being interchanged in some instances, as well as surface flattening and depression. The M. vastus medialis was scored as having a depression in the first round of observation more often than in the second round (average agreement 91%). For the M. pectineus, agreement was good (average 90%) for all traits except porosity. Both the medial and lateral head of m. gastrocnemius showed high intra-observer agreement (on average 86% and 85%, respectively). Finally, on the tibia, the M. soleus had good overall intra-observer agreement, with an average of 94%.

Overall, this assessment shows that while intra-observer error is, on average, low, some traits are more consistently scored than others. Specifically, when two traits are on a more continuous spectrum, they can be scored under one trait in one instance and the other in the second instance (i.e., depression vs. surface flattening).

4.7.3.2 Inter-observer agreement

For inter-observer error, two osteoarchaeologists applied the method, using only a scoring guide that defined the traits and score thresholds (as in section 5), provided images showing the location of the entheses, and supplied a scoring form. Their results were tested against those obtained by the first author (referred to here as observer one). The testing observers had PhDs in osteoarchaeology, with observer two being experienced with scoring EC in adults, and observer three unfamiliar with EC scoring. The observers scored five individuals from various age groups. They were not trained by the method creators in any other way than to give them the written scoring guide. Applying a method without being trained by the original developers can be challenging (Davis *et al.*, 2013; Wilczak *et al.*, 2017), thus the goal of this un-aided testing was to assess whether the descriptions were detailed and clear enough to be understood by other researchers, and whether the scoring method would be applicable auto-didactically. Results of the inter-observer agreement tests will be discussed here per enthesis.

Scapula

Scapula	*Long head of triceps brachii*			
	1 vs.2	**1 vs.3**	**2 vs.3**	**Av.**
Delineation possible	70	70	70	70
Porosity	40	60	30	43
Surface irregularity	80	50	30	53
Ridge formation	30	90	40	53
Surface flattening	100	80	80	87
Depression	80	50	50	60
Tubercle formation	90	90	100	93
Enthesophyte formation	90	100	90	93
n=	10	10	10	
Entheses observable	100	100	100	100

Table 7: inter-observer agreement percentages for the long head of the M. triceps brachii on the scapula (Av. = average).

When regarding the long head of the M. triceps brachii on the scapula (table 7), observer 3, who was unfamiliar with EC research, was more conservative in whether delineation of an enthesis was possible, whereas observer 2 agreed with the method creators. Porosity has the lowest inter-observer agreement, with no clear pattern of one observer consistently over-or underscoring relative to the others. Observer 2 tended to give higher scores for all traits than observers 1 and 3.

Clavicle

Clavicle	Costaclavicular ligament				Conoid				Trapezoid ligament			
	1 vs. 2	1 vs.3	2 vs. 3	Av.	1 vs. 2	1 vs.3	2 vs. 3	Av.	1 vs. 2	1 vs.3	2 vs. 3	Av.
Delineation possible	100	90	90	93	100	100	100	94	100	100	100	100
Porosity	50	70	40	53	10	30	30	34	20	40	50	37
Surface irregularity	0	60	20	27	50	80	30	32	20	50	20	30
Ridge formation	40	80	60	60	50	80	30	57	70	90	80	80
Surface flattening	100	90	90	93	100	100	100	94	100	60	60	73
Depression	60	80	60	67	80	100	80	69	80	80	60	73
Tubercle formation	100	100	100	100	50	70	20	83	100	80	80	87
Enthesophyte formation	80	90	90	87	60	100	60	79	40	100	40	60
n=	10	10	10		10	10	10		10	10	10	
Entheses observable	100	100	100	100	100	100	100	100	100	100	100	100

Table 8: inter-observer agreement percentages for the costoclavicular, conoid, and trapezoid on the clavicle (Av. = average).

The costoclavicular ligament attachment on the clavicle was relatively easy to delineate for all observers. Here, surface irregularity proved the most debatable trait (table 8), with observer 2 consistently scoring higher than the others. Porosity also proved somewhat problematic. Observer 1 and 3 showed relatively high consistency.

The conoid ligament attachment on the clavicle had a similar average agreement of 77%. It showed very low agreement for porosity between all observers. Observer 2 spotted more instances of surface irregularity and ridge formation, where observer 1 and 2 usually agreed on these traits.

In the third enthesis scored on the clavicle, the trapezoid ligament attachment, average agreement was 76%. Porosity scoring was once again inconsistent. What one observer scored as surface irregularity was interpreted as ridge formation or porosity by the other observers, and vice versa. Overall, we see a good agreement, again, between observer 1 and 3.

On the humerus, interobserver agreement for delineation was high for the M. pectoralis major and the M deltoideus, with the M. latissimus dorsii/teres major being scored less consistently (table 9). The M. pectoralis major was scored similarly by all three observers for most traits. Inconsistencies were found at the porosity, surface irregularity, and ridge formation. This is due to observer 1 scoring as porosity what observer three scored as surface irregularity, whereas observer two would score both. For ridge formation there is disagreement as to severity (i.e. score 1 or 2), and as to whether it is surface irregularity or a ridge. The M. latissimus dorsii/teres major showed similar disagreement as to porosity and surface irregularity, less confusion as to what constitutes ridge formation. For the M deltoideus the main discrepancies are found in the scoring of the presence and extent of porosity and surface irregularity. Overall, inter-observer agreement was highest between observer 1 and 3.

Humerus

Humerus	*M. pectoralis major*				*M. Latissimus dorsii/teres major*				*M. Deltoideus*			
	1 vs. 2	**1 vs.3**	**2 vs. 3**	**Av.**	**1 vs. 2**	**1 vs.3**	**2 vs. 3**	**Av.**	**1 vs. 2**	**1 vs.3**	**2 vs. 3**	**Av.**
Delineation possible	100	100	100	100	89	78	60	76	90	90	100	93
Porosity	20	40	20	27	44	44	50	46	44	33	50	42
Surface irregularity	60	60	60	60	44	67	50	54	33	22	60	38
Ridge formation	40	40	60	47	78	89	70	79	33	78	50	54
Surface flattening	80	90	90	87	89	89	100	93	100	100	100	100
Depression	70	80	70	73	78	100	80	86	89	100	90	93
Tubercle formation	100	100	100	100	100	100	100	100	100	100	100	100
Enthesophyte formation	90	100	90	93	100	100	100	100	100	100	100	100
n=	10	10	10		9	9	10		9	9	10	
Entheses observable	100	100	100	100	90	90	100	93	90	90	100	93

Table 9: inter-observer agreement percentages for the M. pectoralis major, M. latissimus dorsii/teres major, and M deltoideus on the humerus (Av. = average).

Radius

Radius	*M. pronator teres*			
	1 vs. 2	**1 vs.3**	**2 vs. 3**	**Av.**
Delineation possible	60	100	63	57
Porosity	80	0	38	52
Surface irregularity	60	60	75	72
Ridge formation	60	100	75	59
Surface flattening	20	60	38	56
Depression	60	60	100	87
Tubercle formation	100	100	100	100
Enthesophyte formation	100	100	100	53
n=	5	5	8	
Entheses observable	50	60	90	67

Table 10: inter-observer agreement percentages for the M. pronator teres on the radius (Av. = average).

The M. pronator teres entheses on the radius were delineated consistently by observer 1 and 3, while observer 2 could not delineate it in several cases (table 10). There was also discussion as to whether the entheses was well enough preserved taphonomically to be analyzed, with observer 1 being the most conservative assessor. Further interobserver disagreement occurred when one observer scored as surface flattening what the other labelled a depression.

Ulna

Ulna	*M. Pronator quadratus*				*M. brachialis*			
	1 vs. 2	**1 vs.3**	**2 vs. 3**	**Av.**	**1 vs. 2**	**1 vs.3**	**2 vs. 3**	**Av.**
Delineation possible	100	83	75	86	100	100	100	100
Porosity	0	50	50	33	30	67	67	55
Surface irregularity	29	83	13	42	30	89	11	43
Ridge formation	71	33	63	56	60	78	56	65
Surface flattening	100	100	100	100	100	89	89	93
Depression	86	100	75	87	50	78	44	57
Tubercle formation	100	100	100	100	100	100	100	100
Enthesophyte formation	100	100	100	100	100	89	89	93
n=	7	6	8	7	10	9	9	9,3
Entheses observable	70	60	90	73	100	90	100	97

Table 11: inter-observer agreement percentages for the M. pronator quadratus and M. brachialis on the ulna (Av. = average).

The two entheses scored on the ulna, the M. pronator quadratus and M Brachialis, both show inter-observer disagreement for the scoring of porosity and surface irregularity (table 11). M. brachialis was consistently delineated, as expected given the distinct anatomy of this enthesis site. For the pronator quadratus, there is some disagreement, both as to whether preservation was sufficient to allow scoring, and as to whether the enthesis could be delineated. As on the rest of the upper limb, observer 2 gave higher scores on average than observers 1 and 3.

Femur

Of the five muscles analyzed on the femur, agreement on whether delineation was possible was lowest for the pectineus (table 12), although the vastus medialis also showed variation in attributed score for this trait. In the M. Gluteus maximus, given scores varied the most for surface irregularity and porosity, most likely because of confusion of these two traits. The observers also often disagreed on what constituted a depression. EC occurring at the M. vastus medialis is inherently rather slight. This led to differences in scoring for porosity, where one observer saw just enough to score whereas the other found it insufficient. The same pattern is seen for depression at this enthesis. For the pectineus, also a trickier enthesis to delineate, porosity was the main source of inter-observer score variation, with incongruities for surface irregularity being notable as well. The lateral and medial attachment sites of the M. gastrocnemius have a very similar inter-observer agreement pattern. At these entheses, the extent of surface irregularity is the main source of difference, with disagreements as to the presence and extent of depression formation notable as well. For all entheses scored on the femur, observer 2 tended to give higher scores than observers 1 and 3.

Femur	*M. Gluteus Maximus*				*Vastus Medialis*				*Pectineus*				*M. gastrocnemius, medial head*				*M. gastrocnemius, lateral head*			
	1 vs. 2	**1 vs.3**	**2 vs. 3**	**AV.**	**1 vs. 2**	**1 vs.3**	**2 vs. 3**	**Av.**	**1 vs. 2**	**1 .3**	**2 vs. 3**	**v.**	**1 vs. 2**	**1 s.3**	**2 vs. 3**	**Av.**	**1 vs. 2**	**1 .3**	**2 vs. 3**	**AV.**
Delineation possible	100	100	100	100	56	67	89	71	78	56	33	56	100	100	100	100	88	100	88	92
Porosity	13	13	56	27	100	44	44	63	56	33	33	41	100	100	100	100				
Surface irregularity	13	13	22	16	89	100	89	93	33	67	56	52	33	56	56	48	13	63	13	30
Ridge formation	63	75	56	65	100	100	100	100	78	100	78	85	67	78	89	78	88	88	100	92
Surface flattening	75	75	78	76	100	89	89	93	100	78	78	85	100	89	89	93	100	75	75	83
Depression	38	50	78	55	78	22	44	48	100	78	78	85	56	78	56	63	75	50	50	58
Tubercle formation	88	88	78	85	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Enthesophyte formation	75	100	78	84	100	100	100	100	100	100	100	100	89	89	78	85	100	100	100	100
n=	8	8	9		9	9	9		9	9	9		9	9	9		8	8	8	
Entheses observable	90	90	100	93	100	100	100	100	100	100	100	100	100	100	100	100	90	100	90	93

Table 12: inter-observer agreement percentages for the M. gluteus maximus, vastus Medialis, Pectineus, M. gastrocnemius, medial head, and M. gastrocnemius, lateral head on the femur (Av. = average).

Tibia

Tibia	*M. Soleus*			
	1 vs. 2	**1 vs.3**	**2 vs. 3**	**Av.**
Delineation possible	100	100	100	100
Porosity	90	100	90	93
Surface irregularity	30	50	40	40
Ridge formation	60	80	70	70
Surface flattening	100	70	70	80
Depression	70	80	70	73
Tubercle formation	100	100	100	100
Enthesophyte formation	100	100	100	100
n=	10	10	10	
Entheses observable	100	100	100	100

Table 13: inter-observer agreement percentages for the M. soleus on the tibia.

All entheses of the M. soleus could be observed on all five individuals (n=10). Interobserver agreement was lowest for surface irregularity (table 13), potentially because of confusion with ridge formation which was also somewhat inconsistent. Observer 2 tended to score higher than observers 1 and 3.

4.7.3.3 Inter-observer agreement general

The inter-observer testing provided valuable information for future implementation of the scoring method. The most prominent result is that assessment of porosity was the least consistently scored trait between observers. This is not surprising, given that nonadult bone is, on average, more porous than adult bone on the entire cortical surface. This makes scoring porosity and assessing when an enthesis is more porous than the surrounding bone challenging. All three observers show high agreement for traits that are uncommon at an enthesis (i.e. tubercle/enthesophyte formation on entheses where this is rare). These traits were not considered as much when assessing inter-observer agreement, as they would inflate agreement rates unrealistically. Many instances of inter-observer disagreement were categorization issues. While observers tended to agree that a topography change was present or absent at an enthesis, they did at times score it under a different trait. This was the case for surface flattening and depression, or pronounced depression (score 2) and ridge formation. The same issue arose for traits that reflect more textural osseous changes, with one observer scoring as porosity an osseous characteristic that the other scored as surface irregularity.

It must be noted that the highest inter-observer agreement was between observer 1 (method creator) and observer 3 (non-EC specialist), rather than between observer 1 and 2 (EC specialist). Observer 2 tended to attribute higher scores overall, a trend that is not obscured in the composite scores (Appendix B2). This could be because observers 1 and 3 were trained for a large part by the same researchers in the European/UK field, whereas observer 2 was trained in the North American field and on very different collections. Both education (i.e., the subtle nuances in knowledge imparted by different researchers) and experience (i.e., the skeletal collections one is familiar with) will impact the way a researcher looks at human bone, and thus the scores ultimately accorded to the observed traits.

This means that if composite scores are used in which all traits per EC are combined, the inter-observer disagreement will be, at least in part, obscured. Although it could be argued that, in this way, composite scores can to a certain extent correct for inter-observer error, it also implies that composite scores are less useful for further method testing.

For some entheses there was a noteworthy amount of disagreement on whether the entheses could be delineated or not. This appeared to be partially dependent on whether the observer had previous experience with EC research, as observer 1 and 2 agreed in the majority of cases. For the M. pronator teres and M. vastus medialis however, agreement on delineation was low among all observers, likely due to their less prominent cortical markings. In some cases, there was also disagreement about whether cortical bone preservation was sufficient to allow observation. This is a factor that cannot be corrected for in the method, except by suggesting that researchers err on the side of caution when in doubt.

4.7.4 Method amelioration based on testing

The most striking result of both the intra-and interobserver method testing was that porosity was the least consistently scored trait on average. Because of this, it was decided to remove porosity as a trait to score for EC in the current method. Although this does not mean that porosity cannot be a trait of EC, it is excluded from the recording method because it is not useful to include a trait if it cannot be scored with acceptable consistency by all observers.

Additionally, the inter-observer testing highlighted that the proposed recording method presented a challenge to observers by allowing too many scoring options for some traits (i.e. absent-present-extensive change). Therefore, scoring options are now reduced to absent-present (i.e. 0-1) for all traits at all entheses.

With these improvements to the method, inter-observer error is considerably reduced. When the data are reworked to exclude porosity and reduce all scores to absent (i.e. 0) or present (i.e. 1), average interobserver agreement percentages are: 74% for the long head of the M. triceps brachii on the scapula; respectively 79%, 77%, and 76% for the costoclavicular, conoid, and trapezoid ligaments on the clavicle; 87% for the M. Pectoralis major, 84% for the M. Latissimus dorsii/teres major, and 85% for the M. deltoideus on the humerus; 76% for the M. pronator teres entheses on the radius, and respectively 81% and 79% for the M. pronator quadratus and M. Brachialis on the ulna. On the femur, average inter-observer agreement was 73% for the M. gluteus maximus, 86% for the M. vastus medialis, 81% for the M. pectineus, 87% for the medial branch of the M. gastrocnemius, and 82% for its lateral branch, and finally on the tibia average inter-observer agreement was 91% for the M. soleus. Inter-observer agreement percentages thus obtained are similar to those presented by Wilczak *et al.*, (2017) for the most prominent adult EC recording method, i.e. the Coimbra method (Henderson *et al.*, 2010, 2013, 2016).

As well as the abovementioned ameliorations to the scoring process, method testing also highlighted the need to provide a workable way to process the obtained data. Both the primary observer and the additional observers found that the current method produces a large dataset. Although this large dataset is inevitable in order to obtain the high-resolution information on changes occurring at the enthesis, it can be unwieldy for some research questions. To create a manageable dataset, a system of categorization is proposed, which sorts entheses into categories of minimal-mild-moderate-pronounced EC. Simply put, the scores for all changes occurring at an entheses are combined into a composite score by adding them up. This composite score is then sorted into a category (table 14) for each enthesis. In addition to creating a workable dataset, creating these categories further minimizes inter-observer error. This extra step of establishing EC categories will be especially useful for large scale studies where researchers aim to evaluate differences in EC within or between skeletal collections, particularly when data collection is done by different observers. For researchers who wish to research the interaction between one specific EC trait and other factors (e.g. osteophyte formation vs. skeletal maturity, or depression formation vs. surface irregularity at an enthesis), this categorization step is not necessary. Thus, the data can be processed according to the requirements of the research question, and the method retains maximum applicability.

Composite Score	Category
0-1	I
2-4	II
5-7	III
8+	IV

Table 14: Composite score categories.

Finally, it must be noted that the inter-observer method testing results underline that it can be beneficial to learn the method from someone already familiar with it. Especially researchers less familiar with entheses and/or nonadult remains could be aided by this.

4.8 Final method creation

The final proposed recording method is presented here. It is the product of the stages of method creation and testing described in the previous sections. This final method represents a viable approach to recording nonadult entheses in a standardized and structured way. With future research and potential learning of the method from those already familiar with it, interobserver agreement can be further increased and method repeatability further optimized.

Eight EC characteristics are retained, all scored as absent (=0) or present (=1) (table 15) (see section 5 for definitions of the traits).

Scored traits		
Delineation possible	0=no	1=yes
Surface irregularity	0=no	1=yes
Ridge	0=no	1=yes
Flattening	0=no	1=yes
Sulcus	0=no	1=yes
Depression	0=no	1=yes
Tubercle	0=no	1=yes
Enthesophyte	0=no	1=yes

Table 15: Scored traits with attributed score based on absent or present.

The traits are structured into a recording form that allows recording of all traits for each side and per enthesis (figure 1). This form also contains columns for initial data processing, with a column for composite score (i.e. the sum of all trait scores for the enthesis) and a column for the category that composite score falls in (indicated with Roman numerals I-IV). All information necessary for method implementation is bundled in a recording guide which contains outlines of enthesis location on the bone, trait definitions, and the scoring form (appendix B4).

	Left								Right							
	Delineation possible	Surface Irregularity	Ridge Formation	Surface flattening	Depression/Sulcus Formation	Tubercle formation	enthesophyte formation	COMPOSITE SCORE CATEGORY	Delineation possible	Surface Irregularity	Ridge Formation	Surface flattening	Depression/Sulcus Formation	Tubercle formation	enthesophyte formation	COMPOSITE SCORE CATEGORY
Clavicle																
Costaclavicular ligament																
Conoid																
Trapezoid ligament																
Humerus																
M. pectoralis major																
M. lat. dorsii/teres major																
M. Deltoideus																
Radius																
M. pronator teres																
Ulna																
Pronator Quadratus																
M. Brachialis																
Femur																
Gluteus maximus																
Vastus Medialis																
Pectineus																
M. gastrocnemius, med. head																
M. gastrocnemius, lat. head																
Tibia																
M. Soleus																

Figure 1: Standardized recording form for subadult EC.

4.9 Discussion and conclusion

The most prominent result of this study of EC in nonadults is that each enthesis has its own unique spectrum of variation, with some osseous characteristics prone to change and others unlikely to occur. This is not entirely surprising, given the different biomechanical properties of different entheses; i.e., their size both absolute and relative to the muscle/ligament attached, and the angle of pull. However, this enthesis-unique spectrum is of the utmost importance to any study analyzing EC, as it means that the results from one enthesis can never be directly compared to another, and that different studies using averages of different sets of entheses cannot be compared. Results also show high inter-individual variation in EC, and even variation between left and right sides within one individual.

No clear unidirectional pattern of age- or sex-related EC occurred in this explorative study. This indicates that other etiological factors are likely also in play. It cannot at this point be excluded that idiosyncratic individual variation is responsible for some entheseal variation. However, given the wide range of observable trait variation, between and within individuals, other factors such as activity are also likely to have impacted the appearance of the entheses. Extensive research on identified skeletal collections of various socio-historical contexts is necessary to help determine the extent of impact different factors have on EC in nonadults.

The proposed standardized method presented here is developed to aid and stimulate this future research. As in all qualitative research, repeatability is one of the main challenges in nonadult EC recording. Intra-observer agreement was high, but inter-observer error showed how some traits presented challenges for consistent scoring. Porosity, especially, was scored rather inconsistently by the three observers, causing it to be discarded in the final method. Many inter-observer points of confusion occurred on the threshold between different traits. Different topographic traits which form a spectrum were at times confused (e.g. surface flattening and depression formation), as were extensive surface irregularity and slight ridge formation. The same issues occurred with textural traits, such as porosity versus slight surface irregularity. The tests also showed that while previous experience with EC can help researchers accurately delineate the entheses, the skeletal collections one is experienced with likely also impacts scoring.

With the invaluable feedback provided by testing in the method creation process, a final scoring method was created that scores each enthesis for eight traits, all of which are scored as being either present or absent. These traits can then be summed for each enthesis to create a composite score, which represents the amount of change occurring at that particular attachment site. These composite scores can then further be sorted into categories that represent a level of EC. This categorization allows for a more manageable dataset, which can be preferable for some research questions as well as partially limiting inter-observer variation when several observers are involved in data collection. When possible, learning the method from someone already acquainted with it can further improve repeatability. A scoring guide and standardized recording form are provided in the appendices to increase utility (appendix B4 and B5).

This paper has shown the wealth of individual variation occurring at nonadult entheses, with pilot results indicating that age and/or sex are not the only determining factors. The proposed standardized scoring method will allow a better comprehension of nonadult EC, thus providing a new insight into the lives of children in the past.

Acknowledgements

The authors would like to thank Dr. R. Schats and Dr. S. Schrader for testing the method and providing feedback.

5

Diversity in death: skeletal evidence of burial preferences in a late to post-medieval convent in Aalst (Belgium)

The Urban Graveyard: Archaeological Perspectives
Urban Graveyards Proceedings 3

Edited by Roos van Oosten and Rachel Schats

Accepted chapter

Author:
J. L. A. Palmer

Abstract

Aalst (Belgium) has a rich and vibrant history, known from historical sources and an increasing wealth of archaeological data. Recently, physical anthropology is adding poignant information to our understanding of this historic city. This paper presents the osteoarchaeological data from a skeletal collection (n=164) excavated in 2016 in the Louis D'haeseleerstraat, at the site of the Theresian convent to identify the type of burial areas in this convent. Both general osteobiographical information and dietary data from carbon and nitrogen isotopic values are discussed. These findings are then compared to data from two other skeletal collections from Aalst, namely the remains recovered in the excavation at the Saint Martin's church and churchyard in 1998 (n=30), and those excavated at the Carmelite friary (present-day Hopmarkt). For the Carmelite friary, both the first half of the collection (n=238), recovered in 2004/2005 and presented by De Groote *et al.*, in the previous volume, and the second half, excavated by Solva in 2011 (n=95) are used. Differences in demographic composition and diet both between these burial locations and within the Louis D'haeseleerstraat site, combined with excavation data, allowed the identification of the Louis D'haeseleerstraat sample as a general cemetery, with a separate zone of (higher ranking) nuns. These data are contextualized within the existing body of knowledge on the history of Aalst and its burial practices. Comparing skeletal data from three distinct archaeological contexts within this city thereby provides insights into the realities of life and death in the post-medieval town of Aalst.

5.1 Introduction and historical context

The town of Aalst is located on the southwestern bank of the Dender river. Both archaeological finds and toponomy indicate relatively continuous human presence in this area from the prehistoric times onwards (De Groote 2010). The earliest historical record of the town can be dated to the 9th century, when the Villa Alost is mentioned, although this settlement probably had its roots in earlier Merovingian times (De Groote 2010). Largely because of its favorable position on the bank of the river and on the crossing of the land route between Bruges and Cologne (De Groote 2010), Aalst grew into a thriving town. It obtained city rights in 1174, which granted the town autonomy (De Schryver 2001). Its general layout was completed in the early 13th century with the construction of the ramparts and moats which are still visible in the current day townscape (De Groote 2010). As Aalst only outgrew these fortifications in the 19th century (Callebaut 1983), the town center forms a rich but complex archaeological palimpsest.

In (post-) medieval times, the economy of Aalst flourished because of specialized crafts, most notably the cloth industry (Courteaux 1973), and the monopoly over the trade in hops (Aerts 1999). The town was under Spanish rule from 1555-1713, which is thought to have negatively impacted on economic prosperity, followed by Austrian rule from 1713-1792 during which the economy picked up again (De Schryver 2001). In terms of population size, historians estimate the population in 1395 at ca. 4000, with a steady increase over time, to 8460 individuals in 1725 (De Brouwer 1968).

In addition to the wealth of historical information, Aalst has seen increased archaeological research in the last decades. Excavations started being undertaken in 1982, yet the first large scale excavation occurred quite recently, in 2004/2005, at the Hopmarkt. Archaeological research in and around the historic town is steadily increasing, as the city is engaging in larger infrastructural works to accommodate the growing population and innovate the cityscape. This influx of archaeological data about the town and its inhabitants provides an as yet untapped wealth of information for synthetic and comparative research.

The current article will present osteological data from one recent excavation in the Louis D'haeseleerstraat (Fig. 1a) and compare it to data from two other burial locations within the city, namely the aforementioned Hopmarkt (Fig. 1b) and the Saint Martin's church (Fig. 1c), to identify the socio-economic status of the individuals buried at the Louis D'haeseleerstraat, and provide insights into life and death in this vibrant town.

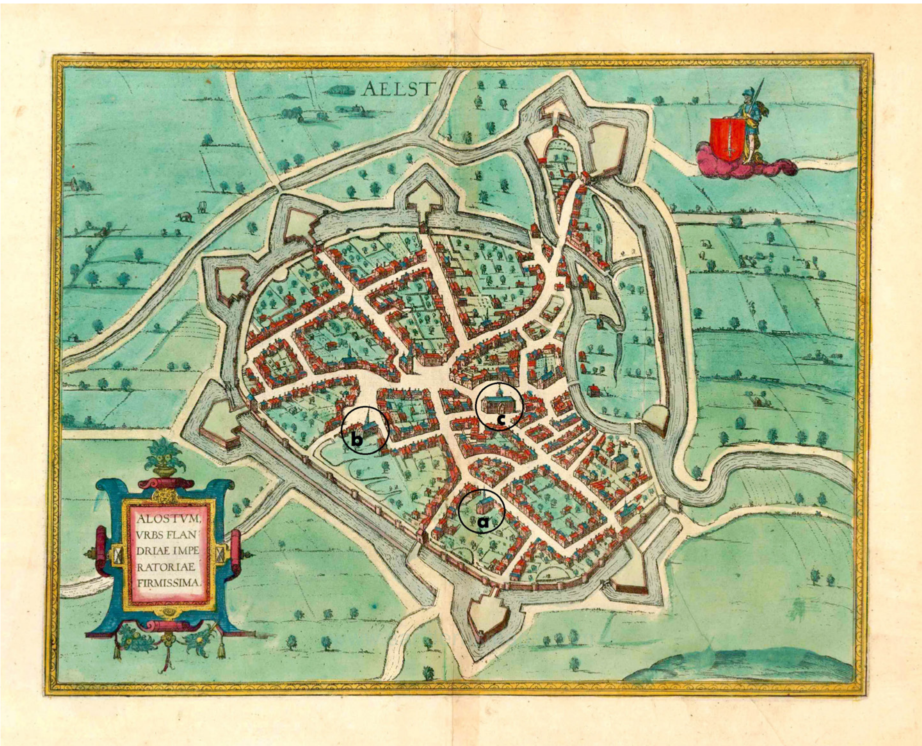


Figure 1: Map by Braun and Hogenberg from 1588, with the three sites discussed in this paper circled. a= Louis D'haeseleerstraat convent, b= Hopmarkt convent, c=Saint Martin's church.

5.2 Archaeological and socio-historical context

5.2.1 Louis D'haeseleerstraat

This article focuses primarily on data from the 2016 excavations at the Louis D'haeseleerstraat. This archaeological site encompasses part of the area where the convent of three consecutive Christian religious orders was located (Fig. 1a). In ca. 1450, the sisters of the Franciscan order started a convent, which, after destruction by the Geuzen in the 16th century, was rebuilt, and became a convent of the sisters of the order of the Annunciation in 1667. A new church was built for the convent in the 18th century. In 1797 the French republic terminated the convent, and it was not rebuilt until 1836, by the Theresian nuns. The current excavation took place in the garden of the later convent, and covers archaeological remains dated between 1450 and 1797 (Bruggeman *et al.*, in prep). The exact location of the buildings from the previous convent phases was unknown at the time of excavation and analysis.

Within the excavation area, there are three discernible zones where human remains were found, (Fig. 2). Most of the human skeletal material represented primary burials, with a total of approximately 200 burials recovered. All burials had a northeast-southwest orientation and were organized in layers in a systemized pattern . Aside from a few deviant burials, individuals were buried in a supine position with their arms either extended along the body or crossed over the torso, with the head on the southwest side. It is as yet unclear which area of the former convent these three burial zones are located in. In (post-)Medieval Flanders, the most expensive burials were usually located inside a church, with middle-class fees for the cloister garth, and a general cemetery where it was cheapest to be buried (De Groote *et al.*, 2018). The burials in the Louis D'haeseleerstraat are located in the convent garden of the later 19th century convent, therefore it can be hypothesized that either the cloister garth of the previous convent phase or its general cemetery is primarily represented, as church location is the most static component of a convent and least likely to have changed location during rebuilding in 1836.

Thus, the burials in the Louis D'haeseleerstraat most likely represent the general cemetery and cloister garth of the previous convent phases. When regarding the orientation (all parallel to each other) and distribution (no square area with a low-density middle ground) of the skeletons in zone 3, this is more likely a general cemetery context than a cloister garth/alley context. Zone two was situated to the Northwest of the Annunciation convent buildings, with a maximum of four layers of organized primary burials present, with ca. 55 individuals identified during excavation. This zone has been more severely disturbed than zone 3, complicating assessment of the burial context. Based on the excavation plan, this area could represent the continuation of the general cemetery, but a cloister or church context is not impossible. Both the burial area of zone 2 and 3 probably continued outside the excavated area. Zone 1 was a small section at the very limit of the excavated area, which seems to suggest that this area was separate from the general cemetery, representing either church or cloister burials.

5.2.2 Hopmarkt and Saint Martin's church

The data from the Louis D'haeseleerstraat excavation are compared to two other burial contexts within the city of Aalst. The Carmelite friary located at the current Hopmarkt, and the materials from the 1998 excavation in and next to the Saint-Martin's church are used. All data were gathered by the author unless otherwise specified.

The Carmelite friary is dated between 1497 and 1797 (De Maeyer *et al.*, 2014). It was excavated in two phases, the first phase in 2004/2005 uncovering skeletons from the church, cloister alleys, and cloister garth, and the second phase in 2011 uncovering burials in the cloister garden and alleys (De Groote *et al.*, 2018 and De Maeyer *et al.*, 2014). Thus, where the Louis D'haeseleerstraat convent is hypothesized to represent mainly regular lay people (cfr. supra), the Hopmarkt convent primarily represents higher class burials and clerics (De Groote *et al.*, 2011). For the first phase of the Hopmarkt, a dietary stable isotope study was done on all three burial zones, i.e., church, cloister alley, and cloister garth, for males and females (Quintelier *et al.*, 2011). On a demographic level, the first excavation phase of the Hopmarkt held relatively few subadults (29 subadults versus 209 adults). The hypothesis was raised that these children were buried in the unexcavated general cemetery, as archival records attest to the majority of burials being of children (De Groote *et al.*, 2011). The second excavation phase, of the other half of the cloister alleys, revealed 31 subadults and 64 adults in the 95 skeletons which were complete enough for a detailed osteological analysis (Palmer 2014, appendix D1), which, when added to the results of phase one, is till significantly less children than the archival data attest to.

The Saint Martin's church is the main church of Aalst, with a long multi-phased history. The skeletal sample that was excavated in1997/1998, however, could be dated between 1655 and 1782 (De Groote and Moens 1999). Unfortunately, no isotopic data are as yet available. Analysis of the 29 skeletons which were complete enough for osteological research revealed that of the 18 individuals buried in the church, only 4 were subadults (Palmer 2016, appendix D3). However, of the 11 individuals attributed to the outside cemetery, only two were subadults. Preservation could be a key issue here. The 1997/1998 excavation covered an area which was cross-cut by a more recent wall, leading to many skeletons effectively being "cut in half" or losing their upper or lower half. It is not unlikely that some smaller child skeletons would have been completely obliterated by this later wall and not recovered in the rescue excavation. Thus, this demographic sample is too small to be useful for comparisons. The Saint-Martin's church context does provide one striking pathological find. In the group of burials located inside the church, a middle-aged woman was found with an advanced case of metastatic carcinoma, most likely as a result of breast cancer (Palmer *et al.*, 2017). This woman had extreme osteoclastic activity in the entire axial skeleton, including major bone resorption on the skull and along the spinal canal. The extent and severity of the lesions attest to her living with this pathology for quite some time.

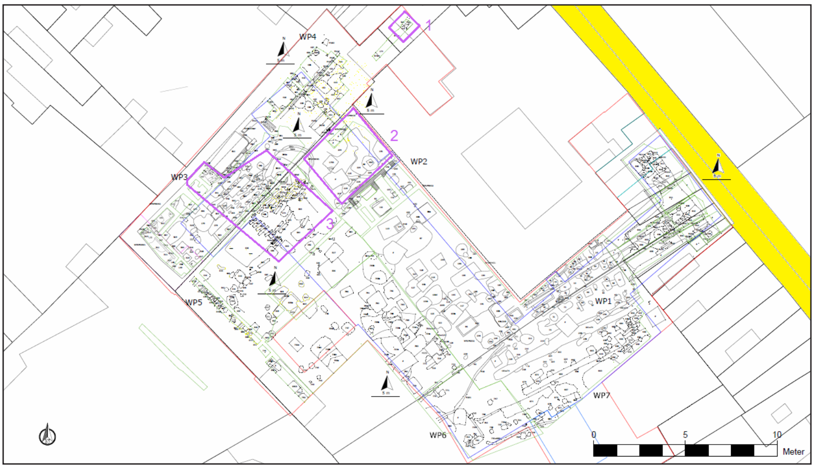


Figure 2: Excavation area, with the three zones where human remains were found indicated in purple. The road is indicated in yellow (adapted from Bruggeman et al.*, in prep).*

5.2.3 Socio-economic context

Historical information on the lives and occupations of the poorer individuals is limited. For the middle class, more data are available. In Aalst, this middle class consisted for a large part of specialized crafts-and tradesmen (most important being blue-and blackdyers, tailors, bakers, and shopkeepers). Within these so-called 'ambachten', predominantly people local to Aalst were employed (De Schryver 2001). Historic sources also make a strict distinction between 'poorters' (townspeople) and 'niet-poorters' (foreigners). When people did move to the town, they usually came from the immediate surrounding countryside of Aalst (De Schryver 2001). From a physical anthropological perspective, this entails that the middle-class component of the cemetery consists of a relatively small genetic group as they prefererred to train and employ townspeople in the trades. Given the social distinction of 'niet-poorters' and the generally limited migration radius, it is likely that the poorer and richer people buried in this convent represent a similarly limited gene pool. As for the lives and occupations of the highest-class individuals, in this convent burial context they were probably highly placed members of the crafts and trades, or highly placed clericals.

5.3 Physical anthropological methods

The historical and archaeological context outlined above showed that the Louis D'haeseleerstraat sample most likely consisted of the general population, buried in a general cemetery, and some higher ranking, possibly clerical individuals, buried in a cloister garth or church. To test this hypothesis, physical anthropological analyses were undertaken. Both general osteological data and dietary isotopes were studied. Of the ca. 200 burials recovered, 164 individuals were complete and well-preserved enough for the assessment of sex, age-at-death, and pathology. Sex was estimated through traits on the pelvis, cranium, and mandible, following the Workshop for European Archaeologists guidelines (Ferembach *et al.*, 1980), the Phenice pubic traits (Phenice 1969), and metrics (McCormick *et al.*, 1991, Stewart 1979, and Steyn and Işcan 1999). Age was estimated using the morphology of the pubic symphysis (Suchey and Brooks 1990), auricular surface (Buckberry and Chamberlain 2002), and sternal rib end (Işcan *et al.*, 1984), as well as dental attrition (Maat 2001), cranial suture closure (Meindl and Lovejoy 1985), and the fusion state of late fusing epiphyses. Subadult age was estimated using Scheuer and Black (2000) and Schaefer *et al.*, (2009). Carbon and nitrogen stable isotope analysis was performed on a subsample of 50 adult individuals to research dietary differences potentially linked to socio-economic status.

5.4 Results

5.4.1 Demography

Of the 164 analyzed individuals, 68 were subadults and 96 were adults (Fig. 3). The subadults were divided into 3 age categories. Individuals between age 0-3 were labelled as infants, age 4-12 as children, and age 13-18 as adolescents. No individuals younger than 40 weeks in utero were found. Children formed the largest group of subadults in the cemetery.

Adults were similarly divided into 4 age categories; early young adult (19-25), late young adult (26-35), middle adult (36-50) and old adult (50+). For 4 adults, exact age estimation was impossible, therefore an 18+ age estimation was given. In the adult group, middle adults formed the biggest part of the demographic.

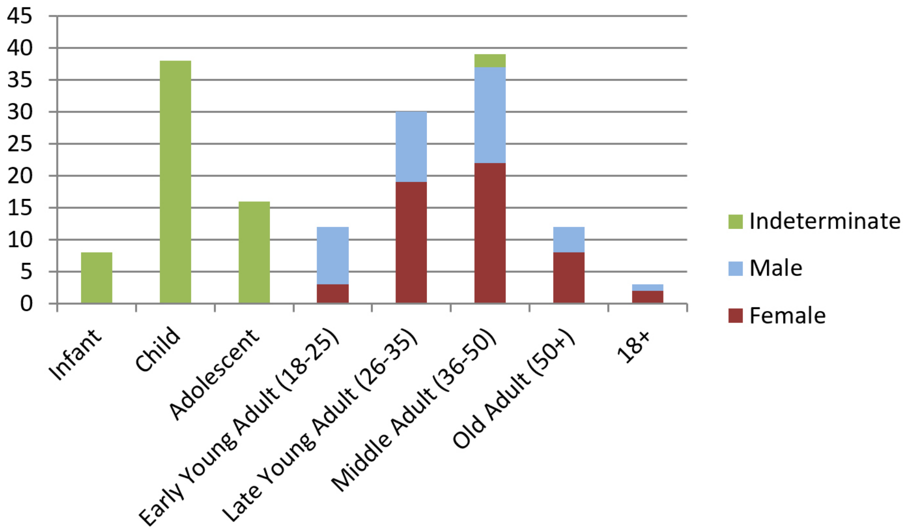


Figure 3: demographic distribution (n=164)

Of the 96 adult individuals analyzed for sex, a slight majority of 53 individuals was female, with 40 males and three individuals for whom sex could not be reliably estimated. When sorted by age distribution, slightly more men are present in the youngest adult age category.

When we can compare the Louis D'haeseleerstraat to the Hopmarkt, the former site had a much larger relative amount of subadults. Thus, these results support the hypothesis of De Groote *et al.*, that children were buried in the general cemetery, or at least less often in the cloister garth and alleys of the convents in post-medieval Aalst.

5.4.2 Pathology

Two individuals within the Louis D'haeseleerstraat population had pathological conditions which set them apart from the rest of the population. Their pathology will be discussed, for one individual to elucidate why she was included in the isotopic research, and for the other for comparison to a similar case from the Saint Martin's church (for an overview of all pathological conditions encountered in this skeletal collection see Palmer 2018 in Bruggeman *et al.*, in prep., and appendix D2).

The first individual, SK80, was a middle-aged woman with severe lesions to the right hand and knee (Fig. 4). The normal distal femoral and proximal tibial joint surfaces have been entirely destroyed, with granular new bone and large pores. A new pseudojoint has formed at the knee, with an associated new pseudofacet for the patella (which has been taphonomically lost). These pathological new facets show macroporosity and lipping and have an irregular granular appearance. When re-articulated, the leg is twisted, with the femur angled antero-medially and the tibia antero-laterally. Given the extensive lipping and angle of false articulation, mobility of this knee would have been severely limited. In conjunction with this knee pathology, the right hand shows several osseous deformations. The hamate has ankylosed with the 4th metacarpal and the trapezoid with the 2nd metacarpal. The two other carpals available for analysis are so deformed as to be near unrecognizable. The phalanges are relatively unaffected, although one bone is too deformed for accurate identification and could represent a phalanx, metacarpal or fusion of multiple hand bones. Throughout the skeleton, anomalies which are likely secondary to these joint pathologies can be observed. The humeral heads are angled more superiorly than normal, and the auricular surfaces on both os coxae and sacrum are more oblong than ear-shaped with granular new bone. The extent of the primary and possible secondary pathological lesions implies that this was a chronic affliction. These joint pathologies would have had a severe impact on the woman's life, as she would need a walking cane at the very least to achieve some mobility, and her right hand would have been very stiff and unsuited to most tasks. She was buried in zone 3 of the cemetery, the proposed general cemetery area. As a proxy for socio-economic status and role in society, she was included in the stable isotope study to analyze whether her diet differed from that of the rest of the cemetery.

Figure 4: right hand and knee of SK80. Note the fused wrist to hand bones and the deformed phalanx/metacarpal on the hand, and the angle of the knee, with the lower leg twisted outwards and the pathological new facet for the patella on the outside of the femur.

The second individual, SK129, was a middle aged (35-50) woman buried in zone 4 (i.e. the potential higher status zone) of the excavation. On her cranium, several vertebrae, sacrum, and os coxae, lytic starburst-like lesions with concave edges are visible (Fig. 5), with the outer cortical surface both ecto-and endocranially less resorbed than the trabecular bone in between. Two vertebrae also show unstructured new bone formation in the vertebral body, with the new bone having a chalky, brittle appearance. These vertebrae are heavy compared to the vertebrae where bone erosion has occurred (for instance, the complete L5 weighed 11.3g whereas the L4 of which only the body was preserved weighed 16.8g. Both have been cleaned through sonication to remove soil particles). Her femora are also affected, particularly on the right anterior diaphysis and near the femoral heads. The type and location of the lesions are concurrent with metastatic cancer (Mundy 2002 and Lieverse *et al.*, 2014). The exact type of cancer cannot be determined. However, the osseous metastasis of cancer is most common in breast cancer, being present in 60-70% of cases (Guise *et al.*, 2006), and this type of cancer is not unlikely given her age and sex. On both legs, dark green-grey stains are visible at regular intervals on tibiae and femora. This could point to a type of brace with metal fittings, which could have allowed her some mobility despite the wide-spread severe pathological condition. This woman's life would have been heavily affected by this pathology. Both the underlying cancer and secondary metastatic osseous pathology would have severely impaired her physical abilities. However, the extent of the lesions does show that she lived with this disease for quite some time, and the possible braces point to care being given by the community.

This is a close parallel to the skeleton in the Saint Martin's church, also a woman with metastatic carcinoma buried in the high status area of the site, i.e. within the church. Her lesions were also extensive, illustrating that she, too, lived with the disease for some time, and in a physical state which would have required her getting help from others. Although it is unlikely that the socio-economic position of these two women had any influence on them getting cancer, their social status might have given them access to better care, which could have allowed to live longer despite the absence of any effective medical treatments at the time. Aside from this similarity, it must be noted that paleopathological cases of cancer are relatively rare. To my knowledge, these women represent the first archaeological cases of cancer from Belgium. It is remarkable that two individuals from this small area and limited time period could be diagnosed. Some types of cancer, including breast cancer, have hereditary genetic risk factors (Turnbull and Rahman 2008). Therefore, one possible explanation for this is that the small gene pool suggested by historical records (cfr. supra) contained a gene which resulted in a higher risk of cancer in this population or some of its families.

Figure 5: skull, right os coxa and legs of SK129. A light source placed endocranially shows the endosteal lesions in both parietals (superior view). Osteoclastic lesions in the right os coxa with hollowed out interior are typical of metastatic carcinoma. The legs show organized pattern of staining which could be indicative of a type of brace. Note also the metastatic lesion on the anterior diaphysis of the right femur.

5.4.3 Dietary isotopes

Diet is intrinsically linked to socio-cultural environment and economic status. Within this convent context, it is hypothesized that nuns as well as lay people were buried, with zone 1 holding higher ranking nuns and zone 2 and 3 holding the general cemetery (cfr. supra). A bone collagen sample was taken from fifty individuals. Sample selection was based primarily on burial location, with representative samples taken from the three burial zones to analyze whether burial location was determined by social factors. For each burial cluster, all layers were sampled to analyze potential chronological changes in diet. Some individuals were also sampled because they had a deviant burial context, i.e. orientation or position in the grave. SK80 was included to evaluate whether she had a different diet from the rest of the population, given her physical impairment. To evaluate sex and age differences in diet, individuals were chosen to represent all adult age categories for both sexes. Thus, a total of 25 women and 25 men of all adult age categories were selected.

These samples were processed and analyzed for the stable isotopic ratios of carbon and nitrogen. Ratios of 13C versus 12C are represented as ∂13C, ratios of 15N versus 14N as ∂15N in amounts pro mille relative to the relevant standards. These isotopes give an indication of the type of plant that is consumed (∂13C) and the amount and potential type of animal protein that is consumed (∂15N) (see Lee-Thorpe 2008 for an overview of the field of dietary stable isotope analysis).

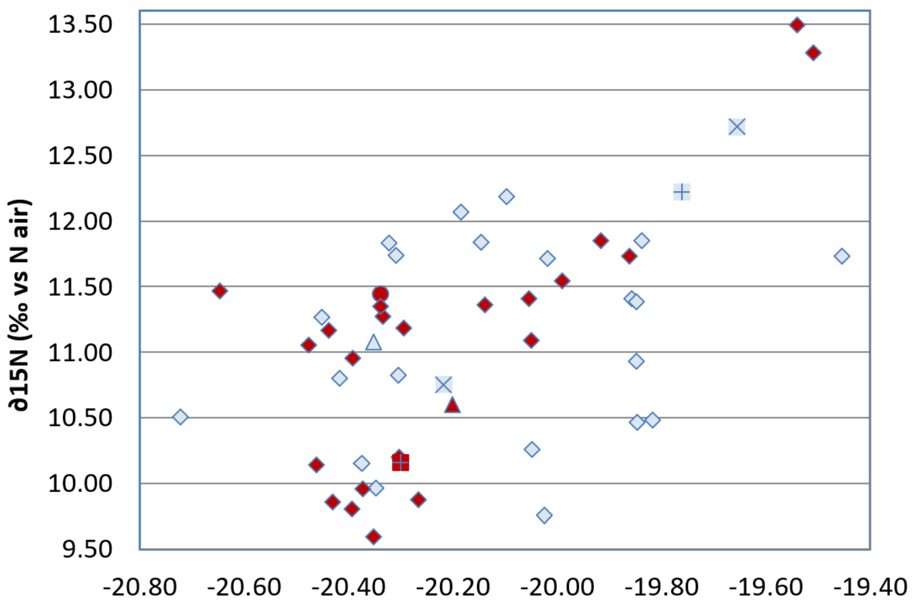


Figure 6: ∂13C and ∂15N values of fifty adult individuals from the Louis D'haeseleerstraat excavation. Women indicated in red, men in blue. A triangle indicates the individual was found lying on their side, an x indicated they were buried facing the other direction, a plus indicates they were buried prone, and the circle indicates the pathological individual.

Results show a marked variety in nitrogen isotopic values, with ∂15N ranging between 9.6 and 13.5 pro mille (∂13C range was more limited, between -20.72 and -19.45 pro mille) (Fig. 6). This range is partially caused by a difference in dietary isotopes between the burial clusters. Specifically, zone 1 (average ∂13C -19.83‰, ∂15N 12.65‰, n=3) has a higher ∂15N isotopic signature than zone 2 (average ∂13C -20.12‰, ∂15N 10.95‰, n=9) and zone 3 (average ∂13C -20.18‰, ∂15N 11.04‰, n=37). Within zones 2 and 3, no differences in isotopic signature were found between the stratigraphic layers. The woman with the severe knee pathology had a diet that was within the normal range of the population (Fig. 6). When all the data are plotted, two individuals stand out due to their high ∂15N values (top right corner of figure 6). These values represent two women, estimated to be between 35-50 years old. Both were buried in zone 1, i.e., quite well separated from the other burial clusters. The third individual sampled from zone 1, a 50+ year old women, had isotopic values more in line with the rest of the population (∂13C-20.44‰, ∂15N 11.17‰).

There are no clear differences between men and women in this sample (Fig. 6). The female average is slightly lower; ∂13C -20.22‰ and ∂15N 11.04‰, whereas the male average is ∂13C -20.09‰ and ∂15N 11.20‰ (see also Table 1). To achieve a sample that is comparable to other isotopic research from Aalst (cfr. infra), women aged 18-35 were grouped as 'younger women' and women aged 35+ as 'older women'. The same was done for the men. These averages show that while no large sexual dietary differences are present, based on the ∂15N values, there is a slight increase in animal protein intake with age.

Figure 8: SK150 with a deviant burial position (photo courtesy of All-Archeo bvba)

	n	**∂13C (‰ vs VPDB)**	**∂15N (‰ vs Nair)**
Younger females	14	-20,24	10,91
Older females	11	-20,18	11,20
Younger males	11	-20,14	10,92
Older males	14	-20,05	11,41

Table 1: average isotopic values per age and sex category.

When these stable isotopic values are compared to the stable isotopic data from the Hopmarkt, the Hopmarkt samples showed similar diversity in diet in the ∂15N ratios, if slightly less variation than at the Louis D'haeseleerstraat. On average, isotopic values were higher at the Hopmarkt, especially for males. This infers that their diet was richer, i.e. higher in animal protein, which supports our hypothesis that zone 2 and 3 of the Louis D'haeseleerstraat formed the general cemetery of the convent, where the regular population was buried. The sexual differentiation seen at the Hopmarkt, with younger males but especially older males showing evidence for a richer diet, is not seen at the Louis D'haeseleerstraat. Indeed, at this site, the highest values are achieved by two women. Given that the Hopmarkt was a male convent and the Louis D'haeseleerstraat a female convent, and that the Louis D'haeseleerstraat contains more females whereas the Hopmarkt contained more males, we can conclude that the nuns were buried at the Louis D'haeseleerstraat, and that high-ranking nuns were buried in zone 1.

Of the deviant burial positions, one individual buried facing the other direction stands out. This 35-50 year old man has the highest ∂15N after the two women mentioned above (Fig. 6). It can be hypothesized that he was a priest. In catholic Christian burials, highly placed clerics were buried in the opposite orientation to the lay people, so that, when the day of Judgement arrived, they would be facing their flock when they rose from the grave. The second man buried facing opposite the rest of the individuals was also middle-aged, buried in zone 2. His stable isotopic values fell within the average range of the population. The rest of the individuals with a deviant burial position also do not diverge significantly in their dietary isotopes either. A possible explanation for these 'deviant' burials with average dietary isotopic values is that they simply represent errors which occurred during the burial practice. When an individual is buried in a shroud or a simple coffin, it is not unheard of that some coffins and shrouds got turned the wrong way around by mistake in the process of burial. No clear explanation arises for the man and women buried lying on their side. For the man, as he was still stretched out almost fully, a burial error is possible. The woman, however, a 17+/-2 year old was curled up on her side in such a way that this explanation is unlikely (Fig. 8). Osteological analysis revealed that at the time of death she had active periosteal new bone formation on both distal tibiae and on the medial end of her left clavicle. This indicates that she was experiencing some form of physical stress in the period prior to death. Furthermore, she showed several asymmetries in her spinal column which could have resulted in abnormal posture. Thus, it can be hypothesized that her burial position reflects her spinal pathology.

In summary, the dietary stable isotope data added unique information to our understanding of this population and the social differentiation in burial location. Two women buried in a distinct separate zone of the site consumed significantly more animal protein than the rest of the sampled individuals. In this socio-historic context, marine fish is an important source of animal protein (Van Neer *et al.*, 2016 and Ervynck *et al.*, 2004), and, given the reservoir effect of the marine environment on fish nitrogen values, seafood consumption likely contributed to these elevated ∂15N ratios. This dietary difference, combined with their separate burial location within the convent context, might imply that these women were nuns, possibly of a high rank. It also indicates that this area was distinct from the general cemetery. The dietary isotopes thus support the hypothesis that zones 2 and 3 at the Louis D'haeseleerstraat represent the general cemetery associated with the convent, whereas zone 1 represents a higher status burial location, most likely the cloister garth from a previous building phase, but possibly a previous church.

5.5 Conclusion

The osteoarchaeological data presented here provide information on burial preferences both within the main analyzed site of the female convent at the Louis D'haeseleerstraat, as well as between the different burials contexts available to the citizens of the post-medieval town of Aalst. The burial pattern revealed during excavation, with a large well-organized area of burials (zone 2+3) and one sequestered area (zone 1), suggested that the larger area represented the general cemetery. Osteobiographic data, which show that this smaller separate area held mainly females whereas the other burial area held all ages and both sexes, corroborates this hypothesis. The addition of isotopic data, providing a distinct dietary isotopic signature for the individuals buried in zone 1 and showing that they enjoyed a richer diet with more marine fish, consolidated that this zone indeed held the higher status burials of the Louis D'haeseleerstraat excavation.

When the isotopic data were compared to those gathered for the higher status individuals of the convent excavated at the Hopmarkt and analyzed by Quintelier *et al.*, (2014), it is clear that while the high status females (potentially nuns) of the Louis D'haeseleerstraat had highly similar isotopic signatures to the male clerics of the Hopmarkt, the general cemetery population had a diet lower in animal protein than these clerics and higher status individuals. In the Hopmarkt, average male ∂15N was 12.3 and average female ∂15N 11.4, whereas at the Louis D'haeseleerstraat the male ∂15N was 11.2‰, and female ∂15N 11.04‰, and when the zone 1 women were excluded the average female ∂15N was 10.82‰.

The demographic composition of the Louis D'haeseleerstraat population, with its high amount of subadults, contrasts with the Hopmarkt. This supports the hypothesis of De Groote *et al.*, (2011) that children were more often buried in the general cemetery rather than the cloister alleys or cloister garden.

Finally, the data gathered here also provide a unique insight into disease in the past, and how this post-medieval society treated those who were, due to physical impairments, unable to function 'normally'. SK80, a woman with impairments to the right hand which would have severely limited the use of her arm and lesions to the right leg which would have prevented her from walking normally ate the same general diet as the other individuals in her community. SK 129, a woman wo suffered from widespread metastatic carcinoma, had staining on her leg bones which can be a results of metal clasps on braces which would have helped her retain some mobility. The presence of two women with metastatic carcinoma in this small post-medieval town furthermore suggests that a genetic factor might be in play, and adds unique and valuable data to our growing understanding of the history of cancer, adding to the hypothesis that cancer is not a disease of modernity.

This research proves the value of comparing osteoarcheological data both between different sites embedded in the historical context. In the current archaeological landscape, with an ever-increasing body of data from excavation reports and isolated sites, this three-site comparison underlines the need for larger studies to fully understand the burial dynamics and physical reality of life within the past urban environment.

Acknowledgements

I would like to thank Drs. Jordi Bruggeman and Dr. Natasja Reyns at All-archaeo bvba for allowing me to analyze the Louis D'haeseleerstraat collection, and Kim Quintelier at the Flemish Heritage Institute for allowing me to analyze the Hopmarkt and Saint Martin's church collection.

6

Acts of Life: assessing the use of entheseal change as an indicator of social differentiation in post-medieval Aalst (Belgium)

International Journal of Osteoarchaeology

DOI: 10.1002/oa.2740

Authors:
J. L. A. Palmer
A. L. Waters-Rist

Abstract

Objectives

Lower levels of physical activity are often linked to higher socio-economic status in past societies. As an activity marker, changes at muscle attachment sites known as entheseal changes (EC) have been used with varying efficacy. This study investigates this proposed link between EC as a physical activity marker and socio-economic status within one well-defined temporo-geographic context.

Materials and Methods

EC data from 16 entheses in three skeletal collections from the post-medieval town of Aalst, Belgium, were evaluated using the Coimbra method. The skeletal assemblages represent distinct socio-economic groups, evidenced by historical and dietary isotope data. The Louis D'haeseleerstraat sample represents lower-class individuals (n=46), the Hopmarkt sample middle-class individuals (n=110), and the Saint-Martins church (n=13) upper-class individuals. EC data are tested for correlation to status, age, and sex.

Results

EC patterns did not differ significantly between the groups at any entheses except the M. iliopsoas and common extensor, where the higher class showed more EC. Within the populations, at the Hopmarkt sexual differences were only observed in the Achilles tendon attachment, whereas at the Louis D'haeseleerstraat sexual differences were present in the M. Triceps Brachii, M. Brachioradialis, and Quadriceps entheses. Only some entheses showed a significant correlation with age, and these were inconsistent between populations.

Discussion

EC are not a reliable indicator of socio-economic status in post-medieval Aalst. This could suggest that the hypothesis that richer people were less physically active oversimplifies the lives of people in the past. It could also suggest that EC is not a suitable proxy for physical activity, or that it cannot be used without in-depth knowledge of the types of activities performed by various socio-economic groups on top of consideration of all other etiological factors. This study thus illustrates the caution necessary when using EC as a proxy for social status in past societies.

Keywords

Musculoskeletal stress markers, activity markers, activity reconstruction, socio-economic status, social status, urban, monastic archaeology, guilds

6.1 Introduction

Division of labor is an essential aspect of the social stratification of a society. Less strenuous labor is often linked to higher socio-economic status (Alves Cardoso and Henderson 2010, Maggiano *et al.*, 2008, Mays *et al.*, 2009, Porčić and Stefanović 2009). Thus, patterns of physical activity have been used by bioarchaeologists as an indicator of social differentiation (e.g. Robb *et al,* 2001, Watkins 2012). To assess physical activity in bioarchaeology, many different osteological markers have been used (see Jurmain *et al.*, 2012 for an overview). One such activity marker is the variation in morphology at muscle attachment sites on bone known as entheseal change (EC) (Villotte and Knüsel 2013).

Studies in a host of different archaeological contexts have used EC to identify social differentiation and socio-economic status (e.g. Havelkova *et al.*, 2011, Palmer *et al.*, 2016, Rodrigues 2005, Schrader 2012). However, there is much debate as to the validity of EC as an indicator of physical activity (Jurmain *et al.*, 2012), with the etiological factors involved in EC expression still being identified and assessed for impact (Acosta *et al.*, 2017). Factors such as age (Alves-Cardoso and Henderson 2013) and body size (Godde *et al.*, 2018) have been shown to be more strongly correlated with EC than activity. Various recent studies have applied EC analysis on identified skeletal collections and found no consistent correlation with activity (Alves Cardoso and Henderson, 2010; Milella *et al.*, 2012, Michopoulou 2015, 2017). Yet, other studies did find correlations (e.g. Milella *et al.*, 2015 on an identified collection, Djukic *et al.*, 2018 on an archaeological collection). The current research aims to evaluate whether higher socio-economic status (SES) is correlated with lower levels of EC in a post-medieval, urban, Belgian town. Thus, this study will test the hypothesis that higher status individuals performed less strenuous physical activity, and whether EC can then be used to identify higher status groups. This research will add to our growing understanding of muscle markings and physical activity in the past, and of the utility of EC in bioarchaeology.

6.2 Materials

Three skeletal populations from the post-medieval town of Aalst, Belgium, are used, namely individuals from the Louis D'haeseleerstraat, the Hopmarkt, and the Saint Martin's church (figure 1). These collections were chosen because they represent three distinct socio-economic groups within one geographic context, i.e., the town of Aalst, and within a well-defined time-period (late 15th to late 18th century AD). In AD 1725 the town of Aalst was historically estimated to have a population of 8640 individuals (De Brouwer 1968). It was a thriving economic center renowned for its specialized crafts, most notably the cloth industry (Courteaux 1973), and its monopoly over the trade in hops (Aerts 1999). From eighteenth century surveys we know that the largest professions in the city were baking (bread bakeries), shopkeeping, tailoring, and different cloth industries such as yarn-making and blue-dyeing of cloth (De Schryver 2001). They were both the cornerstones of the post-medieval economy and the largest forms of employment for the people of Aalst. All specialized crafts were structured in guilds, which favored local, city-born apprentices in their admission system. Historical sources also suggest that a strong social distinction was made between the townspeople and 'outsiders' (so called 'niet-poorters'). When people did move into the town, they usually came from the immediate surrounding countryside (De Schryver 2001). This sociohistorical context allows us to assume a limited gene pool for the three skeletal collections, thus minimizing any potential effect of genetic variation on EC.

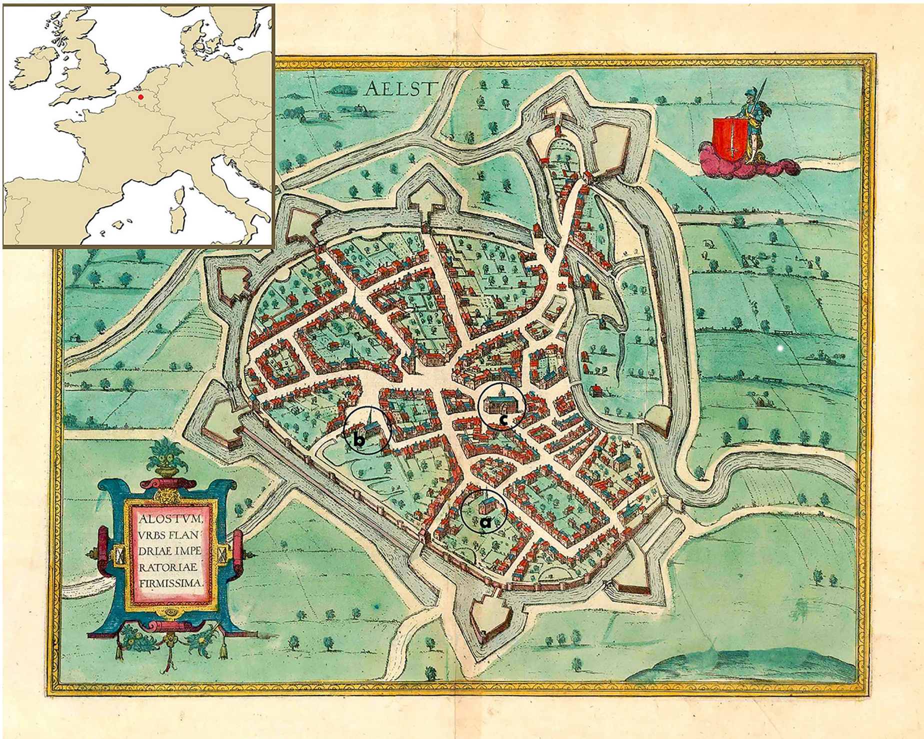


Figure 1: Map by Braun and Hogenberg from AD 1588, with the three sites discussed in this paper circled. a= Louis D'haeseleerstraat convent, b= Hopmarkt convent, c=Saint Martin's church. Location within Northwestern Europe in top left corner inset.

The first skeletal collection was excavated at the Louis D'haeseleerstraat. This site was the location of a female convent with a general population cemetery that was the least expensive place to be buried in post-Medieval Aalst (De Groote *et al.*, 2011). Thus, the skeletal population (n=46) represents individuals from the general population of low socio-economic status. The sisters of the Franciscan order started the convent around AD 1450. Later, in AD 1667, the sisters of the annunciation took over until the convent's termination by the French republic in AD 1797 (Bruggeman 2016, Bruggeman *et al*,. in prep). Thus, the individuals buried in this cemetery can be dated between AD 1450 and 1797.

The second skeletal population, excavated at the Hopmarkt, contains individuals from the cloister garth and alleys of the former Carmelite monastery (n=110) (De Groote *et al.*, 2018; De Maeyer *et al.*, 2014). People were interred in the monastery from AD 1497 to 1797 (De Maeyer *et al.*, 2014). Burial in the cloister garth and alleys would have cost lay people more than being buried in the general cemetery, but was still cheaper than burial inside the church (De Groote *et al.*, 2011). Therefore, the Hopmarkt population represents middle-class individuals and clerics (De Groote *et al.*, 2011). Based on historical information, the middle class would have been largely made up by higher ranking members of the guilds and their families (De Schryver 2001). Both men and women were interred, as well as non-adults (<18 years), although there are relatively fewer children buried here than in the general cemetery (De Groote *et al.*, 2011).

In addition to the historical evidence of the middle-class status of the skeletal collection buried at the Hopmarkt, dietary isotopic analyses of the Hopmarkt and Louis D'haeseleerstraat collections further support their different social status. The stable isotope ratios of carbon (δ13C) and nitrogen (δ15N) from the men and women buried at The Hopmarkt, as published by Quintelier and colleagues (2014), attest to them eating a diet richer in animal protein, including more marine animals, than the individuals at the Louis D'haeseleerstraat, whose δ15N ratios were lower in both men and women (Palmer in press). In this socio-cultural context this richer diet is linked to higher social status (Polet and Katzenberg 2002, 2003).

The last skeletal population used in this study originates from inside the Saint Martin's church. This small subset of individuals (n=13) thus represents people buried in the most expensive of the three burial locations in post-medieval Aalst. Based on church building phases, this population is dated to AD 1655-1782 (De Groote and Moens 1999).

Only adult individuals are included for EC analyses, as EC presents differently in growing individuals (Villotte 2006) and a method to evaluate EC in growing individuals is still under development (Palmer *et al.*, 2017). Both men and women are included (table 1). Individuals for whom sex estimation was indeterminate, or for whom age could not be reliably assessed, were omitted. Individuals showing any kind of pathology that could influence EC (i.e., DISH and other bone-forming diseases, as specified by Henderson (2008)), or any kind of pathology which would have had a profound impact on their physical activity (i.e., pathologies which limited mobility, badly healed fractures, etc.) were also omitted. All osteological analyses were done by the first author.

	18-25 years		26-35 years		36-50 years		50+ years		Total
	F	**M**	**F**	**M**	**F**	**M**	**F**	**M**	
Louis D'haeseleerstraat	2	6	7	5	8	9	5	3	46
Hopmarkt	8	10	16	25	14	21	6	10	110
Saint Martin's Church	1	0	1	3	2	1	3	0	13

Table 1: Demographic composition of the three samples (F=female; M=male).

6.3 Methods

Individuals were grouped into male and female categories, and into four age categories, namely early young adult (18-25 years), late young adult (26-35 years), middle adult (36-50 years) and old adult (50+ years) (table 1). Age was estimated from the morphology of the auricular surface (Buckberry and Chamberlain 2002), pubic symphysis (Suchey and Brooks 1990), and sternal rib end (Işcan *et al.*, 1984), as well as through dental attrition (Maat 2001), cranial suture closure (Meindl and Lovejoy 1985), and the fusion state of late fusing epiphyses (i.e. the sternal end of the clavicle, spheno-occipital synchondrosis, iliac crest, and ischial tuberosities) (Schaefer *et al.*, 2009). Sex was estimated through from the cranium, mandible, and pelvis using the Workshop for European Archaeologists guideline (Ferembach *et al.*,1980) and Phenice (1969), and through metrics (McCormick *et al.*, 1991, Stewart 1979, and Steyn and Işcan 1999).

Entheseal change was recorded using the Coimbra method (Henderson *et al.*, 2016) with the update for the M. biceps brachii on the radius (Henderson *et al.*, 2017a). Sixteen entheses were analyzed for EC, nine on the upper limb and seven on the lower limb. Only fibrocartilaginous attachment sites are used as the method is designed for these. Specifically, on the humerus, the M. supscapularis, M. supra-and infraspinatus, M. teres minor, common extensor (figure 2), and common flexor are used. On the ulna, the M. brachialis and M. triceps brachii are analyzed, and on the radius the M. brachioradialis and M. biceps brachii attachment sites are recorded. For the lower limb, the M. iliopsoas, M. gluteus minimus and M. gluteus medius on the femur, the M. quadriceps and M. popliteus on the tibia, the M. quadriceps on the patella, and the Achilles tendon on the calcaneus are recorded. All entheses will be analyzed and tested separately, as each enthesis has a unique pattern and spectrum of potential change. To test for asymmetry, Wilcoxon paired t-tests are performed (Noldner *et al.*, 2013), and to test for correlation with age, sex, and site/social status, Pearson's chi squares are done. It must be noted that the Saint Martin's church sample is small. It was included in the statistical testing but due to its small sample size, test results from this site will be less reliable. All statistical tests are performed using IBM SPSS 23. Statistical significance is set at $p \leq 0.05$.

Figure 2: Example of entheseal changes occurring at the common extensor attachment site on the lateral epicondyle of the humerus. L: enthesis on the right humerus with no EC. R: enthesis on the left humerus with bone formation in zone 1 (visible as lipping along the edge) and porosity and bone formation in zone 2.

6.4 Results

Old adults have been shown to be less reliable for activity reconstruction (Niinimäki *et al.*, 2013), therefore the Hopmarkt and Louis D'haeseleerstraat samples were compared without the old age category individuals as well as with these 50+ year individuals. Both samples gave the same results (appendix C), therefore the old adults were included in the sample to achieve a larger sample size and generate more robust statistical comparisons.

For the Louis D'haeseleerstraat sample, no statistically significant asymmetry was found between the left and right sides for any of the analyzed muscle attachment sites (table 2). For the Hopmarkt, only the right quadriceps enthesis on the patella scored statistically higher than the left ($p=0.023$, $Z=-2.271$, $n=66$). For the Saint Martin's church, no statistically significant asymmetry was found either, although statistical analyses were not possible for all entheses here due to the small sample size. Because of this lack of asymmetry for all EC at all sites except the patellar quadriceps attachment site at the Hopmarkt, left and right sides are combined for further analyses. When both left and right sides were recorded for an individual, the maximum score is used; when only the left or right side was recorded, that score is used.

6.4.1 Status

Of all entheses included in this study, only two showed any correlation with social status (table 3). The first is the common extensor enthesis on the distal humerus, which had a statistically significant relationship with status when comparing the two main sites. i.e., the Louis D'haeseleerstraat (lowest class) and Hopmarkt (middle class) ($p=0.044$, $\chi(1)=11.414$, $n=106$). In this case, there was more EC at the common extensor in the Hopmarkt sample. The second is the M. iliopsoas, which showed more EC in the high status Saint Martin's church sample when compared to the Louis D'haeseleerstraat sample(p=0.029, χ(1)=10.832, n=35). For all other entheses, no relation to status was found when comparing the three sites.

	Louis D'Haeseleerstraat					*Hopmarkt*					*Saint-Martin's church*				
	n	**mean**	**SD**	**Z**	**p**	**n**	**mean**	**SD**	**Z**	**p**	**n**	**mean**	**SD**	**Z**	**p**
L M. Subscapularis	25	1.24	1.589			45	1.4	1.572			11	0.73	1.421		
R M. Subscapularis	35	1.26	1.633	-0.9	0.379	49	1.45	1.990	-0.42	0.672	11	1.09	1.044	-0.37	0.713
L M. Supra+Infraspinatus	24	0.33	0.637			35	0.89	1.345			12	0.75	0.866		
R M. Supra+Infraspinatus	31	0.74	0.999	-1.4	0.177	35	1.43	2.187	-1.04	0.297	10	1.20	1.549	-1.82	0.068
L Extensor	26	0.58	0.902			43	0.95	1.308			8	1.38	1.061		
R Extensor	31	0.42	0.923	-1.0	0.317	47	0.85	1.021	-1.00	0.317	6	0.67	0.516	-1.63	0.102
L Flexor	27	0.11	0.320			35	0.29	0.710			4	0.50	0.577		
R Flexor	26	0.15	0.368	-1.0	0.317	49	0.39	0.702	-2.00	0.460	0				
L M. Teres Minor	20	0.20	0.410			30	0.53	0.900			6	0.17	0.408		
R M. Teres Minor	24	0.17	0.381	-1.4	0.157	35	0.60	0.775	-1.00	0.317	5	0.20	0.447	0.00	1.000
L M. Brachialis	36	1.14	1.313			69	0.74	0.816			10	1.00	1.491		
R M. Brachialis	39	0.90	1.252	-0.6	0.564	77	0.62	0.859	-0.22	0.830	9	0.67	1.000	0.00	1.000
L M. Triceps Brachii	31	1.13	1.204			56	1.16	1.262			7	0.57	0.535		
R M. Triceps Brachii	36	0.86	0.990	-0.3	0.782	64	1.20	1.184	0.00	1.000	6	1.00	0.632	-1.00	0.317
L M. Brachioradialis	15	0.40	0.828			37	0.59	0.686			8	0.63	0.744		
R M. Brachioradialis	23	0.39	0.499	0.0	1	46	0.76	0.736	-0.43	0.671	3	0.67	1.155	-1.00	0.317
L M. Biceps Brachii	34	1.06	1.043			68	1.32	1.354			10	1.10	1.101		
R M. Biceps Brachii	38	1.16	1.151	-0.9	0.372	72	1.50	1.394	-0.59	0.559	8	1.63	1.598	-0.54	0.589
L M. Iliopsoas	25	1.08	1.038			47	1.32	1.431			3	2.00	1.000		
R M. Iliopsoas	24	1.04	0.908	-1.6	0.102	52	1.02	1.129	-1.07	0.284	4	2.00	2.309		
L M. Gluteus Minimus	24	0.38	0.495			44	1.14	1.391			3	0.00	0.000		
R M. Gluteus Minimus	27	0.52	0.700	-1.3	0,18	51	1.18	1.466	-0.66	0.507	3	1.67	2.082		
L M. Gluteus Medius	21	0.57	0.676			31	0.84	1.068			3	0.00	0.000		
R M. Gluteus Medius	20	0.75	0.851	-0.6	0.577	37	0.86	1.032	-1.16	0.248	1	0.00			
L Quadriceps (tibia)	29	0.76	0.636			45	1.11	1.112			9	0.89	0.782		
R Quadriceps (tibia)	27	0.78	0.751	0.0	1	40	1.15	1.167	-1.21	0.225	5	1.00	1.000	0.00	1.000
L M. Popliteus	34	0.53	0.788			69	0.49	0.720			7	1.14	0.900		
R M. Popliteus	34	0.62	0.817	-0.4	0.655	67	0.55	0.724	-1.39	0.166	6	0.83	1.329	0.00	1.000
L Quadriceps (patella)	18	0.72	0.895			30	1.33	1.124			8	1.13	1.246		
R Quadriceps (patella)	17	0.65	0.786	-1.0	0.317	36	1.28	1.256	-2.27	0.023	6	0.83	1.329	0.00	1.000
L Achilles	23	0.96	0.976			24	1.79	1.103			3	1.00	1.000		
R Achilles	22	1.09	0.921	-1.0	0.317	34	1.65	0.950	-0.45	0.655	6	1.17	0.753	0.00	1.000

Table 2: Wilcoxon paired t-test for asymmetry per entheses in the three skeletal collections. Statistically significant asymmetry in bold, mean values and SD added for left and right sides.

	Louis D'Haeseleerstraat vs. Hopmarkt			*Louis D'Haeseleerstraat vs. Saint-Martin's church*			*Hopmarkt vs. Saint-Martin's church*		
	n	**χ(1)**	**p**	**n**	**χ(1)**	**p**	**n**	**χ(1)**	**p**
M. Subscapularis	107	8.877	0.262	51	2.792	0.834	80	2.107	0.954
M. Supra+Infraspinatus	89	6.663	0.465	48	5.393	0.249	65	4.175	0.759
Extensor	106	11.414	0.044	18	8.844	0.065	76	5.307	0.380
Flexor	93	3.888	0.274	39	1.82	0.177	62	2.364	0.500

M. Teres Minor	82	6.031	0.197	39	0.145	0.703	57	1.115	0.892
M. Brachialis	135	6.997	0.221	55	2.125	0.832	102	9.426	0.051
M. Triceps Brachii	116	3.018	0.697	48	5.089	0.278	80	3.811	0.577
M. Brachioradialis	87	3.755	0.440	36	0.303	0.860	67	0.490	0.974
M. Biceps Brachii	133	1.627	0.898	52	6.945	0.225	101	5.907	0.315
M. Iliopsoas	94	2.779	0.734	35	10.832	0.029	71	7.417	0.191
M. Gluteus Minimus	95	9.327	0.156	37	7.074	0.070	68	7.840	0.250
M. Gluteus Medius	75	2.488	0.478	28	2.900	0.405	53	4.148	0.246
Quadriceps (tibia)	87	6.094	0.297	41	0.221	0.895	64	1.394	0.925
M. Popliteus	114	1.023	0.796	45	3.893	0.273	85	4.310	0.230
Quadriceps (patella)	69	5.738	0.333	30	4.379	0.223	53	5.175	0.395
Achilles	67	10.067	0.073	32	0.732	0.866	45	3.415	0.636

Table 3: Pearson's Chi squares for relationship between site and EC scores. Statistically significant correlations in bold.

6.4.2 Sex

Most entheses analyzed in this study showed no correlation with sex (table 4). Correlation was evaluated for each site separately. At the Louis D'haeseleerstraat (lowest class), the M. triceps brachii showed higher EC scores in women ($p=0.012$, $\chi(1)=12.789$, $n=42$), whereas the quadriceps entheses on the tibia showed higher EC scores in men ($p=0.018$, $\chi(1)=8.067$, $n=32$). At the Hopmarkt, there were no statistically significant correlation between any of the entheses and sex. Finally, at the Saint Martin's church, the M. biceps brachii showed higher EC scores in men ($p=0.019$, $\chi(1)=10$, $n=10$), although it must be noted that this is based on just 10 individuals (6 women and 4 men).

	Louis D'Haeseleerstraat			*Hopmarkt*			*Saint-Martin's church*		
	n	**χ(1)**	**p**	**n**	**χ(1)**	**p**	**n**	**χ(1)**	**p**
M. Subscapularis	39	4.487	0.611	68	7.735	0.357	12	5.200	0.267
M. Supra+Infraspinatus	36	1.522	0.677	53	8.745	0.271	12	6.333	0.176
Extensor	39	4.692	0.320	67	3.967	0.554	9	3.600	0.308
Flexor	35	-0.144	0.393	58	1.735	0.629	4	1.333	0.248
M. Teres Minor	32	1.205	0.272	50	2.060	0.725	7	1.120	0.290
M. Brachialis	44	5.201	0.392	91	0.986	0.805	11	3.942	0.414
M. Triceps Brachii	42	12.789	0.012	74	3.895	0.565	6	3.000	0.223
M. Brachioradialis	28	6.304	0.043	59	3.828	0.430	8	1.333	0.513
M. Biceps Brachii	42	7.772	0.169	91	4.041	0.543	10	10.000	0.019
M. Iliopsoas	29	3.028	0.387	65	9.553	0.089	2	6.000	0.112
M. Gluteus Minimus	32	2.083	0.353	63	7.836	0.250	5	2.222	0.329
M. Gluteus Medius	25	1.407	0.704	50	3.974	0.264	3		
Quadriceps (tibia)	32	8.067	0.018	55	7.043	0.217	9	3.263	0.196
M. Popliteus	37	0.866	0.834	77	2.844	0.416	8	3.333	0.343
Quadriceps (patella)	23	4.191	0.242	46	4.710	0.452	7	3.080	0.214
Achilles	27	2.914	0.405	40	16.455	0.019	13	2.270	0.518

Table 4: Pearson's Chi squares for relationship between sex and EC scores at the three sites. Statistically significant correlations in bold. The M. Gluteus medius correlation with sex could not be calculated at the Saint Martin's church as too few individuals were available for analysis.

6.4.3 Age

Entheses were tested for correlation with age per site. At the Louis D'haeseleerstraat, only the M. supra-and infraspinatus on the proximal humerus (p=0.020, $\chi(1)$=19.746, n=36), M. gluteus medius attachment site on the proximal femur (p=0.001, $\chi(1)$=28.897, n=25) and Achilles tendon entheses on the calcaneus had a statistically significant correlation with age(p=0.018, $\chi(1)$=20.013, n=27) (table 4). At the Hopmarkt, the M. supra-and infraspinatus and Achilles entheses were also significantly correlated with age (respectively p=0.036, $\chi(1)$=33.982, n=53, and p=0.004, $\chi(1)$=33.582, n=40), as were the common extensor enthesis (p=0.008, $\chi(1)$=31.167, n=67), the M. biceps brachii (p=0.027, $\chi(1)$=27.272, n=91), M. iliopsoas (p=0.012, $\chi(1)$=29.878, n=65) and M. gluteus minimus (p=0.024, $\chi(1)$=31.754, n=63). No significant correlations between EC and age were found at the Saint Martin's church site.

	Louis D'Haeseleerstraat			*Hopmarkt*			*Saint-Martin's church*		
	n	**$\chi(1)$**	**p**	**n**	**$\chi(1)$**	**p**	**n**	**$\chi(1)$**	**p**
M. Subscapularis	39	21.639	0.248	68	30.559	0.081	12	12.580	0.4
M. Supra+Infraspinatus	36	19.746	0.02	53	33.982	0.036	12	1.067	0.324
Extensor	39	15.18	0.232	67	31.167	0.008	9	10.125	0.34
Flexor	35	4.583	0.205	58	15.571	0.076	4		
M. Teres Minor	32	1.865	0.601	50	13.151	0.358	7	0.0467	0.792
M. Brachialis	44	23.046	0.083	91	4.590	0.868	11	11.825	0.46
M. Triceps Brachii	42	17.915	0.118	74	20.671	0.148	6	1.500	0.827
M. Brachioradialis	28	7.661	0.264	59	10.433	0.578	8	4.000	0.406
M. Biceps Brachii	42	9.134	0.870	91	27.272	0.027	10	5.333	0.804
M. Iliopsoas	29	9.425	0.399	65	29.878	0.012	6	8.250	0.220
M. Gluteus Minimus	32	7.902	0.245	63	31.754	0.024	5	5.556	0.235
M. Gluteus Medius	25	28.897	0.001	50	11.723	0.229	3		
Quadriceps (tibia)	32	6.044	0.418	55	19.659	0.185	9	5.925	0.432
M. Popliteus	37	13.409	0.145	77	13.334	0.148	8	7.467	0.280
Quadriceps (patella)	23	9.626	0.382	46	11.842	0.706	7	3.500	0.478
Achilles	27	20.013	0.018	40	33.582	0.004	13	7.728	0.562

Table 4: Table 3: Pearson's Chi squares for relationship between age and EC scores at the three sites. Statistically significant correlations in bold.

6.5 Discussion

The historical and dietary isotope data on these three skeletal collections, paired with their archaeological context, provide clear evidence of the social classes they represent. The EC data, however, do not reflect the different socio-economic groups. It must be noted that the high-class group had a very limited sample size (13 individuals), making any results when comparing this group to the other two groups inevitably less robust.

Only the common extensor was significantly correlated with status when comparing the low to the middle-class group, and the iliopsoas when comparing low to high class group. In both these entheses, the high-class group had higher levels of EC than the low-class group. If EC were a direct indicator of strenuous physical activity, this would mean the higher-class individuals were more physically active than the lower-class in activities using these two muscles. However, there are caveats for the positive correlation between EC and socio-economic status for both these entheses. The common extensor was one of the EC positively correlated with age in the middle-class group, but not in the lower-class group, which signifies that other etiological factors might have (co-)created this correlation. The other potential sign of difference in activity between the socio-economic groups, namely increased EC levels in higher-class M. iliopsoas, is also not a very reliable correlation, given that the higher-class iliopsoas sample consists of just six individuals. For all entheses except these two, there was no statistically significant correlation between EC and status. Thus, EC did not provide a useful proxy for social differentiation in this Flemish post-medieval urban context.

It is possible that the levels of physical activity in which the different socio-economic groups engaged were not different enough to show up in the skeletal record. Perhaps we over-simplify the lives of people in the past when we divide a society into socio-economic groups and postulate that this will determine their daily lives to such an extent that their bodies and skeletons will reflect social status. The broad spectrum of physical activities represented by the different crafts which dominated the Aalst economy could also potentially obscure any activity patterns resulting from social status. From an osteoarchaeological perspective, the specialized trades represent a wide spectrum of physical activities. Shopkeeping would not necessarily require intensive manual labor, but it could well require standing for prolonged periods of time. Dyeing cloth, on the other hand, was a tasking physical craft, while tailoring would require more fine motor skills but less extensive use of large muscle groups. Thus, individuals with similar socio-economic status could have engaged in very different physical activities in their professional lives. Finally, it is also possible that EC data recorded macroscopically on the human skeleton are not a sufficiently direct reflection of physical activity load for them to be used to assess activity patterns in this context.

Alongside this primary research question of correlation between socio-economic status and EC, correlations between EC and sex and age are also assessed for in the three skeletal collections. The correlations between sex and EC were not consistent between the three groups. The lower-class population represented by the Louis D'haeseleerstraat showed some significant differences between men and women. The M. triceps brachii, an important biomechanical element of the upper body, essential in the extension of the forearm (Landin *et al.*, 2018) displayed more EC in women than men in this lower-class cemetery. In a contemporary Dutch rural collection for which high levels of physical activity were present, the M. triceps brachii was also more pronounced in women than men (Palmer *et* *al.*, 2016). This could indicate that the lower-class women of Aalst performed strenuous manual labor, similar to the activity pattern of a more rural setting.

This sex difference in M. triceps brachii EC could also point to differing gendered divisions of labor within the different socio-economic groups. There is an anatomical difference in the elbow between men and women which could also form part of the reason for this higher level of EC in women. The angle of the elbow differs between the sexes, being angled slightly more away from the body in women (Paraskevas *et al.*, 2004, Yilmaz *et al.*, 2005). This greater angle changes the angle of pull of the attaching muscles slightly, which could potentially make the enthesis more susceptible to EC.

At the Louis D'haeseleerstraat, the males exhibited significantly higher EC scores than the women at the quadriceps attachment on the tibia, although the attachment of the quadriceps on the patella showed no significant correlation with sex. While it must be noted that the sample size for the tibia was higher than for the patella (n=32 and n=23 respectively), this highlights how different attachment sites, even of the same muscle, can give different results when analysed for EC. The fact that the lowest class population showed statistically significant correlations between sex and EC in both the upper and lower limb whereas the middle- and higher class populations showed none could point to a different division of labor between the classes. However, as only two of the sixteen entheses were significantly correlated with sex this hypothesis remains uncertain. The highest-class sample, as represented by the Saint-Martin's church individuals, like the middle class Hopmarkt sample, did not show any significant correlations between EC and sex, yet sample size limits possible interpretations (n=13).

In much the same fashion as the correlations between sex and EC, in the current study, only some entheses were correlated with age, and these were not consistent across the three skeletal populations. This is remarkable, as in most studies on muscle attachment site morphology, age is positively correlated with higher levels of EC (Meyer *et al.*, 2011), both when age is assessed osteologically (e.g., Weiss 2007, Molnar *et al.*, 2011, Michopoulou *et al.*, 2017, Palmer *et al.*, 2018) and when it is known archivally (e.g. Alves Cardoso and Henderson 2010, Milella *et al.*, 2012, Villotte *et al.*, 2010). At the Saint Martin's church sample, none of the entheses were significantly correlated with age, although this could be due to the limited sample size. At the Louis D'haeseleerstraat, three entheses were positively correlated for EC with age, the M. supra-and infraspinatus, the M. gluteus medius and the Achilles. EC at the Achilles and the M. supra-and infraspinatus were also positively correlated with age at the Hopmarkt, along with EC at the common extensor, M. iliopsoas, and M. gluteus minimus. This result, with correlations for some EC with age but not for others, and with only the Achilles and M. supra-and infraspinatus consistently correlated with age in the two largest populations, suggests that, at least in this population, other factors than age were influencing EC to a greater extent. This hypothesis is supported by a study on archivally identified laborers (i.e., a group with high physical activity levels), where age contributed a maximum of 44% to EC (Henderson *et al.*, 2017b). Furthermore, the effect of age has been shown to vary between entheses in other studies as well; Henderson and colleagues (2012) analyzed five entheses in a male sample and found that one trait of EC incorporated in the Coimbra method, namely bone formation, was correlated with age in the common extensor, M. subscapularis, left M. iliopsoas and left Achilles, but not with the M. biceps brachii, nor the right side of the two lower limb entheses. These results partially overlap with the Hopmarkt results, where the common extensor, M. iliopsoas and Achilles were correlated with age.

6.6 Conclusion

EC are not a reliable indicator of social status in the post-medieval town of Aalst based on the sixteen entheses used in this study. Socio-economic status of the three skeletal assemblages was known through archival data and dietary isotopes, but no consistent correlation between EC and status was found. Correlations between sex and EC differed between the three socio-economic groups, which could point to a potential difference in their division of labor. Age was not consistently correlated with EC at the three sites. Few entheses were positively correlated with age, and only two were correlated with age in the two largest skeletal collections: , namely the M. supra- and infraspinatus and the Achilles. This could indicate that some entheses, such as these two, are more susceptible to age-related changes than others. The inconsistency in correlations between EC, age, and sex could also indicate that other etiological factors are at play. Furthermore, it is also possible that our assumption that richer individuals performed less physical activity than poorer people in this sociohistorical context is an oversimplification of the lives these people led. The current research thus illustrates that EC cannot be used as a marker for socio-economic groups in this context, and that caution is necessary when trying to infer social differentiation through EC in skeletal populations.

Acknowledgements

The authors would like to thank Drs. Jordi Bruggeman and Dr. Natasja Reyns at All-archaeo bvba for granting access to the Louis D'haeseleerstraat collection, Wouter De Maeyer and Stijn Van Cauwenbergh at Solva archaeology for granting access to the Hopmarkt collection, and Kim Quintelier at the Flemish Heritage Institute for granting access to the Saint Martin's church collection.

7

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 morphology. 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 research 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.

References

— A —

Acosta, M. A., Henderson, C. Y., and Cunha E. 2017. The Effect of Terrain on Entheseal Changes in the Lower Limbs. International Journal of Osteoarchaeology 27, 828-838.

Aerts, E. 1999. Hop en bier. Handelsrelaties tussen Aalst en Lier (17de-18de eeuw). Het Land van Aalst 51, 101-126.

Alves Cardoso, F. 2008. A Portrait of Gender in Two 19th and 20th Century Portuguese Populations: A paleopathological Perspective. Department of Archaeology, Durham University: Durham.

Alves Cardoso, F. and Henderson, C. Y. 2010. Enthesopathy Formation in the Humerus: Data from Known Age-at-Death and Known Occupation Skeletal Collections. American Journal of Physical Anthropology 141, 550-560.

Alves-Cardoso, F. and Henderson, C. 2013. The Categorization of Occupation in Identified Skeletal Collections: a Source of Bias? International Journal of Osteoarchaeology 23, 186–196.

Angel, J.L. 1945. Skeletal Material from Attica. Hesperia 14, 279-363.

Angel, J.L. 1966. Early Skeletons from Tranquillity, California. Smithsonian Contributions to Anthropology Volume 2. Smithsonian Press: Washington.

Apostolakos, J., Durant, T. J., Dwyer, C. R., Russell, R. P., Weinreb, J. H., Alaee, F., Beitzel, K., McCarthy, M.B, Cote, M.P., and Mazzocca, A. D. 2014. The Enthesis: a Review of The Tendon-To-Bone Insertion. Muscles, Ligaments and Tendons Journal 4(3), 333–342.

— B —

Baetsen, S. 2001. Graven in de Grote Kerk. Het Fysisch Antropologisch Onderzoek van de Graven in de St. Laurenskerk van Alkmaar. Rapporten over de Alkmaarse Monumentenzorg en Archeologie (RAMA) 8. Gemeente Alkmaar: Alkmaar.

Baldoni, M., Nardi, A., Muldner, G., Lelli, R., Gnes, M., Ferraresi, F., Meloni, V., Cerino, P., Greco, S., Manenti, G., Angle, M., Rickards, O., and Martínez-Labarga, C. 2016.

Archaeo-Biological Reconstruction of the Italian Medieval Population of Colonna (8th–10th Centuries CE). Journal of Archaeological Science: Reports 10, 483-494. DOI: 10.1016/j.jasrep.2016.11.013.

Benjamin, M., Evans, E.J., and Copp, L. 1986. The Histology of Tendon Attachments to Bone in Man. Journal of Anatomy 149, 89-100.

Benjamin, M., Kumai, T., Milz, S., Boszczyk, B.M., Boszczyk, A.A., and Ralphs J.R. 2002. The Skeletal Attachment of Tendons – Tendon 'Entheses.' Comparative Biochemistry and Physiology Part A 133, 931-944.

Benjamin, M., Toumi, H., Ralphs, J.R., Bydder, T.M., and Milz, S. 2006. Where Tendons and Ligaments Meet Bone: Attachment Sites ('Entheses') in Relation to Exercise and/or Mechanical Load. Journal of Anatomy 208(4), 471–490. DOI: 10.1111/j.1469-7580.2006.00540.x

Binde, M., Cochard, D., and Knüsel, C.J. 2018. Entheseal Changes: a Method to Detect Activities in Archaeological Horse Skeletons. Paper presented at the 24th Annual Meeting of the European Association of Archaeologists, Barcelona, Spain 5th-8th September 2018.

Brouwer, J. De. 1968. Demografische Evolutie in het Land van Aalst 1570-1800. Pro Civitate Historische Uitgaven: Brussel.

Bruggeman, J. 2016. Archeologische Opgraving Aalst – Louis D'Haeseleerstraat (Theresianenklooster): Evaluatierapport. All-Archeo bvba: Temse.

Bruggeman, J., Coremans L., Claessens, L., and Reyns, N. in prep. Archeologische Opgraving Aalst – Louis D'Haeseleerstraat. Annunciaden- en Theresianenklooster, Temse (met Bijdrage van Jessica Palmer). Rapporten All-Archeo bvba 316.

Buckberry, J.L. and Chamberlain, A.T. 2002. Age Estimation from the Auricular Surface of the Ilium: a Revised Method. American Journal Of Physical Anthropology 119, 231–239.

— C —

Callebaut, D. 1983. De Topografische Groei van Aalst of Hoe een Zelhof een Gebastioneerde Stad Werd. Archaeologia Belgica 255, 227-249.

Capasso, L., Kennedy, K. A. R., and Wilczak, C. A. 1999. Atlas of Occupational Markers on Human Remains. Journal of paleopathology: Monographic Publications: Volume 3. Edigrafial: Teramo.

Carroll, G., Waters-Rist, A. L., and Inskip, S.A. 2016. Intranasal Papilloma: A Suspected Case of Intranasal Inverted Schneiderian Papilloma in an Adult Male from Post-Medieval Europe. International Journal of Paleopathology 12, 53-62.

Castex, D. 1990. Insertion du Grand Pectoral et du Grand Rond Sous Forme de Fosse.

Problème du Recrutement au Sein de la Nécropole de Saint-Jean-des-Vignes à Chalon-sur-Saône (Saône-et-Loire). Bulletins et Mémoires de la Société d'anthropologie de Paris, Nouvelle Série 2 (3-4), 185-189.

Churchill, S.E. and Morris, A.G. 1998. Muscle Marking Morphology and Labour Intensity in Prehistoric Khoisan Foragers. International Journal of Osteoarchaeology 8, 390–411.

Courteaux, F. and Martens, D. 1973. Het Leven in de Stad. Het Land van Aalst, 25 (5), 258-263.

— D —

Davis, C. B., Shuler, K. A., Danforth, M. E., and Herndon, K. E. 2013. Patterns of Interobserver Error in the Scoring of Entheseal Changes. International Journal of Osteoarchaeology 23, 147-151.

Djukic, K., Miladinovic-Radmilovic, N., Draskovic, M., and Djuric, M. 2018. Morphological Appearance of Muscle Attachment Sites on Lower Limbs: Horse Riders Versus Agricultural Population. International Journal of Osteoarchaeology, 1–13. DOI:10.1002/oa.2680

Dörfl, J. 1980. Migration of Tendinous Insertions. I. Cause and Mechanism. Journal of Anatomy 131 (1), 179–195.

Dörfl, J. 1980. Migration of Tendinous Insertions. II. Experimental Modifications. Journal of Anatomy 131 (2), 229–237.

Drukker, J.W. and Tassenaar, V. 1997. Paradoxes of Modernization and Material Well-Being in the Netherlands during the Nineteenth Century. In: Steckel, R.H. and Floud, R. (eds.), Health and Welfare during Industrialization. University of Chicago Press: Chicago; 331–378.

Dutour, O. 1986. Enthesopathies (Lesions of Muscular Insertions) as Indicators of the Activities of Neolithic Saharan Populations. American Journal of Physical Anthropology 71, 221–224.

— E —

Ervynck, A., Van Neer, W., and Pieters, M. 2004. How the North was Won (and Lost Again). Historical and Archaeological Data on the Exploitation of the North Atlantic by the Flemish Fishery. In: Housley, R.A. and Coles, G. (eds.), Atlantic Connections and Adaptations. Economies, Environments and Subsistence in Lands Bordering the North Atlantic. Oxbow: Oxford; 230-239.

Eshed, V., Gopher, A., Galili, E., and Hershkovitz, I. 2004. Musculoskeletal Stress Markers in Natufian Hunter-Gatherers and Neolithic Farmers in the Levant: the Upper Limb. American Journal of Physical Anthropology 123, 303–315.

— F —

Falger, V. S. E., Beemsterboer-Köhne, C. A., and Kölker, A. J. 2012. Nieuwe kroniek van de Beemster. Canaletto: Alphen aan den Rijn.

Ferembach, D., Schwindezky, I., and Stoukal, M. 1980. Recommendation for Age and Sex Diagnoses of Skeletons. Journal of Human Evolution 9, 517–549.

Finnegan, M. 1978. Non-Metric Variation of the Infracranial Skeleton. Journal of Anatomy 125 (1), 23–37.

— G —

Godde, K., Wilson Taylor, R.J., and Gutierrez, C. 2018. Entheseal Changes and Demographic/Health Indicators in the Upper Extremity of Modern Americans: Associations with Age and Physical Activity. International Journal of Osteoarchaeology 28: 285-293. DOI: 10.1002/oa.2653

Gordon, C. and Buikstra, J. 1981. Soil pH, Bone Preservation, and Sampling Bias at Mortuary Sites. American Antiquity 46 (3), 566-571. DOI:10.2307/280601

Gray, H. 1977. Gray's Anatomy. Bounty Books: London.

Griffioen, A. 2011. Inventariserend Veldonderzoek te Middenbeemster, Middenweg 148. Hollandia reeks 346. Zaandijk.

Griffioen, A., Lemmers, S.A.M., Schats R., Waters-Rist A.L. and Hoogland M.L.P. 2012. Middenbeemster-Middenweg 148. De Archeologische Kroniek van Noord-Holland 2011: Provincie Noord-Holland, 60-64.

Groote, K. De and Moens, J. 1999. Noodonderzoek in de St-Martinuskerk te Aalst (O.-Vl.). Archaeologia Mediaevalis 28, 104-105.

Groote, K. De, Maeyer, W. De, Moens, J., Quintelier, K., Van Cleven, F., Vanden Berghe, I., and Vernaeve, W. 2011. Het Karmelietenklooster van Aalst (Prov. Oost-Vl.) (1497-1797): het Gebouwenbestand, de Begravingen en het Fysisch-Antropologische Onderzoek. Relicta 8, 83-250.

Groote, K. De. 2010. The Contribution of Archaeological Sources to the Research of the Formation of Towns. The Example of Aalst, a Border Town in the County of Flanders. In: De Groote, K., Tys, D., and Pieters, M. (eds.), Exchanging Medieval Material Culture. Studies on Archaeology and History Presented to Frans Verhaeghe. Relicta Monografieën 4. Onroerend Erfgoed: Brussel; 249-266.

Groote, K. De, Moens, J., and Quintelier, K. 2018. The Carmelite Monastery in Aalst, Belgium, Province of East Flanders (1497–1797): An Urban Burial Ground in a Monastic Environment. In: van Oosten, R., Schats, R., Fast, K., Arts, N., and Bouwmeester, J. (eds.), The Urban Graveyard: Archaeological Perspectives. Sidestone Press: Leiden; 219-238.

Guise, T.A., Mohammad, K.S., Clines, G., Stebbins, E.G., Wong, D.H., Higgins, L.S., Vessella, R., Corey, E., Padalecki, S. Suva, L., and Chirgwin, J.M. 2006. Basic Mechanisms Responsible for Osteolytic and Osteoblastic Bone Metastases. Clinical Cancer Research 12, 6213-6216.

— H —

Halcrow, S.E. and Tayles, N. 2011. The Bioarchaeological Investigation of Children and Childhood. In: Agarwal, S.C. and Glencross, B.A. (eds.), Social Bioarchaeology. Blackwell Studies in Global Archaeology. Wiley-Blackwell: Chichcester.

Havelkovà, P., Villotte, S., Velemínsky, P., Poláček, L., and Dobisíková, M. 2011. Enthesopathies and Activity Patterns in the Early Medieval Great Moravian Population: Evidence of Division of Labour. International Journal of Osteoarchaeology 21, 487–504.

Hawkey, D. E. and Merbs, C. F. 1995. Activity-Induced Musculoskeletal Stress Markers (MSM) and Subsistence Strategy Changes Among Ancient Hudson Bay Eskimos. International Journal of Osteoarchaeology 5, 324-338. DOI: 10.1002/oa.1390050403

Henderson, C.Y. 2008. When Hard Work is Disease: the Interpretation of Enthesopathies. In: Brickley, M. and Smith, M. (eds.), Proceedings of the Eighth Annual Conference of the British Association for Biological Anthropology and Osteoarchaeology. British Archaeological Reports, International Series. John and Erica Hedges Ltd.: Oxford; 17-25.

Henderson, C., Mariotti, V., Pany-Kucera, D., Perréard-Lopreno, G., Villotte, S., and Wilczak, C. 2010. Scoring Entheseal Changes: Proposal of a New Standardised Method for Fibrocartilaginous Entheses. [Online]. Poster Presented at the 18th European Meeting of the Paleopathology Association, Vienna, Austria 23rd–26th of August 2010. [Consulted 10/08/2013]. Available from: https://www.uc.pt/en/cia/msm/Vienna2010.pdf.

Henderson, C., Mariotti, V., Pany-Kucera, D., Lopreno, G., Villotte, S., and Wilczak, C. 2012. The Effect of Age on Entheseal Changes at Some Fibrocartilaginous Entheses. American Journal of Physical Anthropology 147, 163.

Henderson, C.Y. 2013. Subsistence Strategy Changes: The Evidence of Entheseal Changes. HOMO - Journal of Comparative Human Biology 64, 491-508.

Henderson, C.Y. and Alves Cardoso, F. 2013. Special Issue Entheseal Changes and Occupation: Technical and Theoretical Advances and Their Applications. International Journal of Osteoarchaeology 23, 127–134.

Henderson, C.Y, Mariotti, V., Pany-Kucera, D., Villotte, S., and Wilczak, C. 2013. Recording Specific Entheseal Changes of Fibrocartilaginous Entheses: Initial Tests Using the Coimbra Method. International Journal of Osteoarchaeology 23, 152-162.

Henderson, C.Y., Mariotti, V., Pany-Kucera, D., Villotte, S., and Wilczak, C. 2016. The New 'Coimbra Method': a Biologically Appropriate Method for Recording Specific Features of Fibrocartilaginous Entheseal Changes. International Journal of Osteoarchaeology 26, 925-932.

Henderson, C.Y. and Nikita, E. 2016. Accounting for Multiple Effects and the Problem of Small Sample Sizes in Osteology: a Case Study Focusing on Entheseal Changes. Archaeological and Anthropological Sciences 8, 805-817.

Henderson, C. Y., Mariotti, V., Santos, F., Villotte, S., and Wilczak, A. 2017. The New Coimbra Method for Recording Entheseal Changes and the Effect of Age-at-Death. Bulletins et Mémoires de la Société d'Anthropologie de Paris 29, 140-149.

Hollander, A. De and Staatsen, B. 2003. Health, Environment and Quality of Life: an Epidemiological Perspective on Urban Development. Landscape and Urban Planning 65: 53-62.

— I —

İşcan, M.Y., Loth S. R., and Wright R. K. 1984. Metamorphosis at the Sternal Rib End: A New Method to Estimate Age at Death in White Males. American Journal Of Physical Anthropology 65, 147-156.

— J —

Jansen, H.A.M. and Maat G.J.R. 2002. Kanunniken Begraven in de Stiftskapel van de Sint- Servaas te Maastricht 1070–1521 na Chr., een Paleopathologisch Onderzoek. Barge's Anthropologica 1. Leids Universiteit Medisch Centrum: Leiden.

Jong, R. de, Smit, M.E., Pielage, G.J., and Haartsen, A.J. 1998. Nominatiedossier Droogmakerij De Beemster aan de Hand Waarvan de UNESCO Droogmakerij De Beemster op 1 december 1999 op de Werelderfgoedlijst heeft geplaatst. Rijksdienst voor de Monumentenzorg: Zeist.

Jurmain, R., Alves Cardoso, F., Henderson, C., and Villotte, S. 2012. Bioarchaeology's Holy Grail: The Reconstruction of Activity. In: Grauer, A.L. (ed.), A Companion to Paleopathology. Blackwell Publishing: Chichester; 531-552.

— K —

Klooster, B., 2008. Programma van Eisen Opgravend Onderzoek Middenweg 148 te Middenbeemster Gemeente Beemster. Stichting Cultureel Erfgoed Noord-Holland: Haarlem.

— L —

Landin, D., Thompson, M., and Jackson, M. 2018. Functions of the Triceps Brachii in Humans: a Review. Journal of Clinical Medicine Research 10(4), 290–293. DOI: 10.14740/jocmr3340w

Lane, W.A. 1888. Anatomy and Physiology of the Shoemaker. Journal of Anatomical Physiology 22, 592–628.

Larsen, C. S. and Walker, P. L. 2010. Bioarchaeology: Health, Lifestyle, and Society in Recent Human Evolution. In Larsen, C. S. (ed.), A Companion to Biological Anthropology. Wiley-Blackwell: Chichester. DOI:10.1002/9781444320039.ch21

Lee-Thorp, J.A. 2008. On Isotopes and Old Bones. Archaeometry 50, 925–950.

Lemmers, S.A.M, Schats, R., Hoogland, M.L.P, and Waters-Rist, A.L. 2013. Fysisch Antropologische Analyse Middenbeemster. In: Hakvoort, A. (ed.), De Begravingen bij de Keyserkerk te Middenbeemster. Hollandia Reeks nr. 464. Hollandia Cultuurhistorisch Onderzoek en Archeologie: Zaandijk.

Lewis, M.E. 2017. Paleopathology of Children. Identification of Pathological Conditions in the Human Skeletal Remains of Non-Adults. Academic Press: London.

Lewis, M.E. 2007. The Bioarchaeology of Children. Perspectives from Biological and Forensic Anthropology. Cambridge University Press: Cambridge.

Liedert, A., Kaspar, D., Augat, P., Ignatius, A., and Claes, L. 2005. Mechanobiology of Bone Tissue and Bone Cells. In: Kamkin, A. and Kiseleva, I. (eds.), Mechanosensitivity in Cells and Tissues. Academia: Moscow.

Lieverse, A. R., Bazaliiskii, V. I., Goriunova, O. I., and Weber, A. W. 2009. Upper Limb Musculoskeletal Markers Among Middle Holocene Foragers of Siberia's Cis-Baikal Region. American Journal of Physical Anthropology 138, 458-472.

Lieverse, A. R., Temple, D. H., and Bazaliiskii, V. I. 2014. Paleopathological Description and Diagnosis of Metastatic Carcinoma in an Early Bronze Age (4588+34 Cal. BP) Forager from the Cis-Baikal Region of Eastern Siberia. PLoS ONE 9(12). DOI: 10.1371/journal.pone.0113919

Littleton, J. 1999. Paleopathology of Skeletal Fluorosis. American Journal of Physical Anthropology 109: 465-483. DOI:10.1002/(SICI)1096-8644(199908)109:4<465::AID-AJPA4>3.0.CO;2-T

Lu, H.H. and Thomopoulos, S., 2013. Functional Attachment of Soft Tissues to Bone: Development, Healing, and Tissue Engineering. Annual Review of Biomedical Engineering 15, 201-226.

— M —

Maat, G.J. 2001. Diet and Age-at-Death Determinations from Molar Attrition. A Review Related to the Low Countries. Journal of Forensic Odontostomatology 19(1), 18–21.

Maat, G.J.R., Mastwijk, R.W., and Sarfatij, H. 1998. Rapportage Archeologische Monumentenzorg 67: Een Fysisch Antropologisch Onderzoek van Begravenen bij het Minderbroeders-Klooster te Dordrecht 1275- 1572 AD. Rijksdienst voor het Oudheidkundig Bodemonderzoek: Amersfoort.

Maeyer, W. De, Cauwenbergh, S. Van, Klinkenborg, S., Taelman, E., and Cherretté, B. 2014. Aalst Hopmarkt - fase 2 Onderzoek van de Pandgangen en de Poel. Solva Archeologie rapport 25. SOLVA: Erpe-Mere.

Maggiano, I.S., Schultz, M., Kierdorf, H., Sosa, T.S., Maggiano, C.M., and Tiesler Blos, V. 2008. Cross-Sectional Analysis of Long Bones, Occupational Activities and Long-Distance Trade of the Classic Maya from Xcambó—Archaeological and Osteological Evidence. American Journal of Physical Anthropology 136, 470-477. DOI:10.1002/ajpa.20830

Mariotti, V., Facchini, F., and M. G. Belcastro, 2004. Enthesopathies - Proposal of a Standardized Scoring Method and Applications. Collegium Antropologicum 28, 145-158.

Mariotti, V., Facchini, F., and M. G. Belcastro, 2007. The Study of Entheses: Proposal of a Standardised Scoring Method for Twenty-Three Entheses of the Postcranial Skeleton. Collegium Antropologicum 31, 291–313.

Matyas, J. R., Bodie, D., Andersen, M., and Frank, C. B. 1990. The Development Morphology of a "Periosteal" Ligament Insertion: Growth and Maturation of the Tibial Insertion of the Rabbit Medial Collateral Ligament. Journal of Orthopaedic Research 8, 412-424. DOI:10.1002/jor.1100080313

Mays, S., Ives, R., and Brickley, M. 2009. The Effects of Socioeconomic Status on Endochondral and Appositional Bone Growth, and Acquisition of Cortical Bone in Children from 19th Century Birmingham, England. American Journal Of Physical Anthropology 140, 410-416. DOI: 10.1002/ajpa.21076

Mays, S., Gowland, R., Halcrow, S., and Murphy, E. 2017. Child Bioarchaeology: Perspectives on the Past 10 Years. Childhood in the Past 10(1), 38-56. DOI: 10.1080/17585716.2017.1301066

Mazza, B. 2018. Entheseal Changes Among Late Holocene Hunter-Gatherers from the Southern Extreme of La Plata Basin (Argentina). Archaeological and Anthropological Sciences. DOI:10.1007/s12520-018-0638-2

McCormick, W.F., Stewart, J.H., and Greene, H. 1991. Sexing of Human Clavicles Using Length and Circumference Measurements. American Journal of Forensic Medicine and

Pathology 12, 175-181.
Meindl, S. and Lovejoy, O. 1985. Ectocranial Suture Closure: A Revised Method for the Determination of Skeletal Age at Death Based on the Lateral-Anterior Sutures. American Journal of Physical Anthropology 68, 57-66.
Meyer, C., Nicklisch, N., Held, P., Fritsch, B., and Alt, K.W. 2011.Tracing Patterns of Activity in the Human Skeleton: an Overview of Methods, Problems, and Limits of Interpretation. HOMO Journal of Comparative Human Biology 62 (3), 202-217.
Michopoulou, E., Nikita, E., and Valakos, E.D. 2015. Evaluating the Efficiency of Different Recording Protocols for Entheseal Changes in Regards to Expressing Activity Patterns Using Archival Data and Cross-Sectional Geometric Properties. American Journal of Physical Anthropology 158, 557-68.
Michopoulou, E., Nikita, E., and Henderson, C. Y. 2017. A Test of the Effectiveness of the Coimbra Method in Capturing Activity-Induced Entheseal Changes. International Journal of Osteoarchaeology 27, 409–417.
Mickleburgh, H.L. 2007. Teeth Tell Tales. Dental Wear as Evidence for Cultural Practices at Anse à la Gourde and Tutu. Sidestone Press: Leiden.
Milella, M., Belcastro, M.G., Zollikofer, C.P.E., and Mariotti, V. 2012. The Effect of Age, Sex, and Physical Activity on Entheseal Morphology in a Contemporary Italian Skeletal Collection. American Journal of Physical Anthropology 148, 379–388.
Milella, M., Alves Cardoso, F., Assis, S., Perreard Lopreno, G., and Speith, N. 2015. Exploring the Relationship Between Entheseal Changes and Physical Activity: A Multivariate Study. American Journal of Physical Anthropology 156, 215–223.
Molnar, P., Ahlstrom, T. J., and Leden, I. 2011. Osteoarthritis and Activity—an Analysis of the Relationship Between Eburnation, Musculoskeletal Stress Markers (MSM) and Age in Two Neolithic Hunter–Gatherer Populations from Gotland, Sweden. International Journal of Osteoarchaeology 21, 283-291.
Mundy, G. R. 2002.Metastasis: Metastasis to Bone: Causes, Consequences and Therapeutic Opportunities. Nature Reviews Cancer 2, 584–593.

— N —

Neer, W. Van, Ervynck, A., Wouters, W., Muylaert, L., Barrett, J., Richards, M., and Johnstone, C. 2016. The Rise of Seafish Consumption in Inland Flanders (Belgium). In: Barret, J. and Orton, D. (eds.), Cod and Consequences: the Archaeology and History of Medieval Sea Fishing. Oxbow: Oxford; 156-171.
Niinimäki, S. 2011.What Do Muscle Marker Ruggedness Scores Actually Tell Us? International Journal of Osteoarchaeology 21, 292–299.
Niinimäki, S. and Baiges Sotos, L. 2013. The Relationship Between Intensity of Physical

Activity and Entheseal Changes on the Lower Limb. International Journal of Osteoarchaeology 23, 221–228.

Niinimäki, S., Niskanen, M., Niinimäki, J., Nieminen, M., Tuukkanen, J., and Junno, J. A. 2013. Modeling Skeletal Traits and Functions of the Upper Body: Comparing Archaeological and Anthropological Material. Journal of Anthropological Archaeology 32, 347-351.

Niinimäki, S. Puolakka, H., and Salmi, A-K. 2018. Recent Developments in the Methods for Physical Activity Assessment of Reindeer. Paper presented at the 24th Annual Meeting of the European Association of Archaeologists, Barcelona, Spain 5th-8th September 2018.

Niskanen, M. 2018 Scaling With Size In Horses May Have Implications For Reconstructing Activity From Entheseal Changes. Paper presented at the 24th Annual Meeting of the European Association of Archaeologists, Barcelona, Spain 5th-8th September 2018.

Noldner, L.K. and Edgar, H.J.H. 2013. Technical Note: 3D Representation and Analysis of Enthesis Morphology. American Journal of Physical Anthropology 152, 417–424.

Novak, M., Howcroft, R., and Pinhasi, R. 2017. Child Health in Five Early Medieval Irish Sites: A Multidisciplinary Approach. International Journal of Osteoarchaeology 27, 398-408 DOI: 10.1002/oa.2549.

— P —

Palmer, J.L.A. 2014. Kort Rapport: Aalst-Hopmarkt 2011: Fysisch Antropologische Analyse. Unpublished Osteological Report.

Palmer, J.L.A. 2016. Kort rapport: Aalst-Sint-Martinuskerk: Fysisch Antropologische Analyse. Unpublished Osteological Report.

Palmer, J.L.A., Hoogland, M.H.L., and Waters-Rist, A.L. 2016. Activity Reconstruction of Post-Medieval Dutch Rural Villagers from Upper Limb Osteoarthritis and Entheseal Changes. International Journal of Osteoarchaeology 26, 78-92. DOI: 10.1002/oa.2397.

Palmer, J.L.A., Waters-Rist, A.L., and Hoogland, M.L.P. 2016. A Re-Assessment of Sex-Differences in a Dutch Post-Medieval Collection Using the Coimbra Method. [Online]. Poster Presented at Working your fingers to the bone. An interdisciplinary conference on identifying occupation from the skeleton, Coimbra, Portugal 6-8th of July 2016. DOI: 10.13140/RG.2.2.31050.21446

Palmer, J.L.A, Waters-Rist, A.L., and Lieverse, A. 2017. A Proposed Method for Scoring Subadult Entheseal Morphology. [Online] Poster Presented at the 86th Annual Meeting of the American Association of Physical Anthropology, New Orleans, United States 19th-22nd of April 2017. DOI: 10.13140/RG.2.2.32815.64160

Palmer, J.L.A, Quintelier, K., and Waters-Rist, A.L. 2017. A Probable Case of Metastatic Carcinoma from Post-Medieval Belgium. Poster Presented at the 44th Annual North American Meeting of the Palaeopathology Association (April 17-19, 2017) New Orleans. DOI: 10.13140/RG.2.2.24007.60322

Palmer, J.L.A. 2018. Diversity in Death: Skeletal Evidence of Burial Preferences in a Late to Post-Medieval Convent in Aalst (Belgium). In: van Oosten, R. and Schats, R., (eds.), The Urban Graveyard 3: Archaeological Perspectives. Sidestone press: Leiden.

Palmer, J.L.A., Quintelier, K., Inskip, S., and Waters-Rist, A.L. 2018. A Comparison of Two Methods for Recording Entheseal Change on a Post-Medieval Urban Skeletal Collection from Aalst (Belgium). Archaeometry. DOI: 10.1111/arcm.12409.

Paraskevas, G., Papadopoulos, A., Papaziogas, B., Spanidou, S., Argiriadou, H., and Gigis, J. 2004. Study of the Carrying Angle of the Human Elbow Joint in Full Extension: a Morphometric Analysis. Surgical and Radiological Anatomy 26, 19-23. DOI: 10.1007/s00276-003-0185-z

Paulsen,F. and Walscke, J. (eds.). 2011. Sobotta Atlas of Anatomy. Elsevier GmbH: Munich.

Pearson, O.M. and Buikstra, J.E. 2006. Behavior and the Bones. In: Buikstra, J.E. and Beck, L.A. (eds.), Bioarchaeology: the Contextual Analysis of Human Remains. Academic Press: London; 207–226.

Phenice, T.W. 1969. A Newly Developed Visual Method of Sexing the Os Pubis. American Journal of Physical Anthropology 30: 297–302.

Polet, C. and Katzenberg, M.A. 2002. Comportements Alimentaires De Trois Populations Médiévales Belges: Apports de la Biogéochimie Isotopique. Revue Belge de Philologie et d'Histoire 80, 1371–1390.

Polet, C. and Katzenberg, M.A. 2003. Reconstruction of the Diet in a Mediaeval Monastic Community from the Coast of Belgium. Journal of Archaeological Sciences 30, 525–533.

Porčić, M. and Stefanović, S. 2009. Physical Activity and Social Status in Early Bronze Age Society: The Mokrin Necropolis. Journal of Anthropological Archaeology 28, 259-273. DOI: 10.1016/j.jaa.2009.06.001.

Primeau, C. 2018. Estimating Subadult Age: Diaphyseal Length. In: López Varela, S. (ed.), The SAS Encyclopedia of Archaeological Science. Wiley-Blackwell: Chichester.

Primeau, C., Friis, L., Sejrsen, B., and Lynnerup, N. 2016. A Method for Estimating Age of Medieval Sub-Adults from Infancy to Adulthood Based on Long Bone Length. American Journal of Physical Anthropology 159, 135-145. DOI:10.1002/ajpa.22860

— Q —

Quintelier, K., Ervynck, A., Müldner, G. , Neer, W. , Richards, M. P., and Fuller, B. T. 2014. Isotopic Examination of Links Between Diet, Social Differentiation, and DISH at the Post-Medieval Carmelite Friary of Aalst, Belgium. American Journal of Physical Anthropology 153, 203-213. DOI:10.1002/ajpa.22420

— R —

Reitsema, L.J., Vercellotti, G., and Boano, R. 2016. Subadult Dietary Variation at Trino Vercellese, Italy, and its Relationship to Adult Diet and Mortality. American Journal of Physical Anthropology 160, 653–664.

Rhode, M.P. 2013. Entheseal Change. In: Mann, R.W. and Hund, D.R. (eds.), Photographic Regional Atlas of Bone Disease: A Guide to Pathologic and Normal Variation in the Human Skeleton. Charles C. Thomas: Illinois; 203-212.

Rijksdienst Voor Cultureel Erfgoed. 2017. Monumentnummer*: 8818. Informatie over het Rijksmonument de Kerk van Middenbeemster. [Online, consulted 13/08/2018] https://cultureelerfgoed.nl/monumenten/8818

Robb, J. 1998. The Interpretation of Skeletal Muscle Sites: A Statistical Approach. International Journal of Osteoarchaeology 8, 363 -377.

Robb, J., Bigazzi, R., Lazzarini, L., Scarsini, C., and Sonego, F. 2001. Social "Status" and Biological "Status": A Comparison of Grave Goods and Skeletal Indicators from Pontecagnano. American Journal of Physical Anthropology 115, 213-222. DOI:10.1002/ajpa.1076

Robijns, L. 1976. Het Koormobilair van de St.-Martinuskerk te Aalst, met een Inleidende Studie over het Ontstaan der St.-Martinusparochie en de Bouwgeschiedenis van haar Kerk. KU Leuven: Leuven.

Rodrigues, T. 2005. Gender and Social Differentiation within the Turner Population, Ohio, as Evidenced by Activity-Induced Musculoskeletal Stress Markers. In: Carr, C. and Case, D.T. (eds.), Gathering Hopewell. Interdisciplinary Contributions to Archaeology. Springer: Boston; 405-427. DOI: 10.1007/0-387-27327-1_10

Rogers, T. 1999. A Visual Method of Determining the Sex of Skeletal Remains Using the Distal Humerus. Journal of Forensic Sciences 44, 57-60. DOI: 10.1520/JFS14411J

Ruff, C.B., Garofalo, E., and Holmes, M.E. 2013. Interpreting Skeletal Growth in the Past From a Functional and Physiological Perspective. American Journal of Physical Anthropology 150, 29-37.

— S —

Saers, J.P.P., Hoogland, M.L.P., van Rijn, R.R., Schats, R., van der Merwe, L.E., and Waters-Rist, A.L. 2017. Habitual Activity in Pre-Industrial Rural and Urban Dutch Populations: a Study of Lower Limb Cross-Sectional Geometry. Bioarchaeology International 1 (3), 1-17. DOI: 10.5744/bi.2017.1006

Saunders, S.R. 1978. The Development and Distribution of Discontinuous Morphological Variation of the Human Infracranial Skeleton. National Museums of Canada: Ottawa.

Schaefer, M., Black, S., and Scheuer, L. 2009. Juvenile Osteology: A Laboratory and Field Manual. Academic Press: San Diego.

Scheuer, L. and Black, S., 2000. Developmental Juvenile Osteology. San Diego: Academic Press.

Schrader, S. A. 2012. Activity Patterns in New Kingdom Nubia: An Examination of Entheseal Remodeling and Osteoarthritis at Tombos. American Journal of Physical Anthropology 149, 60-70. DOI:10.1002/ajpa.22094

Schrader, S. A. 2015. Elucidating Inequality in Nubia: An Examination of Entheseal Changes at Kerma (Sudan). American Journal of Physical Anthropology 156, 192-202. doi:10.1002/ajpa.22637

Schlecht, S. 2012. Understanding Entheses: Bridging the Gap Between Clinical and Anthropological Perspectives. The Anatomical Record 295, 1239–1251. https://doi.org/10.1002/ar.22516

Schryver, S. De. 2001. Aspecten van Sociale Mobiliteit Binnen de 18de-eeuwse Aalsterse Ambachtswereld: Een Prosopografische Benadering. Universiteit Gent: Gent.

Shephard, R.J. 2012. The Development of Understanding of Human Health and Fitness: The Middle Ages. Health and Fitness Journal of Canada 5, 18-46.

Shipley, M., Black, C.M., Compston, J., and O'Gradaigh, D. 2002. Rheumatology and Bone Disease. In: Kumar, P. and Clark, M. (eds.), Clinical Medicine. W.B. Saunders: Edinburgh; 511–586.

Sizer, P.S. and James, C.R. 2008. Considerations of Sex Differences in Musculoskeletal Anatomy. In: Robert- McComb, J.J., Norman, R., and Zumwalt, M. (eds.), The Active Female: Health Issues Throughout The Lifespan. Humana Press: Texas; 25–54.

Spector, T.D. and MacGregor, A.J. 2004. Risk factors for Osteoarthritis: Genetics. Osteoarthritis and Cartilage 12, 39–44.

Stark, R. J. 2014. A Proposed Framework for the Study of Paleopathological Cases of Subadult Scurvy. International Journal of Paleopathology 5, 18-26. DOI: 10.1016/j.ijpp.2014.01.005.

Steen, S. and Lane, R. W. 1998. Evaluation of Habitual Activities Among Two Alaskan Eskimo Populations Based on Musculoskeletal Stress Markers. International Journal of Osteoarchaeology 8, 341-353.

Stern, T., Aviram, R., Rot, C., Galili, T., Sharir, A., Kalish Achrai, N., Keller, Y., Shahar, R., and Zelzer, E. 2015. Isometric Scaling in Developing Long Bones Is Achieved by an Optimal Epiphyseal Growth Balance. PLOS Biology 13(8). DOI: 10.1371/journal.pbio.1002212

Stewart, T.D. 1979. Essentials of Forensic Anthropology. Charles C. Thomas: Springfield.

Steyn, M.Y. and Işcan, M.Y. 1999. Osteometric Variation in the Humerus: Sexual Dimorphism in South Africans. Forensic Science International 106, 77-85.

Stirland, A.J. 1996. Femoral Non-Metric Traits Reconsidered. Anthropologie 34: 249–252.

Stull, K.E., L'Abbé, E.N., and Ousley, S.D. 2017. Subadult Sex Estimation from Diaphyseal Dimensions. American Journal of Physical Anthropology 163, 64–74. DOI: 10.1002/ajpa.23185

Suchey, S. and Brooks, J. M. 1990. Skeletal Age Determination Based on the Os Pubis: a Comparison of the Acsádi-Nemeskéri and Suchey-Brooks Methods. Human Evolution 5, 227-238.

— T —

Thomopoulos, S., Genin, G.M., and Birman, V. 2013. Structural Interfaces and Attachments in Biology. Springer: New York.

Tsutuya, T., Ishida, H., and Yoneda, M. 2015. Weaning Age in an Expanding Population: Stable Carbon and Nitrogen Isotope Analysis of Infant Feeding Practices in the Okhotsk Culture (5th–13th centuries AD) in Northern Japan. American Journal of Physical Anthropology 157 (4), 544–555.

Turnbull, C. and Rahman, N. 2008. Genetic Predisposition to Breast Cancer: Past, Present, and Future. Annual Review of Genomics and Human Genetics 9 (1), 321-345.

— U —

Ubelaker, D. and Newson, L. 2002. Patterns of Health and Nutrition in Prehistoric and Historic Ecuador. In: Steckel, R. and Rose, J. (eds.), The Backbone of History. Cambridge University Press: Cambridge; 343–375.

— V—

Van der Wiel, K. 2012. Melkkoeien, Fokstieren en Vette Ossen; Veehouders in de Beemster. In: Aten, D., Bossaers, B., Dehé, J., Kurpershoek, E., Misset, C., Schaap, E., Steenhuis, M., and van der Wiel, K.(eds.), 400 jaar Beemster. Stichting Uitgeverij Noord-Holland: Wormerveer; 49-81.

Veselka, B., Hoogland, M. L. P., and Waters-Rist, A. L. 2015 Rural Rickets: Vitamin D

Deficiency in a Post-Medieval Farming Community from the Netherlands. International Journal of Osteoarchaeology 25: 665–675. DOI: 10.1002/oa.2329.

Vikatou, I., Hoogland, M. L. P., and Waters-Rist, A. L. 2017. Osteochondritis Dissecans of Skeletal Elements of the Foot in a 19th Century Rural Farming Community from The Netherlands. International Journal of Paleopathology 19, 53-63. DOI: 10.1016/j.ijpp.2017.09.005

Villotte, S. 2006. Connaissances Médicales Actuelles, Cotation des Enthésopathies: Nouvelle Méthode. Bulletins et Mémoires de la Société d'Anthropologie de Paris 18, 65–85.

Villotte, S. 2008. Les Marqueurs Ostéoarticulaires D'activité. In: Charlier, P. (ed.), Manual Pratique de Paléopathologie Humaine. Editions De Boccard: Paris; 383–389.

Villotte, S., Castex, D., Couallier, V., Dutour, O., Knüsel, C.J., and Henry-Gambier, D. 2010. Enthesopathies as Occupational Stress Markers: Evidence from the Upper Limb. American Journal of Physical Anthropology 142, 224-234.

Villotte, S. 2013. Practical Protocol for Scoring the Appearance of Some Fibrocartilaginous Entheses on the Human Skeleton. [Online, consulted 23/08/2013]. http://www.academia.edu/1427191/Practical_protocol_for_scoring_the_appearance_of_some_fibrocartilaginous_entheses_on_the_human_skeleton

Villotte, S., and Knüsel, C.J. 2013. Understanding Entheseal Changes: Definition and Life Course Changes. International Journal of Osteoarchaeology 23, 135–146.

Villotte, S., Assis, S., Alves Cardoso F., Henderson, C. Y., Mariotti, V., Milella M., Pany-Kucera, D., Speith, N., Wilczak C.A., and Jurmain, R. 2016. In Search of Consensus: Terminology for Entheseal Changes (EC). International Journal of Paleopathology 13, 49–55.

— W —

Waldron, T. 2009. Paleopathology. Cambridge University Press: Cambridge.

Waldron, T. and Rogers, J. 1990. An Epidemiologic Study of Sacroiliac Fusion in Some Human Skeletal Remains. American Journal of Physical Anthropology 83, 123–127.

Walker, P. L., Johnson, J. R., and Lambert, P. M. 1988. Age and Sex Biases in the Preservation of Human Skeletal Remains. American Journal of Physical Anthropology 76, 183-188. DOI:10.1002/ajpa.1330760206

Wallace, I. J., Tommasini, S. M., Judex, S., Garland Jr., T., and Demes, B. 2012. Genetic Variations and Physical Activity as Determinants of Limb Bone Morphology: An Experimental Approach Using a Mouse Model. American Journal of Physical Anthropology 148, 24-35.

Waters-Rist, A., Bazaliiskii, V. I., Weber, A., Goriunova, O. I., and Katzenberg, M. A. 2010. Activity-Induced Dental Modification in Holocene Siberian Hunter-Fisher-Gatherers.

American Journal of Physical Anthropology 143, 266-278. DOI:10.1002/ajpa.21313
Waters-Rist, A.L. and Hoogland, M.L.P. 2013. Osteological Evidence of Short-Limbed Dwarfism in a Nineteenth Century Dutch Family: Achondroplasia or Hypochondroplasia. International Journal of Paleopathology 3: 243-256.
Watkins, R. 2012. Variation in Health and Socioeconomic Status Within the W. Montague Cobb Skeletal Collection: Degenerative Joint Disease, Trauma and Cause of Death. International Journal of Osteoarchaeology 22, 22-44. DOI:10.1002/oa.1178
Weisberg, H. 1992. Central Tendency and Variability. Sage Publications: Newbury Park.
Weiss, E. 2003. Understanding Muscle Markers: Aggregation and Construct Validity. American Journal of Physical Anthropology 121, 230–240.
Weiss, E. 2005. Understanding Osteoarthritis Patterns: an Examination of Aggregate Osteoarthritis. Journal of Paleopathology 16, 87–98.
Weiss, E. 2006. Osteoarthritis and Body Mass. Journal of Archaeological Science 33, 690–695.
Weiss, E. 2007. Muscle Markers Revisited: Activity Pattern Reconstruction with Controls in a Central California Amerind Population. American Journal of Physical Anthropology 133, 931–940.
Weiss, E. and Jurmain, R. 2007. Osteoarthritis Revisited: a Contemporary Review of Aetiology. International Journal of Osteoarchaeology 17, 437–450.
Weiss, E. 2012. Examining Activity Patterns and Biological Confounding Factors: Differences Between Fibrocartilaginous and Fibrous Musculoskeletal Stress Markers. International Journal of Osteoarchaeology 25, 281-288. DOI: 10.1002/oa.2290
Weiss, E., Corona, L., and Schultz, B. 2012. Sex Differences in Musculoskeletal Stress Markers: Problems with Activity Pattern Reconstructions. International Journal of Osteoarchaeology 22, 70-80.
Weiss, E. 2015. The Surface of Bones: Methods of Recording Entheseal Changes. Surface Topography: Metrology and Properties 3, 1-11.
Wells, C. 1963. Hip Disease in Ancient Man. Report of Three Cases. Journal of Bone and Joint Surgery 45B, 790-791.
Wilczak, C.A. 1998. Consideration of Sexual Dimorphism, Age, and Asymmetry in Quantitative Measurements of Muscle Insertion Sites. International Journal of Osteoarchaeology 8, 311–325.
Wilczak, C.R., Watkins, R., Null, C.C., and Blakey, M.L. 2004. Skeletal Indicators of Work: Musculoskeletal, Arthritic and Traumatic Effects. In: Blakey, M. and Rankin-Hill, L. (eds.), New York African Burial Ground: Skeletal Biology Final Report Volume 1. Howard University: Washington DC; 403–460.
Wilczak, C., Mariotti, V., Pany-Kucera, D., Villotte, S., and Henderson, C. 2017. Training and Interobserver Reliability in Qualitative Scoring of Skeletal Samples. Journal of Ar-

chaeological Science: Reports 11, 69-79. DOI: 10.1016/j.jasrep.2016.11.033
Wolff, J. 1892. Das Gesetz der Transformation der Knochen. (2010 reprint). Pro Business: Berlin.

— Y —

Yilmaz, E., Karakurt, L., Belhan, O., Bulut, M., Serin, E., and Avci, M. 2005. Variation of Carrying Angle with Age, Sex, and Special Reference to Side. Orthopedics 28 (11), 1360-1363.

— Z —

Zelzer, E., Blitz, E., Killian, M. L., and Thomopoulos, S. 2014. Tendon-to-Bone Attachment: From Development to Maturity. Birth Defects Research. Part C. Embryo Today: Reviews 102 (1), 101–112. DOI: 10.1002/bdrc.21056
Zhai, G., Stankovich, J., Ding, C., Scott, F., Cicuttini, F., and Jones, G. 2004. The Genetic Contribution to Muscle Strength, Knee Pain, Cartilage Volume, Bone Size, and Radiographic Osteoarthritis. Arthritis and Rheumatism 50, 805–810. DOI: 10.1002/art.20108
Ziesemer, K. A., Mann, A. E., Sankaranarayanan, K., Schroeder, H., Ozga, A. T., Brandt, B. W., Zaura, W., Waters-Rist, A., Hoogland, M., Salazar-Garcia, D., Eldenderfer, M., Speller, C., Hendy, J., Weston, D., MacDonald, S., Thomas, G., Collins, M., Lewis, C., Hofman, C, and Warinner, C. 2015. Intrinsic Challenges in Ancient Microbiome Reconstruction Using 16S rRNA Gene Amplification. Nature Scientific Reports 5, 16498. DOI: 10.1038/srep16498
Zumwalt, A., 2006. The Effect of Endurance Exercise on the Morphology of Muscle Attachment Sites. The Journal of Experimental Biology 209, 444-454.

Appendices

Appendix A: appendix to chapter 2

Appendix A1: tables listing OA and EC occurrence per joint surface and per age and sex category.

	Absent(0)	Mild (1)	Moderate (2)	Severe (3)	Not recordable(4)	Element absent (5)	Sum OA	Number of recordable specimens
Late Young Adult females (26–35 years) (n = 19)								
Left Clavicle	6	3	0	0	3	7	3	9
Right Clavicle	8	3	0	0	5	3	3	11
Left Acromion	8	1	0	0	2	8	1	9
Right Acromion	10	0	0	0	3	6	0	10
Left Glenoid	12	3	0	0	2	2	3	15
Right Glenoid	14	3	0	0	1	1	3	17
Left Humeral Head	17	0	0	0	1	1	0	17
Right Humeral Head	16	1	0	0	1	1	1	17
Left Capitulum	18	0	0	0	0	1	0	18
Right Capitulum	18	0	0	0	0	1	0	18
Left Trochlea	18	0	0	0	0	1	0	18
Right Trochlea	16	0	0	0	1	2	0	16
Left Radial Head	16	1	0	0	1	1	1	17
Right Radial Head	17	0	0	0	1	1	0	17
Left Proximal Ulna	17	0	0	0	2	0	0	17
Right Proximal Ulna	18	0	0	0	0	1	0	18
Late young adult males (26–35 years) (n = 13)								
Left Clavicle	4	2	1	0	2	4	3	7
Right Clavicle	3	3	1	0	2	4	4	7
Left Acromion	6	1	1	0	1	4	2	8
Right Acromion	5	1	1	0	1	5	2	7
Left Glenoid	10	2	0	0	0	1	2	12
Right Glenoid	12	0	0	0	0	1	0	12
Left Humeral Head	10	1	0	0	0	2	1	11

Right Humeral Head	8	2	0	0	0	3	2	10
Left Capitulum	12	0	0	0	0	1	0	12
Right Capitulum	11	0	0	0	0	2	0	11
Left Trochlea	13	0	0	0	0	0	0	13
Right Trochlea	10	0	0	0	1	2	0	10
Left Radial Head	11	0	0	0	2	0	0	11
Right Radial Head	8	0	0	0	3	2	0	8
Left Proximal Ulna	12	0	0	0	0	1	0	12
Right Proximal Ulna	8	0	0	0	2	3	0	8
Middle Adult females (36–49 years) (n = 20)								
Left Clavicle	8	3	2	0	3	4	5	13
Right Clavicle	6	3	4	0	2	5	7	13
Left Acromion	11	1	1	1	2	4	3	14
Right Acromion	9	2	1	1	2	5	4	13
Left Glenoid	11	6	1	0	1	1	7	18
Right Glenoid	12	6	1	0	1	0	7	19
Left Humeral Head	12	1	0	0	4	3	1	13
Right Humeral Head	16	0	1	0	2	1	1	17
Left Capitulum	18	0	0	0	1	1	0	18
Right Capitulum	16	0	0	0	4	0	0	16
Left Trochlea	17	1	0	0	1	1	1	18
Right Trochlea	16	1	0	0	3	0	1	17
Left Radial Head	12	2	0	0	5	1	2	14
Right Radial Head	14	1	1	0	2	2	2	16
Left Proximal Ulna	15	2	0	0	3	0	2	17
Right Proximal Ulna	15	2	0	0	3	0	2	17
Middle Adult males (36–49 years) (n = 17)								
Left Clavicle	5	3	1	0	3	5	4	9
Right Clavicle	5	6	1	1	1	3	8	13
Left Acromion	6	4	0	0	2	5	4	10
Right Acromion	8	4	1	1	0	3	6	14
Left Glenoid	12	2	0	0	1	2	2	14
Right Glenoid	10	4	0	0	0	3	4	14
Left Humeral Head	13	1	0	0	0	3	1	14
Right Humeral Head	14	1	0	0	0	2	1	15
Left Capitulum	13	0	1	0	0	3	1	14
Right Capitulum	15	0	1	0	0	1	1	16
Left Trochlea	12	2	0	0	0	3	2	14
Right Trochlea	15	1	0	0	0	1	1	16
Left Radial Head	13	0	1	0	1	2	1	14
Right Radial Head	13	1	0	0	1	2	1	14
Left Proximal Ulna	13	1	0	0	0	3	1	14
Right Proximal Ulna	14	2	0	0	0	1	2	16

Appendix A2: tables listing EC occurrence per entheses and per age and sex category

Late young adult females (26–35 years) (n = 19)

Late young adult female robusticity scores

	Score 1	Score 2	Score 3	Not recordable
Pectoralis Major L	8	7	0	5
Pectoralis Major R	7	7	1	2
Lat.Dorsii/Teres Major L	12	3	0	4
Lat. Dorsii/Teres Major R	14	0	0	2
Deltoid L	10	5	0	3
Deltoid R	10	4	0	1
Brachioradialis L	13	2	0	3
Brachioradialis R	11	3	0	2
Biceps Brachii L	13	5	0	4
Biceps Brachii R	10	7	0	4
Triceps Brachii L	8	7	1	4
Triceps Brachii R	8	7	1	3

Late young adult female osteophyte formation (OF) score

	Score 0 (no OF)	Score 1	Score 2	Score 3	Not recordable
Pectoralis Major L	15	0	0	0	4
Pectoralis Major R	15	0	0	0	4
Lat.Dorsii/Teres Major L	15	0	0	0	4
Lat. Dorsii/Teres Major R	15	0	0	0	4
Deltoid L	14	0	0	0	5
Deltoid R	14	0	0	0	5
Brachioradialis L	15	0	0	0	4
Brachioradialis R	14	0	0	0	5
Biceps Brachii L	17	1	0	0	1
Biceps Brachii R	17	0	0	0	2
Triceps Brachii L	15	1	0	0	3
Triceps Brachii R	15	1	0	0	3

Late young adult female osteolytic lesion (OL) score

	Score 0 (no OF)	Score 1	Score 2	Score 3	Not recordable
Pectoralis Major L	15	0	0	0	4
Pectoralis Major R	14	0	0	0	5
Lat.Dorsii/Teres Major L	13	2	0	0	4
Lat. Dorsii/Teres Major R	12	2	0	0	5
Deltoid L	14	0	0	0	5
Deltoid R	13	0	0	0	6
Brachioradialis L	15	0	0	0	4
Brachioradialis R	14	0	0	0	5
Biceps Brachii L	18	0	0	0	1
Biceps Brachii R	17	0	0	0	2

Triceps Brachii L	16	0	0	0	3
Triceps Brachii R	16	0	0	0	3

Late young adult males (26–35 years) (n = 13)

Late young adult male robusticity scores

	Score 1	Score 2	Score 3	Not recordable
Pectoralis Major L	1	10	0	2
Pectoralis Major R	4	6	0	3
Lat.Dorsii/Teres Major L	7	4	0	2
Lat. Dorsii/Teres Major R	7	3	0	3
Deltoid L	6	4	1	2
Deltoid R	6	4	0	3
Brachioradialis L	5	1	5	2
Brachioradialis R	5	2	3	3
Biceps Brachii L	3	9	1	0
Biceps Brachii R	3	6	1	3
Triceps Brachii L	5	5	0	3
Triceps Brachii R	4	4	0	5

Late young adult male osteophyte formation (OF) score

	Score 0 (no OF)	Score 1	Score 2	Score 3	Not recordable
Pectoralis Major L	11	0	0	0	2
Pectoralis Major R	10	0	0	0	3
Lat.Dorsii/Teres Major L	11	0	0	0	2
Lat. Dorsii/Teres Major R	10	0	0	0	3
Deltoid L	11	0	0	0	2
Deltoid R	10	0	0	0	3
Brachioradialis L	11	0	0	0	2
Brachioradialis R	10	0	0	0	3
Biceps Brachii L	12	1	0	0	0
Biceps Brachii R	9	1	0	0	3
Triceps Brachii L	10	0	0	0	3
Triceps Brachii R	8	0	0	0	5

Late young adult male osteolytic lesion (OL) score

	Score 0 (no OF)	Score 1	Score 2	Score 3	Not recordable
Pectoralis Major L	12	0	0	0	5
Pectoralis Major R	15	0	0	0	2
Lat.Dorsii/Teres Major L	11	2	0	0	4
Lat. Dorsii/Teres Major R	15	0	0	0	2
Deltoid L	14	0	0	0	3
Deltoid R	16	0	0	0	1
Brachioradialis L	14	0	0	0	3
Brachioradialis R	15	0	0	0	2
Biceps Brachii L	13	0	0	0	4
Biceps Brachii R	13	0	0	0	4

Triceps Brachii L	13	0	0	0	4
Triceps Brachii R	14	0	0	0	3

Middle adult females (36–49 years) (n = 20)

Middle adult female robusticity scores

	Score 1	Score 2	Score 3	Not recordable
Pectoralis Major L	4	9	2	5
Pectoralis Major R	5	10	1	4
Lat.Dorsii/Teres Major L	11	3	0	6
Lat. Dorsii/Teres Major R	11	5	0	4
Deltoid L	11	5	0	4
Deltoid R	10	7	0	3
Brachioradialis L	8	5	3	4
Brachioradialis R	7	9	2	2
Biceps Brachii L	11	6	0	3
Biceps Brachii R	9	10	0	1
Triceps Brachii L	4	9	1	6
Triceps Brachii R	4	6	3	7

Middle adult female osteophyte formation (OF) score

	Score 0 (no OF)	Score 1	Score 2	Score 3	Not recordable
Pectoralis Major L	13	2	0	0	5
Pectoralis Major R	14	2	0	0	4
Lat.Dorsii/Teres Major L	14	0	0	0	6
Lat. Dorsii/Teres Major R	16	0	0	0	4
Deltoid L	16	0	0	0	4
Deltoid R	17	0	0	0	3
Brachioradialis L	15	1	0	0	4
Brachioradialis R	18	0	0	0	2
Biceps Brachii L	16	1	0	0	3
Biceps Brachii R	16	3	0	0	1
Triceps Brachii L	9	2	2	1	6
Triceps Brachii R	9	1	0	3	7

Middle adult female osteolytic lesion (OL) score

	Score 0 (no OF)	Score 1	Score 2	Score 3	Not recordable
Pectoralis Major L	15	0	0	0	5
Pectoralis Major R	16	0	0	0	4
Lat.Dorsii/Teres Major L	14	0	0	0	6
Lat. Dorsii/Teres Major R	14	2	0	0	4
Deltoid L	16	0	0	0	4
Deltoid R	17	0	0	0	3
Brachioradialis L	16	0	0	0	4
Brachioradialis R	18	0	0	0	2
Biceps Brachii L	15	2	0	0	3
Biceps Brachii R	16	3	0	0	1

Triceps Brachii L	14	0	0	0	6
Triceps Brachii R	13	0	0	0	7

Middle adult males (36–49 years) (n = 17)

Middle adult male robusticity scores				
	Score 1	**Score 2**	**Score 3**	**Not recordable**
Pectoralis Major L	4	5	3	5
Pectoralis Major R	4	7	4	2
Lat.Dorsii/Teres Major L	7	6	0	4
Lat. Dorsii/Teres Major R	10	5	0	2
Deltoid L	6	8	0	3
Deltoid R	5	11	0	1
Brachioradialis L	4	7	3	3
Brachioradialis R	5	5	5	2
Biceps Brachii L	1	10	2	4
Biceps Brachii R	1	11	1	4
Triceps Brachii L	6	7	0	4
Triceps Brachii R	8	6	0	3

Middle adult male osteophyte formation (OF) score					
	Score 0 (no OF)	**Score 1**	**Score 2**	**Score 3**	**Not recordable**
Pectoralis Major L	11	1	0	0	5
Pectoralis Major R	15	0	0	0	2
Lat.Dorsii/Teres Major L	13	0	0	0	4
Lat. Dorsii/Teres Major R	15	0	0	0	2
Deltoid L	14	0	0	0	3
Deltoid R	16	0	0	0	1
Brachioradialis L	15	0	0	0	2
Brachioradialis R	15	0	0	0	2
Biceps Brachii L	9	2	1	1	4
Biceps Brachii R	9	4	0	0	4
Triceps Brachii L	11	2	0	0	4
Triceps Brachii R	12	2	0	0	3

Middle adult male osteolytic lesion (OL) score					
	Score 0 (no OF)	**Score 1**	**Score 2**	**Score 3**	**Not recordable**
Pectoralis Major L	12	0	0	0	5
Pectoralis Major R	15	0	0	0	2
Lat.Dorsii/Teres Major L	11	2	0	0	4
Lat. Dorsii/Teres Major R	15	0	0	0	2
Deltoid L	14	0	0	0	3
Deltoid R	16	0	0	0	1
Brachioradialis L	14	0	0	0	3
Brachioradialis R	15	0	0	0	2
Biceps Brachii L	13	0	0	0	4
Biceps Brachii R	13	0	0	0	4

Triceps Brachii L	13	0	0	0	4
Triceps Brachii R	14	0	0	0	3

Appendix B: appendix to chapter 4

Appendix B1: muscle marking score gradation as it was envisioned in the first version of the recording method.

This appendix is included to show the range of morphological variation observed per entheses.

	Scapula, long head of triceps brachii (fibrocartilaginous attachment)
Stage 0	Attachment site cannot be delineated.
Stage 1	Attachment site is discernible due to bone contour, with or without porosity.
Stage 2	Attachment site presents as a change in elevation, with a discernible alteration to the profile of the axial border of the scapula; no rugosity is present at this stage; may include porosity.
Stage 3	Attachment site presents as a change in elevation (with discernible alteration to the profile of the axial border of the scapula) with rugosity; may include porosity.
	Clavicle, costoclavicular
Stage 0	Attachment site cannot be delineated.
Stage 1	Attachment site is discernible due to bone contour, with or without one or more of the following: slight raised area, slight depression, slight surface irregularity, porosity.
Stage 2	Attachment site presents as a moderate raised area or depression with slight rugosity/ridge formation; may include a small sulcus with surface area of <50% of the total visible attachment area; may include porosity.
Stage 3	Attachment site presents as pronounced rugosity/ridge formation and/or a large sulcus (50+% of total visible attachment area); may include porosity.
	Clavicle, conoid
Stage 0	Attachment site cannot be delineated; the diaphysis is uniformly curved and smooth to the touch.
Stage 1	Attachment site is discernible due to bone contour (an increase in the angle of the diaphyseal curvature at the position of the attachment without any elevation or surface irregularity of the cortical bone); may include porosity.
Stage 2	Attachment site presents as a distinct change in elevation, such as a smooth ridge or small tubercle that can be easily palpated; may include porosity.
Stage 3	Attachment site presents as a pronounced change in elevation with rugosity; may include porosity.
	Clavicle, trapezoid
Stage 0	Attachment site cannot be delineated.
Stage 1	Attachment site is discernible due one or more of the following: slight raised area, slight depression, slight surface irregularity; may include porosity.
Stage 2	Attachment site presents as a moderate raised area or depression with rugosity or surface irregularity; if a ridge is present, it is smooth (cannot be rugose); may include porosity.
Stage 3	Attachment site presents as a distinct rugose ridge with or without depressions, surface irregularity, and/or porosity.
	Humerus, pectoralis major
Stage 0	Attachment site cannot be delineated.
Stage 1	Attachment site is discernible due to bone contour with our without a low rounded smooth ridge and/or a shallow smooth depression; porosity may be present.
Stage 2	Attachment site present as a moderate raised area or depression with surface irregularity or slight rugosity; porosity may be present.

Stage 3	Attachment site presents as a well-defined ridge with pronounced rugosity and/or a sulcus; porosity may be present.
	Humerus, latissimus dorsi/teres major
Stage 0	Attachment site cannot be delineated.
Stage 1	Attachment site is discernible due to bone contour with our without a low rounded smooth ridge and/or a shallow smooth depression; porosity may be present.
Stage 2	Attachment site present as a moderate raised area or depression with surface irregularity or slight rugosity; small sharp ridges and/or porosity may be present.
Stage 3	Attachment site is rugose, usually with a well-defined ridge and/or a sulcus; porosity may be present.
	Humerus, deltoid
Stage 0	Attachment site cannot be delineated; the diaphysis is uniformly smooth and more or less cylindrical.
Stage 1	Attachment site is discernible due to bone contour (a noticeable lateral torsion of the proximal half of the diaphysis compared to the distal half) and/or slight surface irregularity; porosity may be present.
Stage 2	Attachment site presents as moderate or pronounced surface irregularity or slight rugosity; lateral and anterior ridges, if present, are not well-defined; porosity may be present.
Stage 3	Attachment site is rugose, usually with well-defined anterior and lateral ridges, the lateral ridge altering the anterior profile of the bone; porosity may be present.
	Radius, pronator teres
Stage 0	Attachment site cannot be delineated.
Stage 1	Attachment site is discernible due to a slight flattening and/or depression of the shaft; surface texture is generally smooth to the touch, but bone at the site may be differentiated due to its distinct striations.
Stage 2	Attachment site presents as a flattened or depressed area with surface irregularity and/or slight rugosity; surface changes are typically striated; porosity may be present.
Stage 3	Attachment site is rugose, sometimes surrounding a central depressed or flattened area; surface changes are typically striated; porosity may be present.
	Ulna, pronator quadratus
Stage 0	Attachment site cannot be delineated.
Stage 1	Attachment site is discernible due to bone contour (a noticeable thickening of the diaphysis on the medial aspect of the distal shaft without any elevation or surface irregularity of the cortical bone); porosity may be present.
Stage 2	Attachment presents as a slightly rounded ridge and/or surface irregularity/slight rugosity.
Stage 3	Attachment site presents as a pronounced ridge and/or area of moderate or pronounced rugosity.
	Ulna, supinator
	Supinator insertion cannot be clearly distinguished from that of the inferior oblique band of the annular ligament (see Bozkurt et al., 2005); also, attachment site has no "Stage 0" (complete absence), even on infant and atrophied ulnae.
	Ulna, brachialis (fibrocartilaginous)
Stage 0	Attachment site is only discernible due to bone contour (delineation is always possible, even on infant remains, as the bone flares towards the coronoid process); while a slight smooth depression may be visible, there are no changes to the surface of the bone; porosity may be present.
Stage 1	Surface irregularity or slight rugosity on <50% of total visible attachment area; if a depression is present, the rugosity/irregularity can occur within it and/or along its margins; porosity may be present.

Stage 2	Moderate rugosity on 50+% of the total visible attachment area, forming at least a partial margin; a depression may or may not be present; porosity may be present.
Stage 3	Pronounced rugose margins on at least the medial or lateral side of attachment area with possible surface irregularity or rugosity inside; porosity may be present.
	Femur, gluteus maximus
Stage 0	Attachment site is only discernible due to bone contour (delineation is always possible, even on infant remains), there are no changes to the surface of the bone; porosity may be present.
Stage 1	Attachment site is discernible as a rounded smooth ridge and/or a shallow smooth depression; porosity may be present.
Stage 2	Attachment site presents as surface irregularity or slight rugosity, with or without rounded smooth ridge; porosity may be present.
Stage 3	Attachment site presents as pronounced, rugose—and possibly sharp—
	NOTE: This scoring system does not take into account the third trochanter or hypotrochanteric fossa, both of which occur proximally on the gluteal tuberosity and have a rather obscure etiology. A shallow smooth linear depression may run adjacent and parallel to the lateral side of the gluteus maximus attachment site (i.e., the ridge); this depression is not taken into account because it may represent the vastus lateralis.
	Femur, vastus medialis
Stage 0	Attachment site cannot be delineated.
Stage 1	Attachment site is discernible as very shallow smooth depression or very slight rounded ridge, with or without porosity; often easier to palpate that to observed macroscopically.
Stage 2	No stage two for these individuals.
Stage 3	No stage three for these individuals.
	Femur, pectineus
Stage 0	Attachment site is only "discernible" due to bone contour (delineation is always possible, even on infant remains, as the bone flares towards the lesser trochanter or its growth plate).
Stage 1	Attachment site is discernible as a slightly raised rounded ridge or bump; surface is smooth.
Stage 2	Attachment site is discernible as a slightly raised ridge or bump with surface irregularity or slight rugosity.
Stage 3	Attachment site is discernible as a slightly raised ridge or bump with moderate or pronounced rugosity.
	Femur, gastrocnemius, medial head (fibrocartilaginous attachment)
	When distal epiphysis is unfused or only recently fused and distal metaphysis is uniformly porous:
Stage 0	Attachment site cannot be delineated.
Stage 1	Attachment site is discernible as surface irregularity or slight rugosity.
Stage 2	Attachment site is discernible as surface irregularity or slight rugosity PLUS depression.
Stage 3	Attachment site is discernible as surface irregularity or slight rugosity PLUS Depression and moderate or pronounced rugosity (possibly even a ridge) around area of depression.
	Femur, gastrocnemius, lateral head (fibrocartilaginous attachment)
Stage 0	Attachment site cannot be delineated.
Stage 1	Attachment site is discernible as surface irregularity or slight rugosity.
Stage 2	Attachment site is discernible as a depressed area with surface irregularity or slight rugosity.
Stage 3	Attachment site is discernible as a clear depressed area with surface irregularity or rugosity, as well as moderate or pronounced rugosity (possibly even a ridge) around area of depression.
	NOTE: lateral head is typically less pronounced than medial head. This scoring method can be used when distal epiphysis is unfused or only recently fused (fusion line still visible).

	Tibia, soleus
Stage 0	Attachment site cannot be delineated.
Stage 1	Shallow depression with fine-grained porosity.
Stage 2	Depression with any surface irregularity or slight rugosity along edges or within depression (no ridge formation); porosity may be present.
Stage 3	Depression with moderate or pronounced rugosity along edges or within depression, sometimes forming a clear ridge; porosity may be present.

Appendix B2: inter-observer agreement test data

This section holds the data obtained in the method testing. Please note that in these data, porosity is still scored, and some traits were scored as 0-2. In the final method, porosity was excluded due to its high interobserver variability, and all scores were reduced to 0-1, meaning that all traits which scored 2 below would in the final method simply score as 1.

			Scapula Left									**Scapula Right**								
GE	**SEKS**		**Delineation possible**	**porosity**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**	**Delineation possible**	**porosity**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**
			L Long head of triceps brachii									*R Long head of triceps brachii*								
4	M	Observer 1	1	0	1	0	0	0	0	0	2	1	0	1	1	0	0	0	0	3
		Observer 2	1	1	1	0	0	0	0	0	3	1	1	1	0	0	0	0	0	3
		Observer 3	1	1	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0
5	M	Observer 1	1	1	1	0	0	0	0	0	3	1	1	0	0	0	0	0	0	2
		Observer 2	1	2	1	1	0	0	0	0	5	1	1	0	1	0	0	0	0	3
		Observer 3	1	1	1	0	0	1	0	0	4	1	1	1	0	0	1	0	0	4
9	F	Observer 1	1	1	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0	2
		Observer 2	1	1	1	0	0	0	0	0	3	1	2	2	1	0	2	0	0	8
		Observer 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	F	Observer 1	1	0	1	0	0	0	0	0	2	1	0	0	0	0	0	1	0	2
		Observer 2	1	1	1	1	0	0	0	0	4	1	1	0	1	0	1	0	1	5
		Observer 3	1	0	0	0	0	1	0	0	2	1	0	0	0	0	1	0	0	2
13	F	Observer 1	1	2	2	0	0	0	0	0	5	1	2	2	0	0	0	0	0	5
		Observer 2	1	2	2	0	0	0	0	0	5	1	2	2	1	0	0	0	0	6
		Observer 3	1	1	2	0	1	0	0	0	5	1	2	1	0	1	0	0	0	5
			L Costaclavicular ligament									*R Costaclavicular ligament*								
4	M	Observer 1																		
		Observer 2																		
		Observer 3																		
5	M	Observer 1	1	1	0	0	0	0	0	0	2	1	1	1	0	0	0	0	0	3
		Observer 2	1	1	2	1	0	0	0	0	5	1	1	2	1	0	1	0	0	6
		Observer 3	1	1	1	0	0	0	0	0	3	1	2	1	0	0	0	0	0	4
9	F	Observer 1	1	0	1	0	0	2	0	0	4	1	1	0	0	0	2	0	0	4
		Observer 2	1	2	2	0	0	2	0	1	8	1	1	1	0	0	0	0	0	3
		Observer 3	1	1	1	0	0	2	0	0	5	1	1	1	0	0	2	0	0	5
10	F	Observer 1	1	1	0	0	0	0	0	0	2	1	1	0	0	0	2	0	0	4
		Observer 2	1	1	1	1	0	1	0	0	5	1	2	2	1	0	2	0	0	8
		Observer 3	1	1	0	0	0	1	0	0	3	1	1	0	0	0	2	0	0	4
13	F	Observer 1	1	1	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0	2
		Observer 2	1	2	2	0	0	0	0	0	5	1	2	2	0	0	0	0	0	5
		Observer 3	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	3
			L Conoid									*R Conoid*								

4	M	Observer 1	1	0	1	0	0	0	0	0	2	1	0	1	1	0	0	0	0	3
		Observer 2	1	1	1	0	0	0	0	0	3	1	1	1	1	0	0	0	0	4
		Observer 3	1	1	0	0	0	0	1	0	3	1	1	0	0	0	0	1	0	3
5	M	Observer 1	1	0	1	0	0	0	0	0	2	1	0	1	0	0	0	0	0	2
		Observer 2	1	2	2	0	0	1	0	0	6	1	2	2	0	0	1	0	0	6
		Observer 3	1	1	1	1	0	0	0	0	4	1	1	1	0	0	0	0	0	3
9	F	Observer 1	1	0	0	0	0	0	1	0	2	1	0	1	0	0	0	1	0	3
		Observer 2	1	2	1	1	0	0	0	1	6	1	2	2	1	0	0	0	1	7
		Observer 3	1	1	0	0	0	0	1	0	3	1	2	1	0	0	0	1	0	5
10	F	Observer 1	1	0	1	0	0	0	1	0	3	1	0	1	0	0	0	1	0	3
		Observer 2	1	1	1	1	0	0	0	1	5	1	1	1	1	0	0	0	0	4
		Observer 3	1	0	1	0	0	0	1	0	3	1	0	1	0	0	0	1	0	3
13	F	Observer 1	1	1	1	0	0	0	1	0	4	1	1	1	0	0	0	0	0	3
		Observer 2	1	2	2	1	0	0	0	1	7	1	1	1	0	0	0	0	0	3
		Observer 3	1	0	1	0	0	0	1	0	3	1	0	1	0	0	0	1	0	3
			L trapezoid ligament									*R trapezoid ligament*								
4	M	Observer 1	1	0	1	0	0	0	0	0	2	1	0	1	1	0	0	0	0	3
		Observer 2	1	1	1	0	0	0	0	0	3	1	1	1	1	0	0	0	1	5
		Observer 3	1	1	0	0	1	0	0	0	3	1	1	0	1	0	0	1	0	4
5	M	Observer 1	1	0	1	0	0	0	0	0	2	1	0	1	0	0	1	0	0	3
		Observer 2	1	2	2	0	0	1	0	0	6	1	2	2	0	0	1	0	0	6
		Observer 3	1	1	1	0	1	0	0	0	4	1	1	2	0	1	0	0	0	5
9	F	Observer 1	1	2	0	0	0	1	0	0	4	1	2	1	0	0	1	0	0	5
		Observer 2	1	1	2	0	0	1	0	0	5	1	2	2	1	0	1	0	1	8
		Observer 3	1	1	2	0	0	1	0	0	5	1	2	1	0	1	0	0	0	5
10	F	Observer 1	1	0	0	0	0	1	0	0	2	1	0	0	0	0	1	0	0	2
		Observer 2	1	1	1	1	0	1	0	1	6	1	1	1	0	0	1	0	1	5
		Observer 3	1	0	0	0	0	1	0	0	2	1	0	0	0	0	1	0	0	2
13	F	Observer 1	1	1	0	2	0	0	0	0	4	1	1	0	1	0	1	0	0	4
		Observer 2	1	2	2	1	0	1	0	1	8	1	1	1	1	0	1	0	1	6
		Observer 3	1	0	1	1	0	0	1	0	4	1	1	0	1	0	1	0	0	4
			L m. pectoralis									*R m. pectoralis*								
4	M	Observer 1	1	0	1	1	0	0	0	0	3	1	0	1	1	1	0	0	0	4
		Observer 2	1	1	1	1	0	1	0	0	5	1	1	1	0	0	0	0	0	3
		Observer 3	1	1	0	1	0	1	0	0	4	1	0	1	0	1	0	0	0	3
5	M	Observer 1	1	0	1	2	0	0	0	0	4	1	1	1	2	0	0	0	0	5
		Observer 2	1	2	1	0	0	1	0	0	5	1	2	2	2	0	0	0	1	8
		Observer 3	1	1	1	2	0	0	0	0	5	1	1	2	2	0	0	0	0	6
9	F	Observer 1	1	0	1	0	0	0	0	0	2	1	0	1	0	0	0	0	0	2
		Observer 2	1	1	1	0	0	0	0	0	3	1	1	1	1	0	1	0	0	5
		Observer 3	1	2	1	0	0	0	0	0	4	1	0	1	1	0	0	0	0	3
10	F	Observer 1	1	0	1	1	0	0	0	0	3	1	0	1	1	0	0	0	0	3
		Observer 2	1	2	1	1	0	0	0	0	5	1	2	2	2	0	0	0	0	7
		Observer 3	1	1	0	2	0	0	0	0	4	1	1	1	2	0	0	0	0	5
13	F	Observer 1	1	1	1	0	0	0	0	0	3	1	1	0	1	1	0	0	0	4
		Observer 2	1	1	2	1	0	0	0	0	5	1	1	1	0	0	0	0	0	3
		Observer 3	1	0	1	2	0	1	0	0	5	1	1	1	2	0	0	0	0	5
			L m. latissimus dorsii/teres major									*R m. latissimus dorsii/teres major*								
4	M	Observer 1	1	1	0	0	0	1	0	0	3									
		Observer 2	1	1	1	0	0	1	0	0	4	1	1	1	0	0	0	0	0	3
		Observer 3	1	1	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0
5	M	Observer 1	1	0	0	0	0	1	0	0	2	1	0	1	0	0	1	0	0	3
		Observer 2	1	1	0	0	0	1	0	0	3	1	1	1	1	0	0	0	0	4
		Observer 3	1	1	0	0	0	1	0	0	3	1	1	0	0	0	1	0	0	3

9	F	Observer 1	1	0	0	0	0	1	0	0	2	1	0	0	1	0	0	0	0	2
		Observer 2	1	1	1	1	0	1	0	0	5	1	0	1	1	0	1	0	0	4
		Observer 3	1	1	1	0	0	1	0	0	4	1	0	0	1	0	0	0	0	2
10	F	Observer 1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	2
		Observer 2	1	1	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0	2
		Observer 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	F	Observer 1	1	1	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0	2
		Observer 2	1	1	1	0	0	0	0	0	3	1	1	1	0	0	0	0	0	3
		Observer 3	1	0	1	2	0	0	0	0	4	0	0	0	0	0	0	0	0	0

			L m. deltoideus									*R m. deltoideus*								
4	M	Observer 1	1	1	1	0	0	0	0	0	3	1	1	1	0	0	0	0	0	3
		Observer 2	1	1	1	1	0	0	0	0	4	1	1	1	1	0	0	0	0	4
		Observer 3	1	1	1	0	0	0	0	0	3	1	0	1	0	0	0	0	0	2
5	M	Observer 1	1	0	0	1	0	0	0	0	2	1	0	0	1	0	0	0	0	2
		Observer 2	1	2	1	0	0	0	0	0	4	1	1	1	0	0	0	0	0	3
		Observer 3	1	2	2	0	0	0	0	0	5	1	2	2	0	0	0	0	0	5
9	F	Observer 1	1	1	0	0	0	0	0	0	2	1	2	0	0	0	0	0	0	3
		Observer 2	1	1	1	1	0	0	0	0	4	1	2	1	1	0	1	0	0	6
		Observer 3	1	2	1	0	0	0	0	0	4	1	2	2	0	0	0	0	0	5
10	F	Observer 1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1
		Observer 2	1	1	1	0	0	0	0	0	3	1	1	0	0	0	0	0	0	2
		Observer 3	1	1	1	0	0	0	0	0	3	1	0	2	0	0	0	0	0	3
13	F	Observer 1	1	1	1	1	0	0	0	0	4									
		Observer 2	1	2	2	1	0	0	0	0	6	1	1	1	0	0	0	0	0	3
		Observer 3	1	1	2	1	0	0	0	0	5	1	1	1	1	0	0	0	0	4

			L m. pronator teres									*R m. pronator teres*								
4	M	Observer 1	1	0	1	0	1	0	0	0	3	1	0	1	0	1	0	0	0	3
		Observer 2	1	1	1	1	1	0	0	0	5									
		Observer 3	1	1	1	0	1	0	0	0	4									
5	M	Observer 1										1	0	0	0	1	0	0	0	2
		Observer 2	1	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0
		Observer 3										1	1	0	0	1	0	0	0	3
9	F	Observer 1	1	0	0	0	1	0	0	0	2	1	0	0	0	1	0	0	0	2
		Observer 2	1	0	1	1	0	1	0	0	4	1	0	1	0	0	1	0	0	3
		Observer 3	1	2	1	0	0	1	0	0	5	1	1	1	0	0	1	0	0	4
10	F	Observer 1										1	0	0	0	1	0	0	0	2
		Observer 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Observer 3	1	1	0	0	1	0	0	0	3	1	1	0	0	1	0	0	0	3
13	F	Observer 1																		0
		Observer 2	1	1	1	0	0	0	0	0	3	1	1	1	0	0	0	0	0	3
		Observer 3	1	1	0	0	1	0	0	0	3	1	1	0	0	1	0	0	0	3

			L pronator quadratus									*R pronator quadratus*								
4	M	Observer 1	1	0	1	1	0	0	0	0	3	1	0	1	1	0	0	0	0	3
		Observer 2	1	1	1	1	0	0	0	0	4	1	1	1	1	0	0	0	0	4
		Observer 3										1	1	0	1	0	0	0	0	3
5	M	Observer 1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1
		Observer 2	1	1	1	1	0	0	0	0	4	1	1	1	1	0	1	0	0	5
		Observer 3	1	1	0	1	0	0	0	0	3	1	1	0	1	0	0	0	0	3
9	F	Observer 1																		
		Observer 2	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	0	0	5
		Observer 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	F	Observer 1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1
		Observer 2	1	1	1	0	0	0	0	0	3	1	1	1	0	0	0	0	0	3
		Observer 3	1	0	0	1	0	0	0	0	2	1	0	0	2	0	0	0	0	3

13	F	Observer 1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1
		Observer 2										1	1	1	0	0	0	0	0	3
		Observer 3										0	0	0	0	0	0	0	0	0
			L M. brachialis									*R M. brachialis*								
4	M	Observer 1	1	0	1	0	0	0	0	0	2	1	0	1	0	0	0	0	0	2
		Observer 2	1	1	1	0	0	0	0	0	3	1	1	1	0	0	0	0	0	3
		Observer 3										1	0	0	0	0	1	0	0	2
5	M	Observer 1	1	0	0	0	0	1	0	0	2	1	0	0	0	0	1	0	0	2
		Observer 2	1	1	0	0	0	0	0	0	2	1	1	1	0	0	0	0	0	3
		Observer 3	1	1	0	0	0	1	0	0	3	1	1	0	0	0	1	0	0	3
9	F	Observer 1	1	1	0	0	0	1	0	1	4	1	1	0	0	0	1	0	0	3
		Observer 2	1	1	1	1	0	1	0	1	6	1	1	1	1	0	1	0	0	5
		Observer 3	1	1	0	0	0	1	0	1	4	1	1	0	0	0	1	0	0	3
10	F	Observer 1	1	0	0	0	0	1	0	0	2	1	0	0	0	0	1	0	0	2
		Observer 2	1	0	1	0	0	1	0	0	3	1	1	1	1	0	0	0	0	4
		Observer 3	1	0	0	0	0	1	0	0	2	1	0	0	0	1	0	0	0	2
13	F	Observer 1	1	0	0	1	0	1	0	0	3	1	0	0	1	0	1	0	1	4
		Observer 2	1	1	1	0	0	0	0	0	3	1	1	2	1	0	0	0	1	6
		Observer 3	1	1	0	0	0	1	0	0	3	1	0	0	0	0	1	0	0	2
			L m. gluteus maximus									*R m. gluteus maximus*								
4	M	Observer 1	1	0	1	1	0	0	0	0	3	1	0	2	0	0	0	0	0	3
		Observer 2	1	2	2	0	0	1	0	0	6	1	2	2	0	0	1	0	0	6
		Observer 3	1	1	0	0	0	1	0	0	3	1	1	0	0	0	1	0	0	3
5	M	Observer 1	1	0	0	1	0	2	0	0	4									
		Observer 2	1	2	2	1	0	1	0	1	8									
		Observer 3	1	1	0	0	0	1	0	0	3									
9	F	Observer 1	1	0	0	1	0	0	0	0	2	1	0	0	1	0	0	0	0	2
		Observer 2	1	1	2	1	0	0	1	0	6	1	1	1	1	0	0	0	0	4
		Observer 3	1	1	1	1	1	0	0	0	5	1	1	1	1	0	0	0	0	4
10	F	Observer 1	1	0	0	0	1	0	0	0	2	1	0	0	0	0	0	0	0	1
		Observer 2	1	2	1	1	0	1	0	0	6	1	1	1	1	0	0	0	1	5
		Observer 3	1	1	2	0	0	1	0	0	5	1	1	1	0	0	0	1	0	4
13	F	Observer 1	1	1	0	0	0	1	0	0	3									
		Observer 2	1	1	1	0	1	0	0	0	4	1	1	1	1	0	0	0	0	4
		Observer 3	1	1	2	0	0	1	0	0	5	1	1	2	0	0	1	0	0	5
			L m. vastus medialis									*R m. vastus medialis*								
4	M	Observer 1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
		Observer 2	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1
		Observer 3	1	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0
5	M	Observer 1	0	0	0	0	0	0	0	0	0									
		Observer 2	1	0	0	0	0	0	0	0	1									
		Observer 3	1	1	0	0	1	0	0	0	3									
9	F	Observer 1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1
		Observer 2	1	0	1	0	0	1	0	0	3	1	0	0	0	0	1	0	0	2
		Observer 3	1	1	0	0	0	1	0	0	3	1	1	0	0	0	1	0	0	3
10	F	Observer 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Observer 2	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1
		Observer 3	1	0	0	0	0	1	0	0	2	1	0	0	0	0	1	0	0	2
13	F	Observer 1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1
		Observer 2	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1
		Observer 3	1	1	0	0	0	1	0	0	3	1	1	0	0	0	1	0	0	3
			L m. pectineus									*R m. pectineus*								
4	M	Observer 1	1	0	1	0	0	0	0	0	2	1	0	2	0	0	0	0	0	3

		Observer 2	1	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	4
		Observer 3	1	0	0	0	1	0	0	0	2	1	0	0	0	1	0	0	0	2
5	M	Observer 1	1	1	0	0	0	0	0	0	2									
		Observer 2	1	2	1	0	0	0	0	0	4									
		Observer 3	1	1	1	0	0	0	0	0	3									
9	F	Observer 1	1	1	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0	2
		Observer 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Observer 3	1	0	0	0	0	1	0	0	2	1	0	0	0	0	1	0	0	2
10	F	Observer 1	1	1	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0	2
		Observer 2	1	1	1	0	0	0	0	0	3	1	1	1	1	0	0	0	0	4
		Observer 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	F	Observer 1	1	1	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0	2
		Observer 2	1	1	1	0	0	0	0	0	3	1	1	0	0	0	0	0	0	2
		Observer 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			L m. gastrocnemius medial									*R m. gastrocnemius medial*								
4	M	Observer 1	1	0	0	0	0	1	0	0	2	1	0	0	0	0	1	0	0	2
		Observer 2	1	0	2	0	0	1	0	0	4	1	0	2	0	0	1	0	0	4
		Observer 3	1	0	0	0	0	1	0	0	2	1	0	0	0	0	1	0	0	2
5	M	Observer 1	1	0	0	0	0	1	0	0	2									
		Observer 2	1	0	2	0	0	1	0	0	4									
		Observer 3	1	0	0	0	0	1	0	0	2									
9	F	Observer 1	1	0	1	0	0	2	0	0	4	1	0	1	0	0	2	0	0	4
		Observer 2	1	0	2	0	0	1	0	0	4	1	0	2	2	0	2	0	1	8
		Observer 3	1	0	2	0	0	2	0	0	5	1	0	2	0	0	2	0	0	5
10	F	Observer 1	1	0	1	0	0	0	0	0	2	1	0	1	0	0	0	0	0	2
		Observer 2	1	0	2	0	0	1	0	0	4	1	0	1	0	0	1	0	0	3
		Observer 3	1	0	2	0	0	0	0	0	3	1	0	1	0	0	2	0	0	4
13	F	Observer 1	1	0	2	2	0	1	0	0	6	1	0	2	2	0	2	0	0	7
		Observer 2	1	0	2	0	0	2	0	0	5	1	0	2	0	0	2	0	0	5
		Observer 3	1	0	2	0	2	0	0	2	7	1	0	1	0	0	2	0	0	4
			L m. gastrocnemius lateral									*R m. gastrocnemius lateral*								
4	M	Observer 1	1	0	0	0	0	1	0	0	2	1	0	0	0	0	1	0	0	2
		Observer 2	1	0	2	0	0	1	0	0	4	1	0	2	0	0	1	0	0	4
		Observer 3	1	0	0	0	0	2	0	0	3	1	0	0	0	0	1	0	0	2
5	M	Observer 1	0	0	0	0	0	0	0	0	0									
		Observer 2	1	0	1	0	0	1	0	0	3									
		Observer 3	0	0	0	0	0	0	0	0	0									
9	F	Observer 1	1	0	0	0	0	1	0	0	2	1	0	0	0	0	0	0	0	1
		Observer 2	1	0	2	0	0	1	0	0	4	1	0	2	0	0	1	0	0	4
		Observer 3	1	0	0	0	0	1	0	0	2	1	0	2	0	0	1	0	0	4
10	F	Observer 1	1	0	0	0	0	1	0	0	2	1	0	0	0	0	1	0	0	2
		Observer 2	1	0	2	0	0	1	0	0	4	1	0	1	0	0	1	0	0	3
		Observer 3	1	0	1	0	0	1	0	0	3	1	0	0	0	1	0	0	0	2
13	F	Observer 1	1	0	2	2	0	2	0	0	7									
		Observer 2	1	0	2	0	0	2	0	0	5	1	0	2	0	0	2	0	0	5
		Observer 3	1	0	1	0	2	0	0	0	4									
			L M. Soleus									*R M. Soleus*								
4	M	Observer 1	1	1	0	1	0	0	0	0	3	1	1	1	0	0	1	0	0	4
		Observer 2	1	1	1	1	0	1	0	0	5	1	1	1	0	0	1	0	0	4
		Observer 3	1	1	1	1	1	0	0	0	5	1	1	1	0	0	0	0	0	3
5	M	Observer 1	1	1	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0	2
		Observer 2	1	1	2	1	0	1	0	0	6	1	2	1	1	0	0	0	0	5
		Observer 3	1	1	0	1	1	0	0	0	4	1	1	0	2	1	0	0	0	5
9	F	Observer 1	1	2	0	0	0	1	0	0	4	1	2	0	0	0	1	0	0	4

		Observer 2	1	2	2	0	0	1	0	0	6	1	2	2	0	0	1	0	0	6
		Observer 3	1	2	2	0	0	1	0	0	6	1	2	2	0	0	1	0	0	6
10	F	Observer 1	1	1	0	0	0	0	0	0	2	1	1	0	0	0	1	0	0	3
		Observer 2	1	1	1	1	0	1	0	0	5	1	1	1	1	0	1	0	0	5
		Observer 3	1	1	0	0	0	1	0	0	3	1	1	0	0	0	1	0	0	3
13	F	Observer 1	1	1	1	0	0	1	0	0	4	1	1	1	0	0	1	0	0	4
		Observer 2	1	1	1	0	0	1	0	0	4	1	1	1	0	0	1	0	0	4
		Observer 3	1	1	0	0	0	1	0	0	3	1	1	0	0	0	1	0	0	3

Appendix B3: ec data on all individuals per side, enthesis and trait

Clavicles

		L Costaclavicular ligament								*R Costaclavicular ligament*							
Archival age:	**Seks**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**
6	F	1	1	0	0	1	0	0	3	1	1	1	0	1	0	0	4
4	?	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2
5	M	1	0	0	0	0	0	0	1	1	0	0	0	2	0	0	3
2	F									1	1	0	0	0	0	0	2
4	F																
4	F	1	1	0	0	0	0	0	2								
3	M	1	2	0	0	0	0	0	3	1	1	0	0	0	0	0	2
10	F	1	0	0	0	0	0	0	1	1	0	0	0	2	0	0	3
9	F	1	1	0	0	2	0	0	4	1	0	0	0	2	0	0	3
4	F																
12	F									1	0	0	0	1	0	0	2
5	M	1	1	0	0	2	0	0	4	1	0	0	0	1	1	0	3
4	M	1	0	1	0	2	0	0	4	1	0	1	0	0	0	0	2
7	F																
9	F	1	0	1	0	1	0	0	3	1	1	0	0	2	0	0	4
13	F	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1

		L Conoid								*R Conoid*							
Archival age:	**Seks**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**
6	F	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2
4	?	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2
5	M																
2	F	1	0	0	0	0	1	0	2	1	0	0	0	0	1	0	2
4	F																
4	F	1	0	0	0	0	0	0	1								
3	M	1	0	0	1	0	0	0	2								
10	F	1	1	0	0	0	1	0	3	1	1	0	0	0	1	0	3
9	F	1	0	0	0	0	1	0	2	1	1	0	0	0	1	0	3
4	F																
12	F	1	1	0	0	0	1	0	3	1	0	1	0	0	0	0	2
5	M	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2
4	M	1	1	0	0	0	0	0	2	1	1	1	0	0	0	0	3
7	F																
9	F									1	1	0	0	0	0	0	2
13	F	1	1	0	0	0	1	0	3	1	1	0	0	0	0	0	2

		L trapezoid ligament								*R trapezoid ligament*							
Archival age:	**Seks**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**
6	F	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
4	?	1	1	0	0	1	0	0	3	1	1	0	0	1	0	0	3
5	M																
2	F	1	1	0	0	0	0	0	2	1	1	0	0	1	0	0	3
4	F																
4	F	1	0	0	0	1	0	0	2								
3	M	1	0	0	0	1	0	0	2								
10	F	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
9	F	1	0	0	0	1	0	0	2	1	1	0	0	1	0	0	3
4	F																
12	F	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
5	M	1	0	0	0	1	1	0	3	1	0	0	0	1	0	0	2
4	M	1	1	0	0	0	0	0	2	1	1	1	0	0	0	0	3
7	F								0								
9	F	1	1	0	0	1	0	0	3	1	0	0	0	1	0	0	2
13	F	1	0	2	0	0	0	0	3	1	0	1	0	1	0	0	3

3	M									1	1	0	0	0	0	0	2									1	1	0	0	0	0	0	2																
5	M	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2	1	1	0	0	1	0	0	3
13	M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	3									1	0	0	0	1	0	0	2								
4	F																																																
4	M	1	1	0	0	1	0	0	3	1	1	0	0	1	0	0	3	1	1	0	0	1	0	0	3	1	0	0	0	2	0	0	3	1	0	0	0	1	0	0	2	1	1	0	0	1	0	0	3
9	F	1	0	0	0	0	0	0	1	1	0	0	0	2	0	0	3	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2	1	1	0	0	0	1	0	3	1	1	2	0	0	0	0	4
5	F	1	0	0	0	1	0	0	2																									1	0	0	0	1	0	0	2								
6	M																																																
8	F																																																
11	F																																																
8	M	1	0	0	0	2	0	0	3	1	0	1	0	2	0	0	4	1	1	0	0	0	0	0	2	1	1	0	0	2	0	0	4	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
8	F	1	0	0	0	2	0	0	3	1	0	0	0	2	0	0	3	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2	1	1	1	0	0	0	0	3	1	1	0	0	1	0	0	3
16	M	1	1	1	0	0	0	0	3	1	1	1	0	0	0	0	3																	1	1	0	0	1	0	0	3	1	0	0	0	1	0	0	2

Humerii

		L M. pectoralis major								*R M. pectoralis major*								*L M. Latissimus dorsii/teres major*								*R M. Latissimus dorsii/teres major*								*L M. Deltoideus*								*R M. Deltoideus*							
Archival age:	Seks	Delineation possible	surface irregularity	Ridge formation	surface flattening	Depression	Tubercle formation	enthesophyte formation	COMPOSITE	Delineation possible	surface irregularity	Ridge formation	surface flattening	Depression	Tubercle formation	enthesophyte formation	COMPOSITE	Delineation possible	surface irregularity	Ridge formation	surface flattening	Depression	Tubercle formation	enthesophyte formation	COMPOSITE	Delineation possible	surface irregularity	Ridge formation	surface flattening	Depression	Tubercle formation	enthesophyte formation	COMPOSITE	Delineation possible	surface irregularity	Ridge formation	surface flattening	Depression	Tubercle formation	enthesophyte formation	COMPOSITE	Delineation possible	surface irregularity	Ridge formation	surface flattening	Depression	Tubercle formation	enthesophyte formation	COMPOSITE
6	F	1	0	2	0	1	0	0	4	1	0	1	0	1	0	0	3	1	0	0	1	0	0	0	2	1	0	0	1	0	0	0	2	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
4	?	1	1	0	0	0	0	0	2	1	1	1	0	0	0	0	3									1	0	1	1	0	0	0	3	1	1	1	0	0	0	0	3	1	1	1	0	0	0	0	3
5	M	1	0	0	0	1	0	0	2	1	1	0	0	1	0	0	3									1	1	0	0	1	0	0	3																
2	F	1	1	1	0	0	0	0	3	1	1	0	0	0	0	0	2	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2	1	0	1	0	0	0	0	2	1	0	1	0	0	0	0	2
4	F																																																
4	F	1	1	1	0	0	0	0	3	1	1	0	0	0	0	0	2	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2
3	M	1	1	0	0	0	0	0	2	1	1	1	0	0	0	0	3									1	1	0	0	1	0	0	3									1	1	0	0	1	0	0	3

10	F	1	1	1	0	0	0	0	3	1	1	1	0	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	2	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
9	F	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2	1	0	0	0	1	0	0	2	1	0	1	0	0	0	0	2	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
4	F																																																
12	F	1	0	1	0	0	0	0	2									1	0	0	0	1	0	0	2									1	1	0	0	0	0	0	2								
5	M	1	0	0	0	0	0	0	1	1	0	1	0	0	0	0	2	1	0	0	1	0	0	0	2	1	0	0	0	1	0	0	2	1	0	1	0	0	0	0	2	1	1	0	0	0	0	0	2
4	M	1	1	1	0	0	0	0	3	1	1	1	1	0	0	0	4	1	0	0	0	1	0	0	2									1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2
7	F																																																
9	F	1	0	1	0	0	0	0	2	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	2	1	0	0	1	0	0	0	2	1	0	0	0	0	0	0	1								
13	F	1	1	0	0	0	0	0	2	1	0	1	1	0	0	0	3	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1	1	0	0	0	0	3								
3	M																																																
5	M	1	1	2	0	0	0	0	4	1	1	2	0	0	0	0	4	1	0	0	0	1	0	0	2	1	1	0	0	1	0	0	3	1	0	1	0	0	0	0	2	1	0	1	0	0	0	0	2
13	M	1	0	1	0	0	0	0	2	1	0	1	0	0	0	0	2	1	0	0	1	0	0	0	2	1	0	0	1	0	0	0	2	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2
4	F																																																
4	M	1	1	0	0	0	0	0	2	1	2	0	0	0	0	0	3	1	0	0	1	0	0	0	2	1	1	0	0	1	0	0	3	1	0	1	0	0	0	0	2	1	1	1	0	0	0	0	3
9	F	1	0	1	0	0	0	0	2									1	1	0	0	1	0	0	3									1	1	0	0	0	0	0	2								
5	F	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2									1	1	0	0	0	0	0	2
6	M																																	1	1	1	0	0	0	0	3								
8	F																																																
11	F	1	1	1	0	0	0	0	3	1	1	1	0	0	0	0	3	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2	1	1	0	0	0	0	0	2	1	2	0	0	0	0	0	3
8	M	1	0	0	1	0	0	0	2	1	0	0	1	0	0	0	2	1	0	1	0	0	0	0	2	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	2	1	0	0	0	0	0	0	1
8	F	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	1	0	0	0	2	1	0	0	0	1	0	0	2	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
16	M	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1	0	1	0	0	0	3	1	0	0	1	0	0	0	2	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1

Radii

		L M. pronator teres								*R M. pronator teres*							
Archival age:	**Seks**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**
6	F	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
4	?	1	0	0	1	0	0	0	2	1	0	0	1	0	0	0	2
5	M									1	0	0	1	0	0	0	2
2	F	1	0	0	1	1	0	0	3	1	0	0	1	1	0	0	3
4	F																
4	F																
3	M									1	0	0	1	0	0	0	2
10	F									1	0	0	1	0	0	0	2
9	F	1	0	0	1	0	0	0	2	1	0	0	1	0	0	0	2
4	F																
12	F	1	0	0	1	0	0	0	2								
5	M	1	1	0	1	0	0	0	3	1	1	0	1	0	0	0	3
4	M	1	1	0	1	0	0	0	3	1	1	0	1	0	0	0	3
7	F																
9	F	1	0	0	1	0	0	0	2	1	0	0	1	0	0	0	2
13	F																
3	M																
5	M									1	0	0	1	0	0	0	2
13	M	1	1	0	0	1	0	0	3	1	0	0	0	1	0	0	2
4	F	1	0	0	1	0	0	0	2	1	0	0	1	0	0	0	2
4	M	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	2

9	F	1	1	0	1	0	0	0	3								
5	F																
6	M	1	0	0	0	1	0	0	2								
8	F									1	0	0	1	0	0	0	2
11	F																
8	M	1	0	0	1	0	0	0	2	1	0	0	1	0	0	0	2
8	F	1	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0
16	M	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2

Ulnae

		L pronator quadratus								*R pronator quadratus*								*L M. brachialis*								*R M. brachialis*							
Archival age:	**Seks**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**
6	F	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
4	?	1	0	0	1	0	0	0	2	1	0	0	1	0	0	0	2	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
5	M																																
2	F	1	0	1	0	0	0	0	2	1	0	1	0	0	0	0	2	1	0	1	0	1	0	0	3	1	0	0	0	1	0	0	2
4	F																																
4	F																																
3	M																																
10	F	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
9	F																	1	0	0	0	1	0	1	3	1	0	0	0	1	0	0	2
4	F																																
12	F	1	0	1	0	0	0	0	2									1	0	0	0	0	0	0	1								
5	M	1	0	0	0	0	0	0	1									1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1

4	M	1	1	1	0	0	0	0	3	1	1	1	0	0	0	0	3	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2
7	F																																
9	F	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	2	1	1	0	0	1	0	0	3
13	F	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	1	0	1	0	0	3	1	0	1	0	1	0	1	4
3	M																																
5	M	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
13	M	1	0	1	0	0	0	0	2																	1	0	0	0	0	0	0	1
4	F	1	0	0	0	0	0	0	1	1	0	1	0	0	0	0	2	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
4	M	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
9	F	1	0	0	0	0	0	0	1									1	0	1	1	0	0	0	3								
5	F																																
6	M																																
8	F									1	0	0	0	0	0	0	1	1	0	1	0	1	0	0	3	1	0	1	0	1	0	0	3
11	F																	1	0	1	0	1	0	0	3	1	0	1	0	1	0	0	3
8	M	1	0	1	0	0	0	0	2	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
8	F	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	1	0	0	0	2	1	0	0	1	0	0	0	2
16	M	1	0	0	0	0	0	0	1									1	1	1	1	0	0	0	4	1	1	1	1	0	0	0	4

Femora

		L M. Gluteus Maximus								*R M. Gluteus Maximus*							
Archival age:	**Seks**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**
6	F									1	0	1	0	0	0	0	2
4	?	1	1	0	0	0	0	0	2	1	0	0	0	0	0	0	1
5	M									1	0	1	0	0	0	0	2

		L Vastus Medialis								*R Vastus Medialis*							
Archival age:	**Seks**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**
6	F									1	0	0	0	1	0	0	2
4	?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

		L Pectineus								*R pectineus*							
Archival age:	**Seks**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**
6	F									1	0	0	0	0	0	0	1
4	?	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
5	M									1	0	0	0	0	0	0	1

2	F									1	2	1	0	0	0	0	4									0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
4	F	1	0	1	0	0	0	0	2									0	0	0	0	0	0	0	0									1	0	0	0	0	0	0	1								
4	F									1	0	1	0	0	0	0	2																									1	1	0	0	0	0	0	2
3	M									1	0	1	0	1	0	0	3	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
10	F	1	0	0	1	0	0	0	2	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
9	F	1	0	1	0	0	0	0	2	1	0	1	0	0	0	0	2	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
4	F																																																
12	F	1	1	1	0	1	0	0	4	1	1	1	0	1	0	0	4	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
5	M																																																
4	M	1	1	1	0	0	0	0	3	1	2	0	0	0	0	0	3	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	2	1	2	0	0	0	0	0	3
7	F	1	0	1	0	0	0	0	2	1	0	1	0	0	0	0	2	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2																
9	F																	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2	1	0	1	0	0	0	0	2								
13	F	1	0	0	0	1	0	0	2									1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
3	M	1	1	0	0	1	0	0	3									1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1																
5	M	1	0	1	0	2	0	0	4									0	0	0	0	0	0	0	0									1	0	0	0	0	0	0	1								
13	M									1	1	0	0	0	0	0	2	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	F	1	0	1	0	0	0	0	2	1	0	1	0	0	0	0	2	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
4	M	1	1	2	0	0	0	0	4	1	1	2	0	1	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
9	F	1	0	1	0	0	0	0	2	1	0	1	0	0	0	0	2	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2
5	F	1	1	1	1	0	0	0	4									0	0	0	0	0	0	0	0									1	0	0	0	0	0	0	1								
6	M									1	0	0	1	0	0	0	2									1	0	0	0	1	0	0	2									0	0	0	0	0	0	0	0
8	F	1	0	1	0	0	0	0	2									0	0	0	0	0	0	0	0									1	0	0	0	0	0	0	1								
11	F									1	0	1	0	0	0	0	2									0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
8	M	1	1	0	0	2	0	0	4	1	1	0	0	2	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2
8	F	1	0	0	0	1	0	0	2	1	0	0	0	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
16	M	1	1	0	0	1	0	0	3	1	1	0	0	1	0	0	3	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1

Femora

		L M. gastrocnemius, medial head								R M. gastrocnemius, medial head								L M. gastrocnemius, lateral head								R M. gastrocnemius, lateral head							
Archival age:	**Seks**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**
6	F									1	0	0	0	1	0	0	2									0	0	0	0	0	0	0	0
4	?	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	M									0	0	0	0	0	0	0	0									0	0	0	0	0	0	0	0
2	F	1	0	0	0	1	0	0	2	1	1	0	0	0	0	0	2	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
4	F	1	1	0	0	1	0	0	3									1	0	0	0	1	0	0	2								
4	F									1	0	0	0	1	0	0	2									1	0	0	0	1	0	0	2
3	M	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2																
10	F	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
9	F	1	1	0	0	2	0	0	4	1	1	0	0	2	0	0	4	1	0	0	0	1	0	0	2	1	0	0	0	0	0	0	1
4	F																																
12	F	1	1	0	0	1	0	0	3	1	1	0	0	1	0	0	3	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2
5	M																																
4	M	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
7	F	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
9	F	1	1	0	0	1	0	0	3	1	2	0	0	1	0	0	4	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
13	F	1	2	2	0	1	0	0	6	1	2	2	0	2	0	0	7	1	2	2	0	2	0	0	7								
3	M																																
5	M	1	0	0	0	1	0	0	2									0	0	0	0	0	0	0	0								
13	M	1	2	0	0	1	0	0	4	1	2	0	0	0	0	0	3	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2
4	F	1	1	0	0	1	0	0	3	1	2	0	0	1	0	0	4	1	1	0	0	1	0	0	3	1	1	0	0	1	0	0	3

4	M									1	2	0	0	0	0	0	3									1	0	0	0	1	0	0	2
9	F	1	2	0	0	0	0	0	3	1	1	0	0	1	0	0	3	1	1	0	0	0	0	0	2	1	0	0	0	1	0	0	2
5	F	1	1	0	0	1	0	0	3	1	2	0	0	0	0	0	3									1	1	0	0	1	0	0	3
6	M									1	2	0	0	2	0	0	5									1	1	0	0	0	0	0	2
8	F	1	1	0	0	1	0	0	3	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
11	F	1	2	0	0	1	0	0	4	1	2	0	0	1	0	0	4	1	2	0	0	1	0	0	4	1	2	0	0	1	0	0	4
8	M	1	1	0	0	2	0	0	4	1	1	0	0	1	0	0	3	1	0	0	0	1	0	0	2	1	1	0	0	0	0	0	2
8	F	1	2	0	0	2	0	0	5	1	2	0	0	1	0	0	4	1	1	0	0	1	0	0	3	1	1	0	0	1	0	0	3
16	M	1	1	1	0	1	0	0	4	1	1	1	0	1	0	0	4	1	2	0	0	0	0	0	3	1	1	0	0	1	0	0	3

Tibia

		L M. Soleus								*R M. Soleus*							
Archival age:	**Seks**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**	**Delineation possible**	**surface irregularity**	**Ridge formation**	**surface flattening**	**Depression**	**Tubercle formation**	**enthesophyte formation**	**COMPOSITE**
6	F	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
4	?	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
5	M	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2
2	F	1	0	0	0	2	0	0	3	1	2	0	0	1	0	0	4
4	F	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
4	F	1	0	0	0	1	0	0	2	1	0	0	0	0	0	0	1
3	M	1	0	0	0	2	0	0	3	1	0	0	0	0	0	0	1
10	F	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	2
9	F	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
4	F																

12	F	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
5	M																
4	M	1	0	1	0	0	0	0	2	1	1	0	0	1	0	0	3
7	F	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
9	F	1	1	0	0	1	0	0	3	1	0	1	0	1	0	0	3
13	F	1	1	0	0	1	0	0	3	1	1	0	0	1	0	0	3
3	M																
5	M	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1
13	M	1	0	0	0	1	0	0	2	1	0	0	1	0	0	0	2
4	F	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
4	M	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	2
9	F	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
5	F	1	1	0	0	0	0	0	2	1	1	0	0	0	0	0	2
6	M																
8	F	1	0	0	0	1	0	0	2	1	0	0	0	1	0	0	2
11	F	1	0	1	0	2	0	0	4	1	0	1	0	2	0	0	4
8	M	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	2
8	F	1	1	0	0	1	0	0	3	1	1	0	0	1	0	0	3
16	M	1	0	0	0	1	0	0	2	1	0	1	0	1	0	0	3

Appendix B4: scoring guide

The following gives a brief definition of all scored entheseal change traits as well as stylized images to help locate the relevant entheses.

1 Terminology

1.1 Entheses delineation

Any way in which the entheses can be delineated, whether by visual identification, bone contour, palpation, or any of the traits below. Note: if entheses delineation is not possible, all other traits score zero by default.

1.2 Surface irregularity/rugosity

Any rough bone creation visible or palpable on the entheses surface which does not present distinct enthesophytes.

1.3 Surface flattening

Distinct flattening of the bone surface at the attachment area. I.e. any flat surface at the entheses on an area of bone that would otherwise be convex or concave.

1.4 Ridge formation

Formation of a longitudinal line of elevated bone, creating a distinct ridge. The ridge can present a sharp or rugose 'peak', or a blunt/rounded elevated line.

1.5 Depression/sulcus

Any indentation or cavity of any shape, which causes the entheses to be present on a lower plane than the surrounding bone. The depression can present as a smooth sloping pit, as well as a depression with rounded and smooth edges or sharp edges.

Note: sulci and depressions were combined, as they represent expressions of the same process in different base entheses morphologies (i.e. gastrocnemius will present round/oblong depressions, soleus sulci, simply because of the muscle attachment morphology), and thus a sulcus can be seen as one possible depression shape.

1.6 Tubercle formation

Any observable distinct tubercle, independent of size but larger than an enthesophyte (i.e. ca. >2mm) The surface of the tubercle can be scored for the other traits.

1.7 Enthesophyte formation

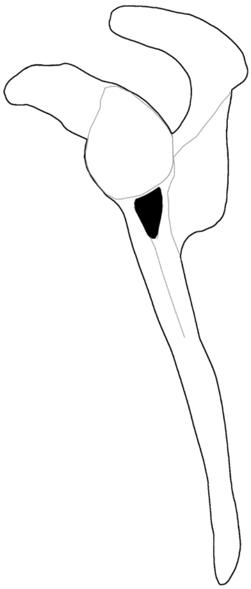
Any new bone formation which forms a distinct nodule, spur, or bony projection.

2 Entheses

Entheses outlined and filled in in black to indicate location. Individual variation in size and exact location can occur.

2.1 Scapula

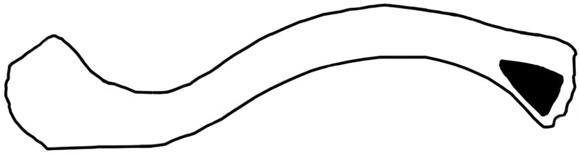
M. triceps brachii



Lateral view of left scapula

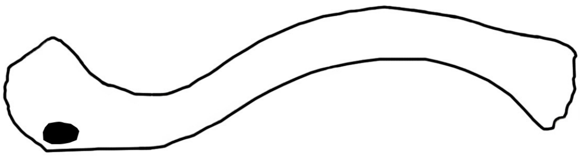
2.2 Clavicle

Costaclavicular ligament



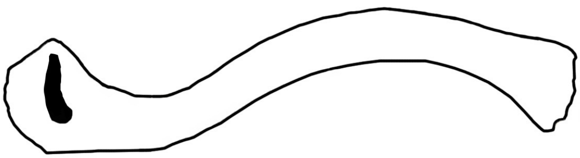
Inferior view of right clavicle

Conoid ligament



Inferior view of right clavicle

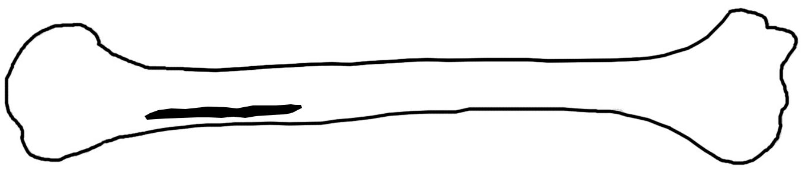
Trapezoid ligament



Inferior view of right clavicle

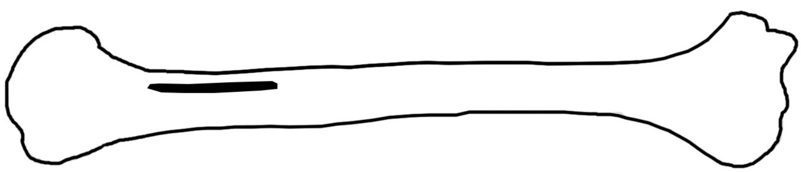
2.3 Humerus

M. pectoralis major



Anterior view of right humerus

M. lat. dorsii/teres major



Anterior view of right humerus

M. Deltoideus

Anterior view of right humerus

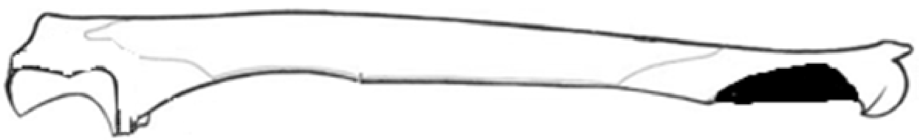
2.4 Radius

M. pronator teres

Lateral view of right radius

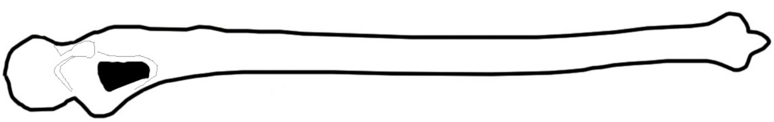
2.5 Ulna

Pronator Quadratus



Medial view of right ulna

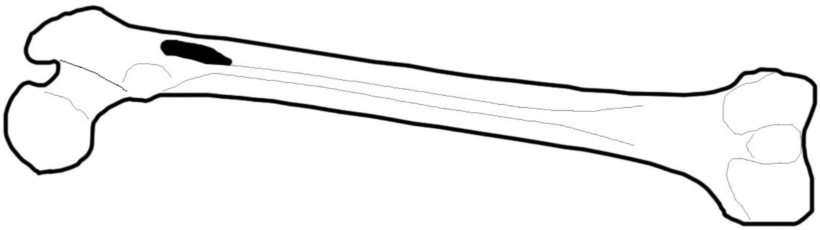
M. Brachialis



Anterior view of ulna

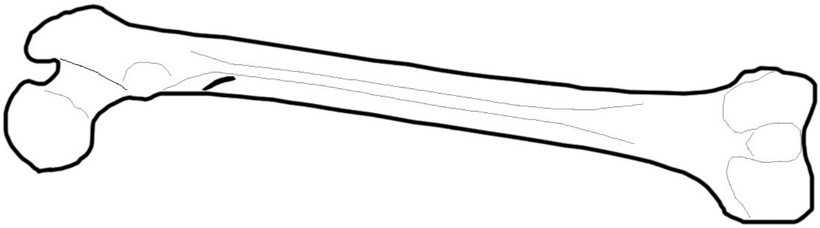
2.6 Femur

Gluteus maximus



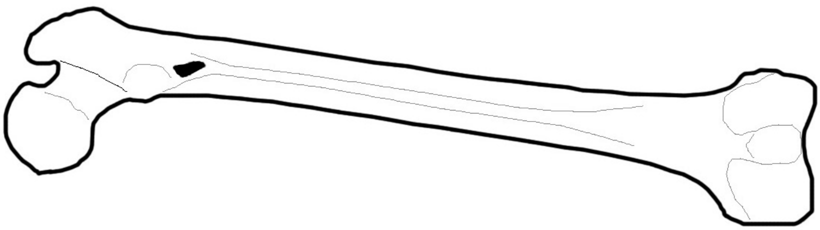
Posterior view of right femur

Vastus Medialis



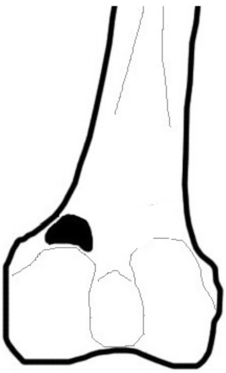
Posterior view of right femur

Pectineus



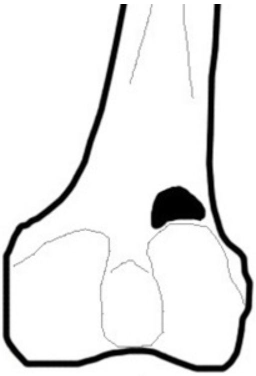
Posterior view of right femur

M. gastrocnemius, med. Head



Posterior view of right distal femur

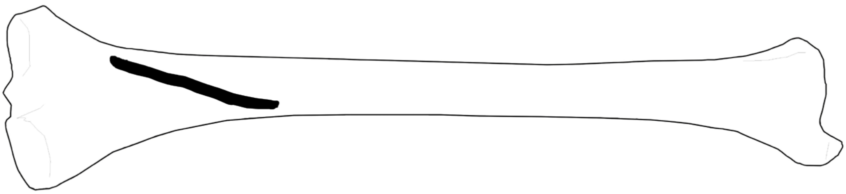
M. gastrocnemius, lat. Head



Posterior view of right distal femur

2.7 Tibia

M. Soleus



Posterior view of right tibia

Appendix B5: recording form

ENTHESEAL CHANGE RECORDING FORM

NONADULT

Site : Individual :

Archive info: **YES** **NO**

General

Osteological age: Sex: **M** **F** **UNKNOWN**

Archival age:

Overall preservation:

Very poor	Poor	Fair	Good	Very Good

Cortical bone preservation state:

Very poor	Poor	Fair	Good	Very Good

Overall completeness:

C= complete (>75%) P = partial (25-75%) F = Fragmented (<25%)

Comments:

Appendix C: appendix to chapter 6

Pearson's Chi squares for relationship between site and EC scores at the Louis D'haeseleer-straat and Hopmarkt when old adults (50+ years) are not included. One difference occurs with the extended sample that did include old adults: here, the common extensor is not significantly correlated with site.

	n	**$\chi(1)$**	**p**
M. Subscapularis	90	8.94	0.177
M. Supra+Infraspinatus	77	5.23	0.632
Extensor	89	8.54	0.074
Flexor	83	2.41	0.491
M. Teres Minor	73	6.06	0.195
M. Brachialis	114	11.4	0.064
M. Triceps Brachii	100	2.49	0.778
M. Brachioradialis	76	5.58	0.233
M. Biceps Brachii	114	2.71	0.745
M. Iliopsoas	86	3.00	0.695
M. Gluteus Minimus	84	8.59	0.126
M. Gluteus Medius	65	5.28	0.153
Quadriceps (tibia)	75	3.82	0.431
M. Popliteus	98	2.25	0.523
Quadriceps (patella)	60	5.56	0.351
Achilles	61	8.96	0.062

Appendix D: appendix to chapters 3, 5, and 6

Appendix D1: kort Rapport: Aalst-Hopmarkt 2011: fysisch antropologische analyse

Bij de archeologische opgraving van de Hopmarkt in Aalst in 2011 kwamen menselijke skeletten aan het licht. Van de aangetroffen resten kwamen 95 individuen in aanmerking voor een gedetailleerde osteologische analyse. De andere specimens waren te incompleet, te sterk beschadigd of te vermengd.

1 Algemene demografische samenstelling

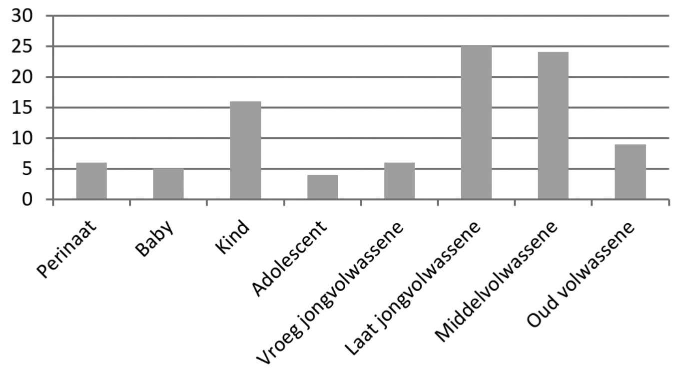
Van de 95 analyseerbare skeletten waren er 31 onvolwassenen en 64 volwassenen. Onder de volwassenen bevonden zich 23 vrouwen en 41 mannen.

De meest courante sterfteleeftijd voor vrouwen was in hun laatvolwassen levensjaren (25-35). Mogelijks houdt deze vroegere sterftepiek voor vrouwen verband met de risico's van het kraambed. Mannen stierven voornamelijk in de laatvolwassen tot middelvolwassen leeftijden.

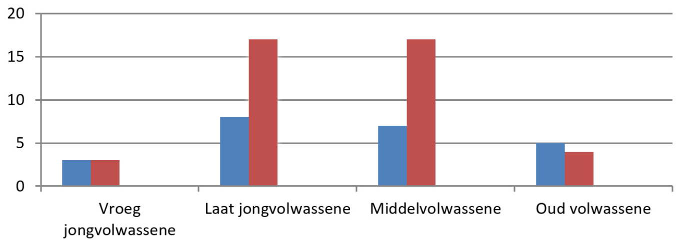
Van onvolwassenen kan geen geslacht achterhaald worden daar de geslachtskenmerken op het skelet onvoldoende ontwikkeld zijn. Indien gewenst kan het geslacht wel via DNA-analyse worden vastgesteld. Opvallend is het groot aantal kinderen tussen 2 en 12.

De gebruikte leeftijdscategorieën zijn:

- Perinaat: rond de geboorte
- Baby: 0-2jaar
- Kind: 3-12 jaar
- Adolescent: 13-18 jaar
- Vroeg jongvolwassene: >19-25
- Laat Jongvolwassene: 26-35
- Middelvolwassene: 36-50
- Oud volwassene: 50+



Leeftijdsindeling van de onderzochte skeletten van Aalst-Hopmarkt 2011



Geslachtsindeling van de volwassenen van Aalst-Hopmarkt 2011. De blauwe blokken indiceren vrouwen, de rode mannen.

2 Lichaamslengte

Er was een verschil in lengte tussen mannen en vrouwen. De gemiddelde lengte voor mannen was 1,69 m (met een standaarddeviatie van 3.5 cm). Voor vrouwen was de gemiddelde lengte 1,59 m (met een standaarddeviatie van 3.9 cm).

3 Pathologie en traumata

Bij de mannen was er een trauma prevalentie van 12.2%, terwijl geen van de vrouwen osteologische tekenen van trauma vertoonden. Dit is een frappant geslachtsgebonden verschil, en wijst op een duidelijk onderscheid in activiteiten tussen mannen en vrouwen.

Verschillende fracturen waren observeerbaar in de mannelijke skeletten:

- Genezen fractuur aan de linker distale tibia en fibula, in combinatie met een geheelde ribfractuur
- Genezen breuk in de rechter distale tibia
- Slecht geheelde chronisch ontstoken fractuur aan de proximale ulna
- Slecht geheelde kaakfractuur
- Geheelde tekenen van stomp trauma op de schedelpan
- Stressfracturen in de ruggengraat

Man met geheeld stop trauma aan de schedelpan. De plaats van impact is nog duidelijk zichtbaar maar het bot heeft zichzelf glad geheel zonder infectie of ernstige verschuiving.

De meest courante pathologie in deze populatie was osteoarthrose, de degeneratieve slijtage van het kraakbeen tussen twee botten in een gewricht. 44% van de mannen en 39% van de vrouwen leden aan osteoarthrose in tenminste één gewricht. De meest getroffen gewrichten zijn die van de rug. Andere locatie waarop osteoarthrose werd waargenomen zijn de vingers, polsen, heup, knie, voet, schouder, ellenboog en kaak. Dit percentage aan osteoarthrose is niet ongewoon hoog, zeker gezien het vrij grote aantal middel-en oud volwassenen in de onderzochte collectie. Ook de locaties waarop arthrose wordt ontwikkeld vallen binnen het normale patroon.

Voorbeeld van ernstige osteoarthrose in het gewricht tussen duim en pols in een oude man. In dit geval was het kaakbeen volledig vergaan en schraapten beide botten over mekaar wat tot polijsting en glans (eburnatie) leidde.

Verder zijn nog twee noemenswaardige pathologieën aangetroffen bij de volwassenen. Eén individu leed aan DISH (diffuse idiopathic skeletal hyperostosis, een ziekte die tot proliferatieve botgroei leidt). Een ander individu vertoonde tekenen van residuele rachitis (ook gekend als de Engelse ziekte). Dit is een aandoening als gevolg van vitamine D deficiëntie die bij kinderen tot gebogen benen en misvormde ribben leidt. Dit individu had gebogen femora als restletsel van deze aandoening in zijn kindertijd.

Onder de kinderen zijn twee duidelijke gevallen van tuberculose herkend. Beide kinderen waren tussen de 6 en 8 jaar oud bij overlijden. De ziekte was bij beide kinderen ver gevorderd, waarbij het bot in de ribben, wervels en heupen aangevreten was door de ziekte, alsook het gezicht bij één kind.

Rib van een kind met tuberculose. Het volledige hoofd van de rib (waar die aanhecht op de wervelkolom) is weggevreten door de infectie.

Verder werd ook één geval van rachitis vastgesteld in een kind van ongeveer 2.5 jaar oud. Beide femora zijn sterk gebogen.

Rachitis in de dijbenen van een kind van ca. 2.5 jaar. Bemerk de uitgesproken kromming ten gevolge van gebrekkige botcalcificatie door vitamine D tekort.

Glazuurhypoplasieën in de bovenkaak van een laatvolwassen vrouw. De tanden vertonen duidelijke onregelmatigheden in glazuurvorming.

4 Verdere analyse

Bovenstaand verslag brengt de eerste resultaten van het macroscopisch skeletonderzoek. Data met betrekking tot verandering in de morfologie van de spieraanhechtingen werden ook verzameld om een inzicht te geven in de fysieke activiteit van de populatie, maar dienen nog verder geanalyseerd. Ook werden stalen genomen voor isotopenonderzoek, waarvan de data nog volgen.

De goede conservering van deze collectie, de aanwezigheid van alle leeftijdsgroepen, de diversiteit aan pathologie en de zichtbare stressindicatoren maken dit een interessante collectie voor verder onderzoek.

Lijst geanalyseerde skeletten Aalst Hopmarkt

Onderstaande tabel bevat alle geanalyseerde skeletten met leeftijd en geslacht.

Legende:
PM = Vermoedelijk man (probable male)
M = man
PF = Vermoedelijk vrouw (probable female)
F = vrouw (female)
EYA = vroeg jongvolwassene (early young adult)
LYA = laatjongvolwassene (late young adult)
MA = middelvolwassene (middle adult)
OA = oud volwassene (old adult)

Nummer	Context	Leeftijd	Leeftijd specificatie	Geslacht
227	II/S4/8	MA		PM
359	III/S2/6	EYA		F
235	II/S5/4	OA		M
345	III/S1/9	MA		F
205	II/S2/18	MA		M
159	II/S1/9	MA		PF
222	II/S4/8	MA		M
343	III/S1/7	EYA		PF
338	III/S1/2	MA		M
234	II/S5/3	MA		PM
344	III/S1/8	MA		PF
356	III/S2/3	LYA		M
342	III/S1/6	MA		PM
185	II/S1/37	MA		M
236	II/S5/6	LYA		F
309	II/S1/42	LYA		PM
195	II/S2/8	OA		PM
427	II/S5/5	LYA		PM
200	II/S2/13	EYA		PF
367	III/S4/1	LYA		PM
357	III/S2/4	MA		PM
240	II/S6/1	MA		M
366	III/S3/4	LYA		PF
199	II/S2/12	LYA		PM
241	II/S6/2	MA		M
221	II/S4/2	MA		M
114	II/B/47/AB/1	LYA		PM
218 (ind 2)	II/S3/13	CHILD	2,8 +- 0,78	
218 (ind 1)	II/S3/13	LYA		PF
335	II/S4/14	INFANT	0,45+-0,34	
336	II/S4/15	INFANT	1,3+-0,35	
229	II/S4/10	EYA		M
238	II/S5/8	CHILD		
198	II/S2/11	ADOLESCENT	16+-1	
433	III/S1/12	ADOLESCENT	17+-1	
153	II/S1/5	LYA		PM
201	II/S2/14	MA		M
190	II/S2/3	MA		PF
174	II/S1/26	LYA		PM
160	II/S1/10	LYA		M
233	II/S5/2	MA		PF
239	II/S5/9	OA		F
99	II/B/16	EYA		PM
326	II/S2/27	OA		M
361	III/S2/8	MA		PM
245	II/S5/6	MA		F
64	II/S1/2	LYA		PF

161	II/S1/11	OA		PF
223	II/S4/4	OA		PF
228	II/S4/9	MA		PM
232	II/S5/1	LYA		M
177	II/S1/29	CHILD	6,9+-1,4	
65	II/S1/3	CHILD	2,45+-0,27	
182 (ind 1)	II/S1/34	CHILD	7+-1	
182 (ind 2)	II/S1/34	CHILD	4+-1	
203	II/S2/16	INFANT	1,77+-0,6	
204	II/S2/17	CHILD	2,2+-0,6	
197	II/S2/10	OA		PF
202	II/S2/15	MA		F
219	II/S3/14	CHILD	2,55+-45	
216	II/S3/11	ADOLESCENT	15,6+-1,6	
337	III/S1/1	OA		PM
358	III/S2/5	CHILD	8,4+-1,6	
341	III/S1/5	CHILD	6+-1	
183	II/S1/35	LYA		PM
352	III/S1/20	MA		PM
230	II/S4/11	INFANT	4,5+-1,5	
142	II/B/27	LYA		F
193	II/S2/6	MA		M
363	III/S2/10	LYA		PM
155	II/S1/8	LYA		PF
166	II/S1/18	ADOLESCENT		
165	II/S1/17	LYA		PM
328	II/S3/16	INFANT	0,44+-0,33	
212	II/S3/7	LYA		PF
323	II/S2/24	CHILD	2,66+-0,64	
429	III/S2/1	LYA		PF
172	II/S1/24	CHILD	3+-0,6	
173	II/S1/25	CHILD	5,5+-1	
171	II/S1/23	CHILD	4,8+-1	
313	II/S1/49	PERINATE	0,13+-0,25	
312	II/S1/45	PERINATE	0,13+-0,22	
306	II/S1/39	PERINATE	0,16+-0,26	
350 (ind 1)	III/S1/18	MA		M
317	II/s1/48	PERINATE		
311 (ind 1)	II/S1/44	PERINATE		
311 (ind 2)	II/S1/44	CHILD	4,2+-0,8	
184	II/S1/36	OA		F
168	II/S1/20	PERINATE		
331	II/S3/19	CHILD	4+-1	
325	II/S2/26	CHILD	2,14+-0,83	
237	II/S5/7	LYA		M
207	II/S3/2	EYA		PM
225	II/S4/6	LYA		PM
364	III/S3/2	LYA		M
217	II/S3/12	LYA		M

Appendix D2: fysisch antropologische analyse Aalst-Louis D'haeseleerstraat

1 Inleiding

De menselijke resten van de Louis D'haeseleerstraat zijn onderworpen aan een uitgebreide fysisch antropologische analyse om meer te weten te komen over het menselijk verleden. Door te kijken naar het stoffelijke overschot van deze Aalstenaren biedt fysische antropologie een direct inzicht in de levens van de mensen uit het verleden. Zo geeft de analyse van de menselijke skeletten een beeld van de levensomstandigheden, levensverwachting, en gezondheidstoestand van zowel het individu als de populatie. Wanneer de resultaten van dit skeletonderzoek gecombineerd worden met de andere archeologische analyses krijgen we zicht op de vele facetten van leven in het verleden, en wat het betekende een inwoner van Aalst te zijn in de periode waarin dit grafveld in gebruik was.

Het huidige onderzoek richt zich op de menselijke resten opgegraven op de site van de Louis D'haeseleerstraat. Daarbij werden in drie onderscheidbare zones menselijke skeletresten aangetroffen. Deze drie zones zullen hier samen behandeld worden m*et als* doel een totaalbeeld te geven van de populatie.

2 Doelstellingen

Het osteoarcheologische onderzoek van deze skeletcollectie, samengevat in dit rapport, had als doel om voor elk individueel skelet:

- De leeftijd bij overlijden te bepalen
- Het geslacht te bepalen (enkel toepasbaar op volwassen individuen)
- Ziektes te diagnosticeren

Verder werd ook van vijftig individuen een staal genomen voor stikstof- en koolstofisotopenanalyse als indicator van dieet (cfr. infra). Daarenboven wordt deze skeletcollectie ook gebruikt binnen het kader van mijn promotieonderzoek naar activiteitspatronen in de Lage Landen in de laatmiddeleeuwse en postmiddeleeuwse periode. De resultaten van dit onderzoek worden later gepubliceerd. Tenslotte wordt op basis van de resultaten van de algemene skeletanalyse aan het einde van dit rapport nog een overzicht gegeven van beloftevolle paden voor verder onderzoek op deze collectie skeletten.

3 Methoden en technieken

3.1 Algemeen

De mate waarin biologische gegevens kunnen worden afgeleid uit skeletresten is sterk afhankelijk van de conservering en volledigheid van het onderzochte skelet. De skeletten hebben lang in de grond gelegen en zijn blootgesteld aan verschillende factoren zoals verstoring van het graf maar aan ook chemische processen die de kwalitatieve conservering en volledigheid hebben beïnvloed. De conservering van de skeletresten wordt met het blote oog beoordeeld. Bij het bepalen van de volledigheid van een skelet wordt gekeken naar de aanwezigheid van de verschillende skeletdelen. Enkel wanneer een skelet voldoende goede conservering en volledigheid heeft voor de bepaling van leeftijd en (bij volwassenen) geslacht wordt het meegenomen in dit rapport.

3.2 Geslachtsbepaling

Het geslacht van de individuen wordt bepaald aan de hand van geslachtspecifieke anatomische kenmerken van de schedel, de onderkaak en het bekken. Voor de determinatie werd gebruik gemaakt van de richtlijnen opgesteld door de Workshop of European Anthropolgists (1980). De methode kent de verschillende kenmerken op de schedel, onderkaak en bekken een score toe binnen een interval van -2 (zeer vrouwelijk) tot +2 (zeer mannelijk). De scores worden vermenigvuldigd met de gewichtsscore van het specifieke kenmerk (op basis van diens betrouwbaarheid) en vervolgens bij elkaar opgeteld/afgetrokken en gedeeld door de som van de gewichtscores (Maat *et al.*, 2007, WEA 1980). Hiernaast is gebruik gemaakt van de kenmerken beschreven door Phenice (1969). De methode kijkt specifiek naar de morfologie van het schaambeen (os pubis) en beoordeelt drie kenmerken: de aanwezigheid van de ventral arc, het mediale aspect van de ischiopubic ramus, en de subpubic concavity. Phenice beschrijft een nauwkeurigheid van 96% bij het gebruik van alle drie de kenmerken (Phenice 1969). Daarnaast wordt gekeken naar de morfologie van het heiligbeen (sacrum). Bij mannen is de kromming van het heiligbeen sterker en de vorm smaller dan bij vrouwen, aangezien bij de vrouw het geboortekanaal wijd genoeg moet zijn voor de bevalling (Bass 1987).

Naast morfologische kenmerken wordt er ook gebruik gemaakt van enkele osteometrische technieken bij het bepalen van het geslacht. Met behulp van een schuifmaat worden skeletdelen opgemeten, en de waarden worden vergeleken met standaardwaarden die algemeen gelden als mannelijk of vrouwelijk. Specifiek worden de maten van de kop van de bovenarm (caput humeri) en de kop van het bovenbeen (caput femoris) (Stewart 1979), de maximale breedte van het distale uiteinde van de bovenarm en de maximale omtrek van de aanhechting van de deltoideus spier op de bovenarm (Steyn en Iscan 1999), de maximale lengte en omtrek van het sleutelbeen (clavicula) (McCormick *et al.*, 1991), en de maximale lengte van het schouderblad (scapula) (Bainbridge & Genovés Tarazaga 1956). Deze metingen zijn niet afdoende om tot een definitieve geslachtbepaling te komen; ze dienen slechts ter ondersteuning van de morfologische geslachtdeterminatie. Uiteindelijk zal waar mogelijk aan elk individu een geslacht worden toegekend. In het geval dat de morfologische en metrische kenmerken niet eenduidig, overtuigend of in voldoende mate aanwezig zijn, zal een "probable" aan het geslacht worden toegevoegd, bijvoorbeeld: Probable male. Wanneer het niet mogelijk is om het geslacht te bepalen omdat de kenmerken te ambigue zijn zal aan het individu een I worden toegekend van indeterminate (onbepaald). In totaal zijn er dus vijf mogelijkheden: M, PM, I, PF F, waarin de F staat voor vrouwelijk (female).

Geslachtsbepaling van onvolwassen individuen zal niet worden gedaan in dit onderzoek. De geslachtspecifieke kenmerken die gebruikt kunnen worden zijn op jonge leeftijd nog niet ontwikkeld. Hoewel er verschillende methodes bestaan om ook van jongere individuen het geslacht te bepalen, de betrouwbaarheid van deze methodes is erg laag (Mays & Cox 2000). De enige betrouwbare techniek tot op heden om het geslacht van nog groeiende individuen te achterhalen is DNA-analyse. Daarom zal in dit onderzoek geen geslacht worden toegekend aan individuen wiens leeftijdsbepaling lager dan achttien jaar is.

3.3 Leeftijdsbepaling

De sterfteleeftijd in het skelet wordt bepaald aan de hand van verschillende kenmerken. Bij groeiende individuen (<18) wordt de leeftijd vastgesteld op basis van gebitseruptie (Ubelaker 1979), tand- en tandwortelformatie (Moorrees *et al.*, 1963), de algemene ossificatie (verbening) van het skelet (schedelbasis en wervelkolom) (Schaefer *et al.*, 2009), het sluiten van de groeischijven (epifysen) van de lange pijpbeenderen (Schaefer *et al.*, 2009), de lengte van de lange pijpbeenderen (Maresh 1955), en de lengte van het sleutelbeen (Black & Scheuer 1996). Vanwege de aanzienlijke veranderingen tijdens de groei is het mogelijk om aan onvolwassen individuen een zeer nauwkeurige leeftijd toe te schrijven. Zo wordt voor onvolwassen individuen steeds een leeftijd met een +/- factor bepaald. Vervolgens worden de onvolwassenen ingedeeld in de volgende leeftijdsgroepen:

- Fetus: <0
- Infant: 0-3
- Child: 4-12
- Adolescent: 13-18

De leeftijdsbepaling van volwassen individuen (>18) wordt gedaan aan de hand van de slijtage en ossificatie van verschillende elementen van het skelet. Er wordt gekeken naar de slijtage van de symfyse van het schaambeen (facies symphalis) (Brooks & Suchey 1990; Todd 1920), de slijtage van het gewrichtsoppervlak van het darmbeen (facies auricularis) (Lovejoy *et al.*, 1985, Buckberry & Chamberlain 2002), de sluiting van de schedelnaden aan de buitenzijde van de schedel (Meindl & Lovejoy 1985), en de ossificatie van de mediale uiteindes van de ribben, liefst de vierde (Iscan *et al.*, 1986). Daarnaast wordt er gekeken naar de vergroeiing van de groeischijven die pas rond of na het 18e levensjaar sluiten, zoals bovenste rand van het darmbeen (crista iliaca), de groeischijf van het zitbeen en de mediale epifyse van het sleutelbeen.

Daarnaast wordt gebruik gemaakt van de mate van slijtage van de kiezen. Deze slijtage wordt beïnvloed door de leeftijd van de persoon, maar is ook sterk afhankelijk van de periode waarin de persoon leefde. Om deze reden is gekozen om gebruik te maken van het schema speciaal ontworpen voor middeleeuwse populaties (Maat 2001:20). Bij de skeletten van de Louis D'haeseleerstraat was deze methode echter weinig behulpzaam gezien de hoge graad van gebitspathologie en ongewone tandslijtage (cfr. Infra).

Net zoals bij de geslachtsbepaling worden ook bij de bepaling van de leeftijd zo veel mogelijk indicatoren in overweging genomen. Het vaststellen van een exacte leeftijd is helaas niet mogelijk met de beschikbare methodes. Hierom worden de individuen (waar mogelijk) verdeeld over de volgende leeftijdsintervallen:

- Early Young Adult: 19-25 (vroeg jongvolwassen)
- Late Young Adult: 26-35 (laat jongvolwassen)
- Middle Adult: 36-50 (middel volwassen)
- Old Adult: 50+ (oud volwassen)

In enkele gevallen is het niet mogelijk om het individu in een van de bovengenoemde leeftijdscategorieën te plaatsen. Dit is meestal het gevolg van slechte conservering of van de onvolledigheid van het skelet, maar soms ook het gevolg van ambiguïteit tussen de verschillende leeftijdsindicators. Echter, meestal kan op basis van de sluiting van de groeischijven en de afmetingen wel worden vastgesteld of een individu volwassen of onvolwassen is. Om deze reden kunnen volwassen individuen ook in de categorie 'Volwassene: 18+' worden geplaatst.

3.4 Pathologieën

Het menselijk lichaam kan worden aangetast en veranderd door een breed spectrum aan ziektes en aandoeningen. Een deel van dit spectrum laat sporen na op het skelet, daar waar de rest van het spectrum slechts de zachte weefsels aantast. Voornamelijk traumata en langdurige of chronische ziektebeelden kunnen worden opgemerkt. Voor de opkomst van de moderne geneeskunde en antibiotica overleed echter het gros van de mensen aan een acute infectie welke van te korte duur was om de botten aan te tasten. Om deze reden is h*et all*een in sommige gevallen mogelijk om vast te stellen waaraan de persoon is gestorven (Waldron 2009:1).

Ondanks deze inherente beperkingen tegenover autopsie op een nog niet geskeletoniseerd lichaam kunnen veel aandoeningen alsnog worden gediagnosticeerd op basis van macroscopische observatie van het skelet. Op droog bot kunnen zo de gewrichtsaandoeningen, ziektes ten gevolge van vitaminetekorten, en specifieke (langdurige) infecties worden vastgesteld. Daarnaast is skeletmateriaal ook uitermate geschikt voor het observeren van trauma zoals botbreuken, dislocaties, en andere verwondingen. Voor de beschrijvingen en diagnose van de pathologie is gebruik gemaakt van de standaardwerken (Auferderheide & Rodríquez-Martín 1998, Rogers &Waldron 1995, Ortner 2003, Waldron 2009, alsook Radiopaedia en Pubmed).

4 Resultaten

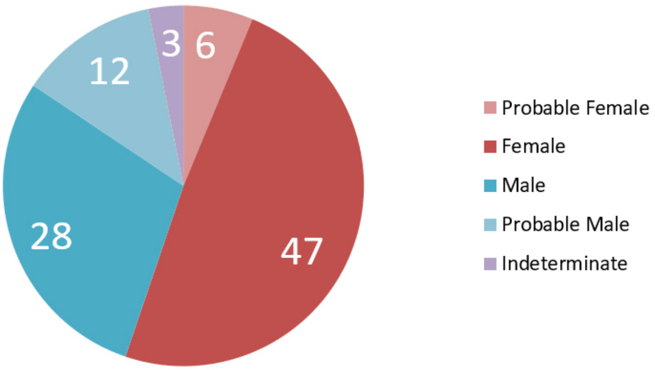
In de onderstaande paragrafen zullen de resultaten van het fysisch antropologisch onderzoek van de begravingen worden besproken.

4.1Bewaring

Het botmateriaal was gemiddeld gezien goed geconserveerd. Bij het merendeel van de skeletten was het corticaal bot nog in goede staat. Wel was er veel variatie in kleur van de botten en ging deze meestal gepaard met de bewaringstoestand, wat vermoedelijk wijst op verschillende bodemtoestanden qua watertafel en Ph-waarde van de omgevende grond. Gezien de stedelijke context van de opgraving is dit niet verwonderlijk. De geanalyseerde skeletten bevonden zich in variabele staat van compleetheid, met een grote groep naar archeologische normen heel complete (75%+) individuen. Met name het hoge aantal goed bewaarde kinderskeletten is van belang, daar de resten van onvolwassenen slecht zelden zo goed bewaard en volledig beschikbaar zijn voor analyse.

4.2 Geslacht

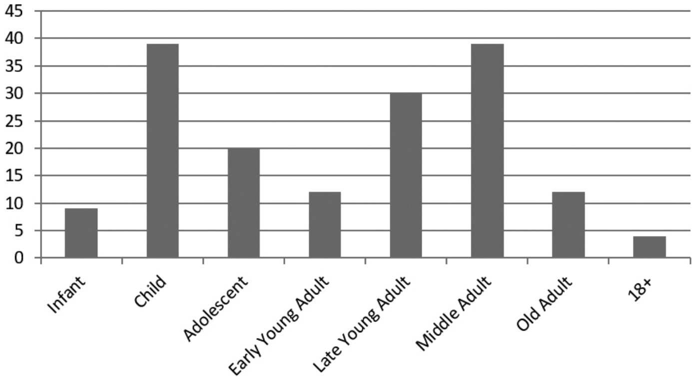
Van de 96 volwassen individuen waarbij voldoende skeletelementen aanwezig waren waarop een betrouwbare geslachtsbepaling kon worden uitgevoerd, waren er 53 vrouwen en 40 mannen (afb. 1). Bij drie individuen waren de geslachtskenmerken te ambigue om te bepalen of het om een man of vrouw ging.



Afbeelding 1: Geslachtsverdeling (n=96)

4.3 Leeftijd

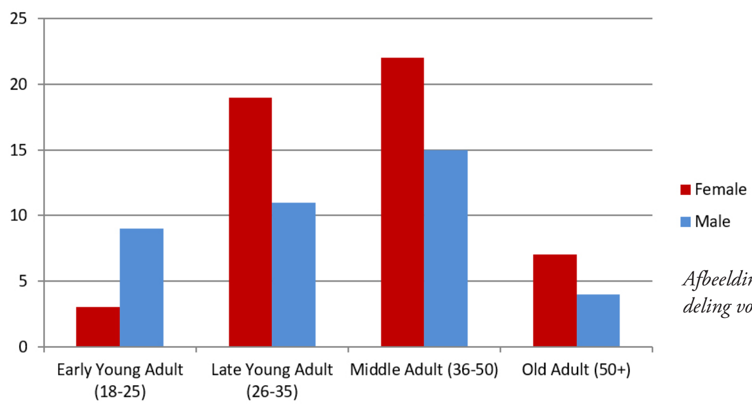
Van de 165 individuen waarbij voldoende skeletelementen aanwezig waren waarop een betrouwbare leeftijdsbepaling kon worden uitgevoerd, kon van 161 individuen een schatting worden gemaakt van de sterfteleeftijd (afb. 2). Van de overige vier individuen kon wel worden vastgesteld dat ze een volwassen leeftijd (18+) hadden bereikt op basis van grootte en robuustheid van de botten en sluiting van de groeischijven. In totaal was er sprake van 68 minderjarigen en 94 volwassenen.



Afbeelding 2: Leeftijdsverdeling (n=165)

Dit grote aandeel onvolwassen individuen is uitzonderlijk, en kan erop wijzen dat de zone van de oorspronkelijke begraafplaats die in de Louis D'haeseleerstraat werd opgegraven een zone was die voornamelijk voor kinderen voorbehouden was. Het is ook mogelijk dat dit oude klooster de voorkeur genoot voor begraving van kinderen, maar dit valt niet bewijzen aangezien niet het hele grafveld opgegraven is door verstoring en begrenzingen van de opgravingszone.

Bij de volwassenen valt op dat er in alle leeftijdscategorieën meer vrouwen aanwezig zijn, behalve in de jongste groep (18-25) (afb. 3).



Afbeelding 3: Geslacht- en leeftijdsverdeling volwassenen

4.4 Pathologie

4.4.1 Gebitspathologie

Uit het skeletmateriaal van Aalst blijkt dat de gebitshygiëne in deze populatie laag was. Zo heeft bijna elke volwassene wel één of meerdere cariës (gaatjes), die variëren van een klein gaatje tot de afbraak van het hele tandglazuur. Ook bij de kinderen is er vaak ernstige cariës aangetroffen, zelfs in het melkgebit. In veel van de gevallen, voornamelijk bij volwassenen, zijn deze cariës ook overgegaan in een abces. Dit betekent dat de ruimte tussen tandwortel en bot geïnfecteerd raakt. Deze abcessen zijn makkelijk zichtbaar op de schedel en kaak als uitgeholde ruimten rond en boven de tand, waar de vorming van etter het bot heeft doen resorberen (afb. 5-7). Verder zien we ook veel tandverlies (afb. 4), zelfs al op jonge leeftijd (bijvoorbeeld SK171 en SK77, twee jongvolwassen (18-25) mannen die al een deel van hun permanent gebit verloren zijn).

Antemortem tandverlies is vaak een gevolg van gaatjes, of van dusdanig heftige tandslijtage dat het pulpkanaal in de wortel bloot komt te liggen. In andere gevallen is tandverlies een gevolg va botverlies rondom de tandwortel, door leeftijd of tandvleesproblemen (afb. 8). Osteologisch zien we dat de boven-en onderkaak de holte waarin de tand verankerd zat weer opvullen met nieuw bot. Ook bij niet-volwassenen zien we al veel gaatjes, zelfs in het melkgebit.

Deze hoge frequentie van cariës en gerelateerde tandproblemen wijst mogelijks op een dieet dat rijk was aan koolhydraten, die vaak de oorzaak zijn van gaatjes. Zowel voedsel (bijvoorbeeld graan) als drank (bijvoorbeeld bier) kan zo een kweekgrond in de mond creëren voor de bacteriën die gaatjes in het glazuur maken.

Afbeelding 4: Boven-en onderkaak van SK43, waarbij alle tanden antemortem verloren zijn en nieuwe botgroei de tandholtes heeft opgevuld.

Afbeelding 5: Schedel van SK50 (vrouw, 36-50 jaar oud), waarvan het glazuur van de linker tweede snijtand en hoektand, en beide rechtersnijtanden, is weggevreten door cariës. Aan de rechter voorste snijtand en linker hoektand zien we ook een abces rond de wortel.

Naast gaatjes hadden ook bijna alle individuen in Aalst last van milde tot matige tandsteen (calculus) (afb. 6). Tandsteen is op zich een heel gewone aandoening van het menselijk skelet, zelfs tot op vandaag. Wat wel opmerkelijk is, is dat de individuen van Aalst tegelijk last hadden van tandsteen en gaatjes, soms zelf op dezelfde tand. Dit is eerder ongewoon, omdat de licht basische omgeving die tandsteen creëert meestal de zure omgeving waarin cariës-creërende bacteriën floreren tegenhoudt. Zo vormt tandsteen dus in andere populaties vaak een soort natuurlijke bescherming tegen cariës.

Afbeelding 6: Linkerzijde van de bovenkaak van SK12, met een abces aan de wortel van de eerste premolaar en tandsteen op het glazuur van dezelfde tand.

Afbeelding 7: abces rond de tandwortels van de premolaren in de bovenkaak van SK84.

Afbeelding 8: onderkaak van SK161 met cariës aan de grens tussen wortel en glazuur aan de maaltanden, en veel botverlies rondom de tandwortels. De hoektand en premolaren zijn al lang voor de dood verloren en de tandholtes ingevuld met nieuw bot.

Tenslotte dient ook vermeldt dat er in Aalst een hoge prevalentie van glazuur hypoplasie heerste (afb. 18 en afb. 20). Dit zijn kleine onderbrekingen in de vorming van tandglazuur die wijzen op perioden van lichamelijke stress tijdens de vorming van dit glazuur. Ze indiceren dat het lichaam de normale ontwikkeling als het ware even pauzeerde om alle energie op de genezing van een ziekte/ontbering te kunnen richten. Osteologisch zijn ze zichtbaar als horizontale groeven in het glazuur, of als putten en onregelmatigheden. Aangezien ze een kenmerk zijn van de groeiende tand wijzen ze zo op ontbering in de kindertijd. Glazuurhypoplasie is echter een aspecifieke indicator van gezondheid, dus wat voor fysieke stress het betreft kunnen we hiermee niet achterhalen. Vaak wijst het op perioden van ziekte, ondervoeding of vitaminetekorten in de kindertijd.

4.4.2 Algemene pathologie

In een deel van de populatie werden cribra orbitalia aangetroffen. Dit zijn poreuze zones in de bovenkant van de oogkas die kunnen wijzen op bloedarmoede en soms gelinkt worden aan malaria of darmziekten die ijzertekort veroorzaken. Deze aandoening werd zowel in (semi-)actieve vorm als helende vorm aangetroffen, dit wil zeggen zowel hevig poreus, waarbij het bot uitbuikt in de oogkas, als in de vorm van gladde vervagende porositeit.

Een andere niet-specifieke aandoening is periostitis, een inflammatie van het botvlies die zowel een gevolg kan zijn van lokaal trauma op het bot als van wijdverspreide infectie in het lichaam (al dan niet levensbedreigend). Osteologisch zien we een fijne laag nieuw bot bovenop het corticale botoppervlakte verschijnen. Deze periostitis werd voornamelijk aangetroffen op de scheenbeenderen, wat ook de meest voorkomende locatie ervoor is in andere populaties. Hiernaast werd echter ook in zowel volwassenen als kinderen periostaal nieuw bot aangetroffen op de voorzijde van het heiligbeen (afb. 9).

Afbeelding 9: Heiligbeen van SK 132, waarbij aan de voorzijde van de sacrale wervellichamen een poreus sponzig laagje nieuw periostaal botweefsel te zien is.

Aan de gewrichten van de bevolking begraven in de Louis D'haeseleerstraat zien we het gewoonlijke patroon van leeftijdsgebonden slijtage, zowel in de ruggengraat in de vorm van artrose in de facetten en compactie van de tussenwervelschijven, als in de andere gewrichten in de vorm van artose en osteochondritis dissecans. Dit laatste is een activiteitsgerelateerde aandoening waarbij een stukje bot loskomt in de gewrichtshole tussen twee botten (afb. 10). Gezien de osteochondritis met name voorkomt in de enkels en voeten van deze Aalstenaren zou dit kunnen wijzen op schoeisel dat onvoldoende de schokken van het lopen opvangt.

Afbeelding 10: Talus (sprongbeen) van SK192 met op het voorste gewrichtsoppervlak osteochondritis dissecans.

Twee mensen leden aan een ernstigere gewrichtsaandoening. Zo was bij SK48, een man van 50+, de linker pols helemaal aan mekaar gegroeid, waarbij de carpalen (kleine botjes tussen de onderarm en de handpalm) met elkaar gefuseerd waren en reactief nieuw bot hadden gemaakt (afb. 11). Dit zou voor dit individu de mobiliteit van de hand danig beperken, of zelfs volledig verhinderen. Het andere individu, SK80was een vrouw van 36-50 jaar oud wiens rechterhand en rechterknie misvormd waren. Zo waren verscheidene handbotjes vergroeid en misvormd, en zat het onderbeen onder een foute hoek onder het bovenbeen en was het hele kniegewricht aangetast door onregelmatige nieuwe botgroei (afb12-14). Bij dit individu is het weinig plausibel dat ze nog kon lopen op dit been. De oorzaak van deze aandoening is niet met zekerheid te achterhalen, maar septische artrose is de sterkst naar voren komende diagnose.

Afbeelding 11: De linkerhand van SK48, aan de kant van de handpalm.

Afbeelding 12: Vooraanzicht van de rechterknie van SK80. De normale gewrichtsfacetten zijn niet langer in gebruik en nieuwe pseudofacetten hebben zich gevormd onder een onnatuurlijke hoek. Bovenop de femur zien we een iets lichtere gladdere vervormde zone waar de knieschijf zou hebben gezeten, verder lateraal dan waar dat gewrichtsvlak hoort te zitten. De knieschijf is echter niet bewaard gebleven.

Afbeelding 13: Zijaanzicht van de rechterknie van SK80. Het scheenbeen zit onder een naar buiten getorseerde hoek onder het dijbeen. De botten waren nog niet gefuseerd maar de gewrichtsruimte was zo goed als afwezig.

Afbeelding 14: Rechterhand van SK80. Bemerk de aan de handpalmbeenderen vastgegroeide polsbeentjes en het meest linksboven op de foto zichtbare bot, dat dusdanig vervormd was dat exacte identificatie onzeker is.

Er werden ook enkele botbreuken aangetroffen in deze populatie. SK141 was een vrouw van middelbare leeftijd met één goed geheelde ribbreuk. Hiernaast was er SK67, een man van middelbare leeftijd met drie geheelde ribbreuken en een goed geheelde breuk onderaan zijn rechterbeen. Mogelijks was dit het gevolg van één trauma-incident (bijvoorbeeld een val). Verder hadden SK43, een oude vrouw, en SK77, een vroegjongvolwaasen man, trauma aan de schedelpan. Bij SK43 was ook een geheelde fractuur onderaan de radius (Colles' fracture) aanwezig, wat kan wijzen op een val, waarbij ze met de handen de val probeerde te breken. Haar schedeltrauma was geheeld als een ondiepe deuk. Bij SK77 is een opening gebleven in de schedel (afb. 15), wat een blijvend gezondheidsrisico veroorzaakte. Beide schedelbreuken zijn het gevolg van "blunt force trauma", ofwel een klap van/tegen een stomp object.

Afbeelding 15: Bovenaanzicht van de schedel van SK77, waarbij het schedeltrauma zichtbaar is. De afgeronde randen met nieuw corticaal bot langs de breuk wijzen op een genezingsproces, waardoor tafonomische oorzaak uit te sluiten is.

Bij één individu werd DISH vastgesteld (diffuse idiopathische skeletale hyperostose), een ziekte waarbij verbeningen optreden langs de wervelkolom, aan spieraanhechtingen en in kraakbeen. Deze ziekte komt vooral bij oudere mannen voor en wordt gelinkt aan een rijk dieet met veel eiwitconsumptie. In deze collectie werd DISH aangetroffen bij SK93 een man van 50+. Een andere indicator van rijk dieet is jicht, een aandoening die vooral op oudere leeftijd vaak voorkomt en gelinkt is aan overgewicht en alcoholconsumptie. Bij SK67 werd jicht in de voet vastgesteld, in de vorm van uitgeholde ruimtes waarin urinezuurkristallen zich in vivo bevonden (afb. 16).

Afbeelding 16: Vervorming aan de voorzijde van de metatarsaal voor de grote teen (bovenaan) en aan een proximaal vingerkootje (onderaan) van SK67 ten gevolge van jicht.

Bij de kinderen werd opvallend veel periostale nieuwe botgroei vastgesteld (afb. 17). De oorzaak hiervan is niet duidelijk maar mogelijks kan dit worden gelinkt aan infecties.

Afbeelding 17: Achterzijde van de bovenarm van SK37, een kind (8 +/-1 jaar oud) met een actieve laag nieuwe botgroei.

Bij SK42, een kind van 11+/-2.5 jaar werd tuberculose gediagnosticeerd, waarbij de ribben aan de rechterzijde het zwaarst geaffecteerd waren. Deze ribben waren vervormd door de longziekte. SK42 had meerdere glazuur hypoplasieën in alle observeerbare tanden, wat erop wijst dat dit kind gedurende een lange periode voor diens overlijden niet gezond was (afb. 18).

Afbeelding 18: Links: Onderkaak van SK42 waarbij de defecten in het tandglazuur zichtbaar zijn. Rechts: ribben van SK42 met verdikking en destructie aan de longzijde.

4.4.3 Conclusie pathologie

Algemeen kunnen we stellen dat de gebitsgezondheid laag was in Aalst, met een hoge frequentie van abcessen en antemortem tandverlies. Het voorkomen van glazuur hypoplasie in de meeste skeletten en de vorming van periostaal nieuw bot wijzen ook op een vrij hoge lading aan fysieke stress in de verschillende levensfasen, waarbij het glazuur een beeld geeft van de kindertijd en het bot eerder van de laatste jaren voor de dood. Enkele indicatoren van rijk dieet kunnen mogelijks gekoppeld worden aan de hogere sociale status van de begravenen (mogelijks gildeleden of hogere geestelijken). De goed geheelde traumata alsook de individuen met ernstigere gewrichtsaandoeningen wijzen op een samenleving waarin, althans voor de bevolkingsklasse waartoe deze individuen behoorden, gezorgd werd voor zieke en gekwetste personen.

5 Toekomstig onderzoek

5.1 Pathologie

De algemene osteologische analyse die in dit rapport wordt samengevat toont dat deze skeletcollectie veel mogelijkheden biedt tot verder onderzoek. Zo is de gebitspathologie met de hoge frequentie van abscessen zeker grond voor meer gedetailleerd onderzoek, om te kijken naar locatie van caries en abscessen, tandslijtage en tandgebruik, etc.

Verder onderzoek naar maxillaire en frontale sinusitis zou ook interessant zijn. In deze schedelholtes werden namelijk sporen van infectie aangetroffen. Om dit degelijk te onderzoeken zouden echter alle schedels uit collectie waarbij de holtes observeerbaar zijn systematisch geanalyseerd moeten worden, met een gestandardiseerde observatiemethode. De collectie van de Louis D'haeseleerstraat leent zich hier uitstekend toe aangezien sinusitis geobserveerd werd (afb. 19), bewaring van het materiaal goed is, en de meeste schedels wel compleet maar in stukken aangetroffen werden, en de binnenzijde dus observeerbaar is zonder destructief onderzoek of (micro-)CT.

Afbeelding 19: Linker maxillaire sinusholte van SK106, waarin in plaats van een glad botoppervlak een dunne laag onregelmatig nieuw bot te zien is. Dit wijst op een sinusinfectie.

De vaak aangetroffen hypoplasie van het tandglazuur is ook opmerkelijk (afb. 20). Verder onderzoek hiernaar, met telling van het aantal en soort hypoplasie en exacte meting van de locatie op de tand, kan meer informatie verschaffen over welke perioden in de kindertijd het vaakst tot fysieke stress leidden. Zo kan gekeken worden naar of dit mogelijks rond de periode van ontwenning van moedermelk was, of of bepaalde leeftijden het meest onderhevig waren aan ziektes.

Afbeelding 20: Tand van SK205 waarop glazuur hypoplasie zichtbaar is in de vorm van ribbels.

5.2 Non-metrische variaties

Opvallend in Aalst was de relatieve frequentie van enkele eerder uitzonderlijke niet-pathologische variaties in het skelet. Deze zogenaamde “non-metric traits” zijn onschadelijke genetische variaties. In de Louis-D’haeseleerstraat zien we vaak het voorkomen van sacralisatie van de laatste lumbale wervel (afb. 21), het voorkomen van een extra rib boven de gewone ribben, die aanhecht aan de zevende cervicale wervel, en een boemerang-vormige kromming van de tweede bovenste snijtand (afb. 22). Deze variaties zijn niet pathologisch, maar kunnen erop wijzen dat op dit grafveld mensen uit een vrij kleine genetische poel zijn begraven, of kunnen op familieverbanden wijzen. Om dit goed te onderzoeken moet een grondig onderzoek worden ondernomen naar zowel de non-metrische variaties van de tanden als van het skelet, ter vergelijking met data van andere populaties. Ook binnen het kerkhof kan gekeken worden naar of individuen met dezelfde variant nabij mekaar begraven liggen, om zo mogelijks families te onderscheiden.

6 Conclusie

In de opgraving langs de Louis D’haeseleerstraat werden iets meer vrouwen (53) dan mannen (40) aangetroffen, wat ondersteunt dat hier naast stadslieden ook de nonnen van het klooster begraven werden. Er werden ook veel kinderen aangetroffen (67 van de 164 geanalyseerde skeletten), mogelijks omdat de opgravingszone samenviel met de zone van het grafveld oorspronkelijk voorbehouden voor kinderen, of door andere mortuaire praktijken.

De individuen opgegraven in de Louis D’haeseleerstraat vertonen een onverwacht breed spectrum aan pathologische aandoeningen. Deze aandoeningen wijzen mogelijks op een vrij hoge ziektelading op de toendertijdse populatie, wat een gevolg kan zijn van leven in een vrij dichtbevolkte stadszone. Zo verspreid tuberculose zich makkelijker in kleine slecht verluchte ruimtes, en word sinusitis gekoppeld aan verminderde luchtkwaliteit die irritatie en dus kwetsbaarheid van de slijmvliezen veroorzaakt. De hypoplasie in het tandglazuur en de kinderen met periostale nieuwe botvorming tonen aan dat infectie veel voorkwam onder de hier begraven individuen. Ook de kwaliteit van het drinkwater kan hier een rol in spel-en. Bij de ene oude man met DISH kan worden aangenomen dat het om een individu van hoge klasse ging, al dan niet geestelijk, met een rijk dieet. De herhaaldelijk voorkomende ongewone genetische variaties in het skelet kunnen wijzen op een kleine genetische poel of het begraven van families nabij elkaar.

Afbeelding 21: Heiligbeen van SK192, waarbij de onderste lumbale wervel vergroeid is aan het sacrum (sacralisatie).

Afbeelding 22: Linker bovenkaak van SK122 waar een "boemerangvor-mige"variatie van de tweede snijtand zichtbaar is. Bemerk ook de tandsteen op de maaltanden en het absces boven de oorspronkelijke locatie van de hoektand.

7 Tabel van geanalyseerde onderzochte individuen

Hieronder staan leeftijd en waar mogelijk geslacht van alle geanalyseerde individuen, gerangschikt op SK nummer. Voor de kinderen werd een leeftijdsschatting gedaan met een +/- factor.

SK NUMMER	**LEEFTIJDSCATEGORIE**	**LEEFTIJD**	**PLUS OF MIN**	**SEKS**
1	Late Young Adult			Female
3	Child	6	1	
4	Late Young Adult			Female
5	Middle Adult			Probable Male
6	Child	7,5	1	
8	Child	10	1,5	
9	18+			Probable Male
12	Early young adult			Male
13	Late Young Adult			Female
15	Child	10,5	1,5	
20	Child	7	1	
21	Infant	2,5	0,5	
22	Child	10,5	1,5	
23	Child	11	1,5	
24	Child	5	1	
27	Middle Adult			Indeterminate
28	Old Adult			Male
32	Child	5,5	1	
33	Child	5	1	
34	Late Young Adult			Female
35	Child	8	2	
36	Middle Adult			Female
37	Child	8	1	
38	Adolescent	17	2	
42	Child	11	2,5	
43	Old Adult			Female
44	Adolescent	15	2	
45	Adolescent	16	2	
47	Late Young Adult			Female
48	Old Adult			Male
49	Child	8	2	
50	Middle Adult			Female
52	Child	9	1	
54	Child	8,5	1,5	
56	Adolescent	12	1,5	
57	Late Young Adult			Female
58	Middle Adult			Female
59	Child	5	1	
61	Middle Adult			Female
62	Child	10	2	

63	Child	6	1	
64	Late Young Adult			Male
65	Late Young Adult			Female
66	Late Young Adult			Probable Male
67	Middle Adult			Probable Male
68	Child	8	2	
69	Late Young Adult			Probable Female
70	Middle Adult			Female
71	Child	7,5	1	
72	Middle Adult			Male
73	Late Young Adult			Female
74	Child	8,5	1,5	
75	Child	4.5	1.5	
77	Early Young Adult			Probable Male
78	Adolescent	13	1	
79	Middle Adult			Male
80	Middle Adult			Female
81	Adolescent	17	2	
82	Child	10,5	1,5	
83	Child	3,5	1,2	
84	Late Young Adult			Male
85	Infant	1,25	0,5	
86	Old Adult			Female
87	Infant	0,5	0,2	
91	Child	5	0,5	
92	Middle Adult			Indeterminate
93	Old Adult			Male
94	Adolescent	14	2	
95	Adolescent	18	1	
97	Child	11	2	
98	Middle Adult			Male
99	Middle Adult			Male
100	Adolescent	16	1	
101	Infant	2,5	1	
104	Child	9	1	
105	Early Young Adult			Female
106	Late Young Adult			Female
107	Infant	2,5	0,5	
108	Late Young Adult			Male
109	Late Young Adult			Probable Male
112	Late Young Adult			Male
113	Child	9	1	
116	Child	8	2	
117	Infant	1,5	0,5	
118	Late Young Adult			Male
119	Middle Adult			Female
120	Early Young Adult			Male
122	Middle Adult			Female
123	Middle Adult			Female
126	Old Adult			Female

127	Child	9	1	
130	Old Adult			Female
132	Adolescent	13	1	
133	Child	9	1	
134	Child	6,5	0,5	
136	Child	11	2	
137	Middle Adult			Male
140	Late Young Adult			Probable Male
141	Middle Adult			Probable Male
143	Middle Adult			Female
144	Adolescent	18	1	
145	Late Young Adult			Male
146	Adolescent	16	2	
147	Late Young Adult			Female
148	Adolescent	17	2	
149	Middle Adult			Female
150	Adolescent	17	2	
151	Early Young Adult			Male
152	Early young adult			Probable Male
153	Middle Adult			Female
154	Late Young Adult			Female
157	Middle Adult			Female
158	Early Young Adult			Male
160	Late Young Adult			Female
161	Middle Adult			Male
162	Early Young Adult			Probable Male
163	Child	9	1	
164	Adolescent	16	2	
165	Old Adult			Female
168	Middle Adult			Female
169	Late Young Adult			Female
171	Early young adult			Male
173	Middle Adult			Male
174	Adolescent	15,5	1,5	
175	Late Young Adult			Female
176	Middle Adult			Female
177	Child	6	1	
178	Late Young Adult			Female
179	Infant	2,5	0,5	
180	Child	6,5	1	
181	Adolescent	18	2	
182	Adolescent	13,5	1,5	
183	Middle Adult			Female
184	Early Young Adult			Female
185	Old Adult			Probable Female
186	Middle Adult			Female
187	Late Young Adult			Female
188	Middle Adult			Probable Female
189	Middle Adult			Male
190	18+			Female

191	Child	10	2	
192	Early young adult			Female
193	Middle Adult			Probably Female
195	Middle Adult			Probable Male
196	Adolescent	14,5	1,5	
197	Old Adult			Female
198	Late Young Adult			Male
199	Child	7,5	1	
201	Middle Adult			Probable Female
203	Adolescent	16	2	
204	Middle Adult			Male
205	Old Adult			Male
206	Infant	1	0,2	
207	Middle Adult			Female
208	Late Young Adult			Probable Female
209	Middle Adult			Male
210	Middle Adult			Female
103A	Old Adult			Female
103B	Early Young Adult			Male
120B	18+			Indeterminate
127B	Infant	1,5	0,5	
189b	18+			Female
25-31	Middle Adult			Probable Male
40-41	Late Young Adult			Probable Female
SK096	Late Young Adult			Male

8 Bibliografie

Auferderheide, Arthur C. en Conrado Rodríguez-Martín, 1998. The Cambridge Encyclopedia of Human Paleopathology. Cambridge University Press, Cambridge.

Bainbridge, Douglass. and Santiago Genoves Tarazaga, 1956. A study of sex differences in the scapula. Journal of the Royal Anthropological Institute of Great Britain and Northern Ireland 86:109-134.

Bass, William M., 1987. Human Osteology: A Laboratory and Field Manual. Missouri Archaeological Society, Columbia, Missouri, VS.

Black, Sue and Louise Scheuer, 1996. Age Changes in the Clavicle: from the Early Neonatal Period to Skeletal Maturity. International Journal of Osteoarchaeology 6:425-434.

Breitinger E., 1937. Zur Berechnung der Körperhöhe aus den langen Gliedmassenknochen. Anthropologische Anzeiger 14: 249–274.

Brooks, S. en J.M. Suchey, 1990. Skeletal Age Determination Based on the Os Pubis: A Comparison of the Acsadi-Nemeskeri and Suchey-Brooks Methods. Human Evolution 5(3):227-238.

Buckberry, Jo L. en Andrew T. Chamberlain, 2002. Age Estimation from the Auricular

Surface of the Ilium: A Revised Method. Am J Phys Anthropol. 2002 Nov;119(3):231-9.

Finnegan, Michael, 1978. Non-Metric Variation of the Infracranial Skeleton. Journal of Anatomy 125(1):23-37.

Cox, Margaret en Simon Mays, 2000. Human Osteology: In Archaeology and Forensic Science. Greenwich Medical Media, Londen.

Hauser, Gertrud en Gian De Stefano. Epigenetic Variants of the Human Skull. Schweizerbart, Stuttgart.

Iscan, M. Yasar, Susan R. Loth, en Ronald K. Wright, 1984. Metamorphosis at the Sternal Rib End: A New Method to Estimate Age at Death in White Males. American Journal of Physical Anthropology 65(2):147-156.

Iscan, M. Yasar, Susan R. Loth, en Ronald K. Wright, 1985. Age Estimation from the Rib by Phase Analysis: White Females. Journal of Forensic Sciences 30(3):853-863.

Lovejoy, C. Owen, Richard S. Meindle, Thomas R. Pryzbeck en Robert Mensforth, 1985. Chronological Metamorphosis of the Auricular Surface of the Ilium: A New Method for the Determination of Adult Skeletal Age. American Journal of Physical Anthropology 68:15-28.

Maat, George J.R., 2001. Diet and Age-At-Death Determination from Molar Attrition: A Review Related to the Low Countries. The Journal of Forensic Odonto-Stomatology 19:18-21.

Maresh, M.M., 1955. Linear Growth of Long Bones of Extremities from Infancy through

Mays, Simon, 1998. The Archaeology of Human Bones. Routledge, Londen.

Mays, Simon, G.M. Taylor, A.J. Legge, D.B. Young, G. Turner-Walker, 2001. Paleopathological and Biomolecular Study of Tuberculosis in a Medieval Skeletal Collection from England. American Journal of Physical Anthropology 114(4):298-311.

McCormick, William F., John Harlan Stewart en Holly Greene, 1991. Sexing Human Clavicles using Length and Circumference Measurements. American Journal of Forensic Medicine and Pathology 12(2):175-181.

Meindle, Richard S. en C. Owen Lovejoy, 1985. Ectocranial Suture Closure: A Revised Method for the Determination of Skeletal Age at Death Based on the Lateral-Anterior Sutures. American Journal of Physical Anthropology 68:57-66.

Moorrees C. F. A., E. A. Fanning, E. E. Hunt, 1963. Age Variation of Formation Stages for Ten Permanent Teeth. Journal of Dental Research 42: 1490-502.

Ortner, Donald J., 2003. Identification of Pathological Conditions in Human Skeletal Remains. Academic Press, San Diego, California, VS.

Phenice, T.W., 1969. A Newly Developed Visual Method of Sexing the 0s Pubis. American Journal of Physical Anthropology 30(2):297-301.

Roberts, Charlotte A. en Keith Manchester, 2005. The Archaeology of Disease. Cornell

University Press, Ithaca, New York, VS.

Rogers, Juliet en Tony Waldron, 1995. A Field Guide to Joint Disease in Archaeology. J. Wiley, Oxford.

Schaefer, Maureen, Sue Black, en Louise Scheuer, 2009. Juvenile Osteology: A Laboratory and Field Manual. Elsevier Academic Press, Burlington, Massachusetts, United States of America

Steyn, Maryna en M. Yasar Iscan. Osteometric Variation in the Humerus: Sexual Dimorphism in South Africans. Forensic Science International 106(2):77-85.

Todd, T., 1920. Age Changes in the Pubic Bones, I: The White Male Pubis. American Journal of Physical Anthropology 3: 285-334.

Trotter, M., en G.C. Gleser, 1958. A Re-evaluation of Estimation of Stature Based on Measurements of Stature Taken during Life and of Long Bones after Death. American Journal of Physical Anthropology 16:79–123.

Trotter, M., 1970. Estimation of stature from intact limb bones. In Personal Identification in Mass Disasters, Stewart TD (ed.). National Museum of Natural History: Washington; 71–84.

Waldron, Tony, 2009. Palaeopathology. Cambridge Manuals in Archaeology, Cambridge University Press, Cambridge, United Kingdom.

Workshop for European Anthropologists (WEA), 1980. Recommendations for Age and Sex Diagnoses of the Skeleton. Journal of Human Evolution 9:517-549.

Appendix D3: Fysisch antropologische analyse Aalst-Sint Martinuskerk

This appendix lists the individuals analyzed from the 97-98 Saint Martin's church excavation, with basic osteobiographical data and their burial context. Only the individuals from within the church were used in the thesis.

Find number	Context	Church or Cemetery?	Age	Age range	Sex	Stature	SD stature
34 e	97/AA.SM	Church	MA		M	158,99	3,27
43	97/AA.SM	Church	CHILD	4-6			
14	97/AA.SM	Church	CHILD	5.4-6.6			
15	97/AA.SM	Church	LYA		F	152,9	3,72
17	97/AA.SM	Church	EYA		F	152,9	3,72
16	97/AA.SM	Church	MA		F	157,1	3,72
12	97/AA.SM	Church	CHILD				
8	97/AA.SM	Church	MA		F	155,37	3,72
10	97/AA.SM	Church	OA		F	158,26	4,24
6+83	97/AA.SM	Church	MA		M	163,67	3,66
26	97/AA.SM	Church	OA		F	154,14	3,72
31	97/AA.SM	Church	LYA		PM	166,85	4,05
90	98/AA.SM	Church	LYA		PM	167,78	4,05
88+19	98/AA.SM	Church	ADOLESCENT		nr		
86+7	98+97/AA.SM	Church	MA		PM	155,42	3,27
74+21	97/AA.SM	Church	OA		F	150,92	3,72
72+20	97/AA.SM	Church	LYA		M	170,18	3,27
71							
46	97/AA.SM	Cemetery	ADOLES-CENT	14-18			
58	97/AA.SM	Cemetery	ADOLES-CENT	15-23			
25	97/AA.SM	Cemetery	LYA		PF	156,11	3,72
47	97/AA.SM	Cemetery	LYA		M	174,94	3,27
87+23	98/AA.SM	Cemetery	LYA		PF	166,73	3,72
41	97/AA.SM	Cemetery	LYA		F	160,06	3,72
37	97/AA.SM	Cemetery	MA		F	155,12	3,72
42	97/AA.SM	Cemetery	MA		M	170,24	4,05
65	97/AA.SM	Cemetery	LYA		M	169,94	3,27
64	97/AA.SM	Cemetery	LYA		PF	167,47	3,72
96	97/AA.SM	Cemetery	MA		F	nr	
89	97/AA.SM	?	OA		F	161,55	3,72

Appendix E: additional literature

This appendix provides a list of additional relevant literature on entheseal change in archaeology.

Al-Oumaoui, I., Jiménez-Brobeil, S., and du Souich, P. 2004. Markers of Activity Patterns in some Populations of the Iberian Peninsula. International Journal of Osteoarchaeology 14, 343–359.

Djukic, K., Milovanovic, P., Hahn, M., Busse, B., Amling, M., and Djuric, M. 2015. Bone Architecture at Muscle Attachment Sites: the Relationship Between Macroscopic Scores of Entheses and their Cortical and Trabecular Microstructure Design. American Journal of Physical Anthropology 15, 81–93.

Drapeau, M.S.M. 2008. Enthesis Bilateral Asymmetry in Humans and African Apes. HOMO—Journal of Comparative Human Biology 59, 93–109.

Foster, A., Buckley, H., and Tayles, N. 2014. Using Enthesis Robusticity to Infer Activity in the Past: A Review. Journal of Archaeological Method and Theory 21, 511-533. DOI: 10.1007/s10816-012-9156-1

Foster, A., Buckley, H., Tayles, N., Spriggs, M., and Bedford, S. 2015. Gender, Labour Division and the Skeleton: A Case Study from The Teouma Lapita Cemetery. University of Otago Studies in Archaeology 25, 76-90

Gresky, J., Wagner, M., Schmidt-Schultz, T., Schwarz, L., Wu, X., Aisha, A., Tarasov, P.E., and Schultz, M. 2015. 'You Must Keep Going'—Musculoskeletal System Stress Indicators of Prehistoric Mobile Pastoralists in Western China. Quaternary International 405 (B), 186–199.

Henderson, C.Y. and Gallant, A.J. 2007. Quantitative Recording of Entheses. Paleopathology Newsletter 137, 7–12

Henderson, C.Y. 2013. Technical Note: Quantifying Size and Shape of Entheses. Anthropological Science 121. DOI: 10.1537/ase.121017

Henderson, C. Y., Craps, D. D., Caffell, A. C., Millard, A. R., and Gowland, R. 2013. Occupational Mobility in 19th Century Rural England: The Interpretation of Entheseal Changes. International Journal of Osteoarchaeology 23, 197-210. DOI:10.1002/oa.2286

Henderson, C. Y., Wilczak, C., and Mariotti, V. 2017. Commentary: An Update to the new Coimbra Method for Recording Entheseal Changes. International Journal of Osteoarchaeology 27, 521-522. http://doi.org/10.1002/oa.2548

Hoyte, D.A.N. and Enlow, D.H. 1966. Wolff's Law and the Problem of Muscle Attachment on Resorptive Surfaces of Bone. American Journal of Physical Anthropology 24, 205–213.

Ibáñez-Gimeno, P., Galtés, I., Jordana, X., Fiorin, E., Manyosa, J., and Malgosa, A. 2013. Entheseal Changes and Functional Implications of the Humeral Medial Epicondyle. International Journal of Osteoarchaeology 23, 211-220. DOI:10.1002/oa.2299

Ibáñez-Gimeno, P., Galtés, I., Jordana, X., Manyosa, J., and Malgosa, A. 2015. Activity-Related Sexual Dimorphism in Alaskan Foragers from Point Hope: Evidences from the Upper Limb. Anthropologischer Anzeiger: Journal of Biological and Clinical Anthropology 72, 473-489.

Jorgensen, K.C. and Kranioti, E.F. 2017. Testing the Coimbra Method: Discovering Possible Causes of Fibrocartilaginous Entheseal Change. American Journal of Physical Anthropology 162, 235-235.

Karakostis, F.A. and Lorenzo, C. 2016. Morphometric Patterns among the 3D Surface Areas of Human Hand Entheses. American Journal of Physical Anthropology 160, 694–707.

Karakostis, F.A., Hotz, G., Scherf, H., Wahl, J., and Harvati, K. 2017.Occupational Manual Activity is Reflected on The Patterns Among Hand Entheses. American Journal of Physical Anthropology 164, 30–40. DOI:10.1002/ajpa.23253

Karakostis, F.A., Hotz, G., Scherf, H., Wahl, J., and Harvati, K. 2018. A Repeatable Geometric Morphometric Approach to the Analysis of Hand Entheseal Three-Dimensional Form. American Journal of Physical Anthropology 166 (1), 246-260.

Kennedy, K. 1983. Morphological Variations in Ulnar Supinator Crests and Fossae as Identifying Markers of Occupational Stress. Journal of Forensic Sciences 28, 871– 876.

Kennedy, K. 1989. Skeletal Markers of Occupational Stress. In: Iscan, M.Y and Kennedy, K.A.R. (eds.), Reconstruction of Life from the Skeleton. Wiley-Liss: New York; 130-160.

Kennedy, K. 1998. Markers of Occupational Stress: Conspectus and Prognosis Research. International Journal of Osteoarchaeology 8, 305-310.

Lai, P. and Lovell, N.C. 1992. Skeletal Markers of Occupational Stress in the Fur Trade: a Case Study from a Hudson's Bay Company Fur Trade Post. International Journal of Osteoarchaeology 2, 221–234.

Lieverse, A. , Stock, J.T., Katzenberg, M., and Haverkort, C. 2011. The Bioarchaeology of Habitual Activity and Dietary Change in the Siberian Middle Holocene. In: Pinhasi, R. and Stock, J.T. (eds.) Human Bioarchaeology of the Transition to Agriculture. John Wiley & Sons, Ltd: Chichester; 263-291. doi:10.1002/9780470670170.ch11

Listi, G.A. 2016. The Use of Entheseal Changes in the Femur and Os Coxa for Age Assessment. Journal of Forensic Science 61, 12-18. DOI:10.1111/1556-4029.12905

Lopreno, G.P.L., Alves Cardoso, F., Assis, S., Milella, M., and Speith, N. 2013. Categorization of Occupation in Documented Skeletal Collections: Its Relevance for the Interpretation of Activity-Related Osseous Changes. International Journal of Osteoarchaeology

23, 175–185.

Mariotti, V. and Belcastro, M.G. 2011. Lower Limb Entheseal Morphology in the Neandertal Krapina Population (Croatia, 130 000 BP). Journal of Human Evolution 60, 694–702.

Marzke, M.W., Linscheid, R.L., Marzke, R.F., Reece, S., Steinberg, B., Smutz, P., and An, K.-N. 1998. An EMG Study of Hand Muscle Recruitment During Hard Hammer Percussion Manufacture of Oldowan Tools. American Journal of Physical Anthropology 105, 315–332.

Molnar, P. 2010. Patterns of Physical Activity and Material Culture on Gotland, Sweden, during the Middle Neolithic. International Journal of Osteoarchaeology 20, 1–14.

Mountrakis, C. and Manolis, K.M. 2015. Entheseal Change of the Upper Limb in a Mycenaean Population from Athens. Mediterranean Archaeology and Archaeometry 15 (1), 209-220.

Mulder, B., Van Rietbergen, B., and Waters-Rist, A. 2016. Is Entheseal Change a Marker of Activity? American Journal Of Physical Anthropology 159, 235-235.

Munson Chapman, N.E. 1997. Evidence for Spanish Influence on Activity Induced Musculoskeletal Stress Markers at Pecos Pueblo. International Journal of Osteoarchaeology 7, 497–506.

Myszka, A. and Piontek, J. 2011. Shape and Size of the Body vs. Musculoskeletal Stress Markers. Anthropologischer Anzeiger: Journal of Biological and Clinical Anthropology 68, 139-152.

Myszka, A. and Piontek, J. 2013. The Effect of Age on External Bone Morphology Properties in Adults. Anthropologie 51, 409–420.

Myszka, A., Weiss, E., and Piontek, J. 2014. Is Vertebral Body Osteophytosis a Reliable Indicator of Occupational Stress? Anthropologischer Anzeiger: Journal of Biological and Clinical Anthropology 71, 381-389.

Nikita, E. 2014. The use of Generalized Linear Models and Generalized Estimating Equations in Bioarchaeological Studies. American Journal of Physical Anthropology 153, 473-483. DOI:10.1002/ajpa.22448

Nolte, M. and Wilczak, C. 2013. Three-dimensional Surface Area of the Distal Biceps Enthesis, Relationship to Body Size, Sex, Age and Secular Changes in a 20th Century American Sample. International Journal of Osteoarchaeology 23, 163-174. DOI:10.1002/oa.2292

Niinimäki, S. 2012. The Relationship Between Musculoskeletal Stress Markers and Biomechanical Properties of the Humeral Diaphysis. American Journal of Physical Anthropology 147 (4), 618-628.

Niinimäki, S. and Salmi, A-K. 2016. Entheseal Changes in Free-Ranging Versus Zoo Reindeer–Observing Activity Status of Reindeer. International Journal of Osteoarchaeology

26 (2), 314-323. DOI: 10.1002/oa.2423
Pluskowski, A., Seetah, K., and Maltby, M. 2010. Potential Osteoarchaeological Evidence for Riding and the Military Use of Horses at Malbork Castle: Poland. International Journal of Osteoarchaeology 20, 335-343.
Rabey, K. N., Green, D. J., Tayler, A. B., Begun, D. R., Richmond, B. G., and McFarlin, S. C. 2015. Locomotor activity influences muscle architecture and bone growth but not Muscle Attachment Site Morphology. Journal of Human Evolution 78, 91–102.
Salmi, A-K. and Niinimäki, S. 2017. Entheseal Changes and Pathological Lesions in Draught Reindeer Skeletons – Four Case Studies from Present-Day Siberia. International Journal of Paleopathology 14, 91-99.
Santana-Cabrera, J., Velasco-Vázquez, J., and Rodríguez-Rodríguez A. 2015. Entheseal Changes and Sexual Division of Labor in a North-African Population: The Case of the Pre-Hispanic Period of the Gran Canaria Island (11th–15th c. CE). HOMO - Journal of Comparative Human Biology 66 (2), 118-138.
Santos, A. L., Alves-Cardoso, F., Assis, S., and Villotte, S. 2011. The Coimbra Workshop in Musculoskeletal Stress Markers (MSM): an Annotated Review. Antropologia Portuguesa 28, 135-161.
Schrader, S.A. and Buzon, M.R. 2017. Everyday Life after Collapse: a Bioarchaeological Examination of Entheseal Change and Accidental Injury in Postcolonial Nubia. Bioarchaeology International 1, 19-34.
Shuler, K.A., Zeng, P., and Danforth, M.E. 2012. Upper Limb Entheseal Change with the Transition to Agriculture in the Southeastern United States: a View from Moundville and the Central Tombigbee River valley. HOMO - Journal of Comparative Human Biology 63 (6), 413-434. DOI: 10.1016/j.jchb.2012.09.002.
Stefanović, S. and Porčić, M. 2011. Between-Group Differences in the Patterning of Musculo-Skeletal Stress Markers: Avoiding Confounding Factors By Focusing on Qualitative Aspects of Physical Activity. International Journal of Osteoarchaeology 23, 94-105. DOI: 10.1002/oa.1243
Williams-Hatala, E. M., Hatala, K. G., Hiles, S., and Rabey, K. N. 2016. Morphology of Muscle Attachment Sites in the Modern Human Hand does not Reflect Muscle Architecture. Scientific Reports 6, 28353–28310. DOI: 1038/srep28353
Yonemoto, S. 2016. Differences in the Effects of Age on the Development of Entheseal Changes Among Historical Japanese Populations. American Journal of Physical Anthropology 159, 267-283. DOI:10.1002/ajpa.22870
Zumwalt, A. 2005. A New Method for Quantifying the Complexity of Muscle Attachment Sites. Anatomical Record. Part B, New Anatomist 286, 21–28.
Zumwalt, A., Ruff, C. B., and Wilczak, C. A. 2000. Primate Muscle Insertions: What Does Size Tell You? American Journal of Physical Anthropology 30, 331.

Affiliations of co-authors

Dr. M.L.P. Hoogland
Leiden University, Department of Archaeological Sciences
Van Steenis Building, Einsteinweg 2, 2333 CC Leiden, The Netherlands
m.l.p.hoogland@arch.leidenuniv.nl

Dr. Sarah Inskip
University of Cambridge McDonald Institute for Archaeological Research
Downing Street CB2 3ER, Cambridge United Kingdom
sai31@cam.ac.uk

Dr. Angela R. Lieverse
University of Saskatchewan, Department of Archaeology and Anthropology
9 Campus Drive, SK S7N 5A5 Saskatoon, Canada
angela.lieverse@usask.ca

Dr. Andrea L. Waters-Rist
Western University Faculty of Social Science, Department of Anthropology
Social Science Centre Rm. 3326, N6A 3K7 London, Ontario, Canada
awaters8@uwo.ca

Kim Quintelier
Flanders Heritage Agency
Herman Teirlinckgebouw, Havenlaan 88 bus 5, 1000 Brussel, Belgium
kim.quintelier@rwo.vlaanderen.be

Summary

Chapter 1

The first chapter sets the scene for the current research. It points out how physical activity and the social perception thereof form an important aspect of a society, and details how archaeologists aim to research this societal element. Homing in on the current research, the chapter discusses archaeological research on human remains, and the markers of physical activity that have been analyzed on the human skeleton. The commonly used activity marker of entheseal change (EC) is singled out. ECs are the changes occurring at the attachment sites of muscles and ligaments (=entheses) to human bone. The premise is that entheses will adapt morphologically to the strain they are under, i.e., muscle use, and that osteoarchaeologists can then interpret past physical human behavior from them. Entheseal change is a highly active field of research, having gained traction in the 1990's and being continuously researched ever since. As such, much progress has been made, but there are several persistent problems and gaps in the knowledge. This dissertation identified and addressed four such issues. The first question is how entheseal change interacts with another often used marker of physical activity, namely osteoarthritis (i.e., joint wear). The second problem is posed by the myriad of different recording methods existent for EC, and the implications thereof for study comparability. The third issue is that there is as yet no system for the observation of EC in growing, nonadult individuals, even though they make up a substantial segment of society. Finally, the fourth issue is that entheseal change is often used as a proxy for social differentiation. This is based on the assumption that poor people perform more manual labor and that this will become apparent in their skeleton, yet this assumption has not been tested, and therefore does not pose a solid ground for conclusions on past peoples. The current thesis will address these four challenges within entheseal change research, using two unique post-medieval skeletal societies from the Low Countries, namely Middenbeemster (The Netherlands) and Aalst (Belgium). The ultimate goal of this dissertation is to provide the reader with a comprehensive study of the potential and limitations of entheseal change as well as new tools to address these limitations.

Chapter 2

Chapter two compares entheseal change to another osseous activity marker, osteoarthritis, within the post-medieval farming community of Middenbeemster (The Netherlands). Using upper limb entheses and joints, this research found that the correlation between entheseal change and osteoarthritis is limited. This infers that if both are markers of physical strain on the body, they represent different types or aspects of strain. Additionally, this article evaluated whether signs of social differentiation were visible in the entheseal change data. No groups of higher social status could be discerned, but there was a gendered division of labor, with men having more pronounced ECs in all attachment sites except the one for the M. triceps brachii, which showed substantially more osseous adaptation in women.

Chapter 3

Chapter three compares the two currently most used methods for entheseal change observation and scoring to each other. Over the years, many different recording methods for entheseal change have been designed. The most commonly used methods as of now are the Hawkey and Merbs (1995) method (and the updated version thereof created by Mariotti (2004, 2007)), and the Coimbra method (2016). This last method aims to be biologically appropriate and replace all past recording systems. However, if data gathered using this method are not compatible with data gathered using the previous methods, this would mean that much previous research becomes incomparable and therefore obsolete. This chapter compares results obtained using the older method to results gained using the newer method, and found that, although some differences in nuance are present, the methods produce overall highly similar results. This proof of compatibility is crucial in activity marker research, where comparisons between different populations are key.

Chapter 4

Chapter four addresses the current lacuna in EC research, that there is no standardized method to observe and record EC in growing individuals. This research paper presents the first system for EC scoring in nonadults. The method is developed on a sample of known age-at-death and sex nonadults from Middenbeemster. As an explorative aspect of this chapter, correlation between age, sex, and EC is tested. No significant statistical correlations between these three factors were found in this sample of 29 individuals. This paper shows the spectrum of EC variation in growing individuals, and that this variation reflects more than just age, potentially implying that activity and/or unknown aspects of growth and development are causative factors. Thus, chapter 4 presents both a method to score EC and a motivation to do so.

Chapter 5 and 6

Chapters 5 and 6 present two halves of one study, with the main aim to assess whether EC can be used as a proxy for social differentiation. Chapter 5 provides a socio-economic and historical context for the three skeletal collections from Aalst that are used (i.e., Saint-Martin's church, Hopmarkt and Louis D'haeseleerstraat) through a combination of historical, archaeological, and stable isotope data. Historic sources state that burial in the church was cheapest, burial in a cloister garth was less expensive, and burial in the general cemetery was the least expensive. The stable isotope ratios of carbon (χ13C) and nitrogen (χ15N) show that individuals at the Louis D'haeseleerstraat ate a substantially poorer diet than those at the Hopmarkt. Additionally, at the Louis D'haeseleerstraat the burials were organized in a large grid pattern which does not suggest a cloister context. Thus, the Saint-Martin's church sample is identified as the highest class individuals, the Hopmarkt (monastery, mainly cloister garth and alleys) sample as the middle class individuals, and the Louis D'haeseleerstraat (convent, outside later wall) individuals as the lowest class individuals. Chapter 6 then evaluates whether EC are correlated with these established socio-economic groups. For the 16 entheses of the upper and lower limb tested, no clear correlation between EC and social status was found. In the two cases where a correlation with burial site was statistically significant, the higher class individuals had more EC. Thus, EC was not a suitable proxy for socio-economic status in the post-medieval Belgian town context. This chapter thus serves as a cautionary tale against using EC to answer research questions concerning socio-economic status.

Chapter 7

Chapter seven summarizes the results from the five research papers discussed above, and presents a comprehensive conclusion about the value, potential, and limitations of EC research. By presenting the ways in which EC cannot be used (i.e., as a proxy for socio-economic status, or interchangeably with other activity markers), establishing that the predominant scoring methods give comparable results, and providing a tool for the study of nonadult EC, the current dissertation provides researchers with valuable information for research into physical activity in past societies.

Nederlandse samenvatting

Hoofdstuk 1

Het eerste hoofdstuk legt de basis voor het huidige onderzoek. Het toont aan hoe fysieke activiteit en de sociale perceptie ervan een belangrijk aspect van een maatschappij zijn, en hoe archeologen deze maatschappelijke factor onderzoeken. Het specifieert verder hoe binnen de archeologie houdt osteoarcheologie zich bezig houdt met onderzoek op menselijke resten, en dat er verschillende kenmerken van menselijk bot gebruikt kunnen worden om fysieke activiteit te achterhalen. Het huidige onderzoek focust op een zo'n activiteitskenmerk, namelijk entheseale veranderingen (= entheseal change of EC). ECs zijn de veranderingen die we kunnen waarnemen aan de aanhechtingsplaatsen van ligamenten en spieren op bot (=enthesen). Onderzoek naar EC gaat uit van de stelling dat enthesen zich morfologisch aanpassen aan de spanning die ze ondervinden, dus aan spierspanning, en dat osteoarcheologen hierdoor fysiek gedrag uit het verleden eruit kunnen afleiden. EC vormen een actief onderzoeksveld, dat vooral sinds de jaren '90 populair wordt en tot op vandaag druk bestudeerd wordt. Hierdoor is al veel vordering gemaakt, maar desondanks zijn er nog enkele hardnekkige problemen en dingen die nog niet onderzocht zijn. Deze doctoraatsthesis heeft vier zulke kwesties geïdentificeerd en behandeld. De eerste vraag is hoe EC interageren met een ander vaak gebruikt activiteitskenmerk op bot, namelijk osteoarthrose (= gewrichtsslijtage). De tweede moeilijkheid is dat er veel verschillende methoden zijn ontwikkeld om naar EC te kijken, en dat niet geweten is of de resultaten van de verschillende methoden met elkaar vergeleken kunnen worden. Een derde gebrek is dat er tot op heden nog geen methode bestaat om EC registreren in groeiende onvolwassen individuen, ondanks het feit dat zij een belangrijk onderdeel van de samenleving vormen. Het vierde vraagstuk, tenslotte, is of EC, die vaak als een indicator van socio-economische status worden gebruikt, hier wel geschikt voor zijn. Dit soort hypothese gaat namelijk uit van de premisse dat arme mensen meer handenarbeid doen en dat dit zich zal uiten in hun skelet, maar deze aanname is nog niet getest en vormt dus geen goede basis om reconstructies van leven in het verleden te maken. Deze dissertatie gaat deze vier kwesties binnen EC onderzoek bestuderen op twee unieke post-middeleeuwse samenlevingen uit de Lage Landen, namelijk Middenbeemster (Nederland) en Aalst (België). Het einddoel is om de lezer te voorzien van een omvattende studie van het potentieel en de beperkingen van EC, en van nieuwe wetenschappelijke instrumenten voor verder onderzoek.

Hoofdstuk 2

In hoofdstuk twee worden EC vergeleken met een ander activiteitskenmerk op menselijk bot, namelijk osteoarthrose, binnen de post-middeleeuwse landbouwgemeenschap van Middenbeemster (Nederland). Door de analyse van spieraanhechtingen en gewrichten van de arm en schouder toonde dit onderzoek aan dat de correlatie tussen EC en osteoarthose beperkt is. Dit betekent dat, als beiden kenmerken zijn van indicatoren van activiteit zijn, ze een gevolg zijn van verschillende aspecten van fysieke inspanning. Hiernaast evalueert dit hoofdstuk ook of tekenen van sociale differentiatie te vinden zijn in de EC data. Er werden geen groepen van hogere sociale status onderscheiden, al was wel een arbeidsverdeling tussen man en vrouw gevonden. Mannen hadden meer EC in alle spieraanhechtingen behalve de M. triceps brachii, die bij de vrouwen meer ontwikkeld was.

Hoofdstuk 3

Hoofdstuk drie vergelijkt de twee tegenwoordig vaakst gebruikte methoden om EC te registreren. Doorheen de tijd zijn veel verschillende methoden hiervoor ontwikkeld. De meest gebruikte zijn de Hawkey en Merbs (1995) methode (en diens bijgewerkte versie gecreëerd door Mariotti *et al.*, (2004, 2007)), en de Coimbra methode. Deze laatste streeft ernaar om de biologisch gepaste methode te zijn die alle voorgaande methoden vervangt. Echter, als de resultaten verkregen met deze methode niet vergeleken kunnen worden met resultaten uit vorige methode, worden decennia aan onderzoek plots achterhaald. Dit hoofdstuk vergeleek daarom of, wanneer de twee methoden toegepast worden op een zelfde populatie, de resultaten vergelijkbaar zijn, en vond dat, hoewel wat nuanceverschillen te bemerken zijn, de methoden in feite heel gelijkaardige resultaten gaven. Dit bewijs van compatibiliteit is cruciaal in activiteitskenmerkenonderzoek, waar vergelijkingen tussen studies essentieel zijn.

Hoofdstuk 4

Hoofdstuk vier pakt de lacune in het huidig EC onderzoek aan, namelijk dat er geen methode is om EC te observeren en registeren in groeiende individuen. Het presenteert een gestandaardiseerde methode om EC te evalueren in onvolwassenen. De methode is ontwikkeld op een staal van kinderen waarvoor leeftijd en geslacht door archiefmateriaal bekend zijn uit Middenbeemster. De correlatie tussen leeftijd, geslacht en EC werd ook getest, maar er warden geen statistisch significante correlaties hiertussen gevonden in dit staal van 29 individuen. Dit hoofdstuk toont het spectrum van variatie in EC in groeiende mensen, en dat deze variatie het gevolg is van meer dan enkel leeftijd, wat kan betekenen dat andere factoren zoals activiteit en/of onontdekte aspecten van groei en ontwikkeling

EC veroorzaken. Aldus presenteert dit hoofdstuk zowel een methode om naar EC in onvolwassenen te kijken en een reden daartoe.

Hoofdstuk 5 en 6

Hoofdstukken 5 en 6 zijn twee helften van eenzelfde studie, m*et als* doen te kijken of EC kunnen gebruikt worden als een indicator van sociale differentiatie. Hoofdstuk 5 schetst met behulp van historische, archeologische en stabiele isotopendata een socio-economische en historische context voor de drie collecties uit Aalst die worden gebruikt (de Sint-Martinuskerk, Hopmarkt en Louis D'haeseleerstraat). Historische bronnen dat begraving in de kerk het duurst was, begraving in de kloostertuin wat minder duur, en begraving op h*et alg*emeen kerkhof het goedkoopst. De stabiele isotopen van koolstof (δ13C) en stikstof (δ15N) tonen dat de mensen begraven in de Louis D'haeseleerstraat een armer dieet aten dan die begraven op Hopmarkt. Daarenboven zijn de graven in de Louis D'haeseleerstraat georganiseerd in een rasterpatroon, wat geen kloostertuincontext suggereert. Hierdoor kon de Sint-Martinuskerk geïdentificeerd worden als de rijkste klasse, de Hopmarkt (Karmelietenklooster, voornamelijk kloostertuin) als de middenklasse, en de Louis D'haeseleerstraat (buiten de muren van het latere klooster) als de laagste klasse. Hoofdstuk 6 evalueert hiermee dan of EC statistisch gecorreleerd zijn met deze socio-economische groepen. Voor de 16 spieraanhechtingen om armen en benen die werden getest, was er geen correlatie aanwezig, behalve voor twee aanhechtingen die hogere scores hadden in de rijkere klassen. Dit wijst erop dat EC geen goede indicator zijn van sociale klasse in deze post-middeleeuwse Vlaamse stad. Dit hoofdstuk dient dus om onderzoekers af te raden EC te gebruiken om dit soort onderzoeksvragen te beantwoorden.

Hoofdstuk 7

Hoofdstuk zeven vat de resultaten van de vijf onderzoekshoofdstukken samen, en biedt een omvattende conclusie over de waarde, het potentieel en de beperkingen van EC onderzoek. Door aan te tonen hoe EC niet gebruikt kunnen worden (dus ni*et als* indicator van sociale differentiatie, of inwisselbaar met andere activiteitskenmerken), te demonsteren dat de belangrijkste methoden om ze te registreren vergelijkbare resultaten te geven, en een werktuig te creëren om naar EC in groeiende individuen te kijken, levert deze dissertatie waardevolle informatie voor wetenschappelijk onderzoek naar activiteit in het verleden.

Samenvatting voor niet-specialisten

Archeologen gebruiken materiele resten om het leven van mensen in het verleden te reconstrueren. Binnen de archeologie bestudeert de menselijke osteoarcheologie de stoffelijke overschotten van mensen die worden aangetroffen op archeologische vindplaatsen. Osteoarcheologen gebruiken het menselijke beendermateriaal om informatie te achterhalen over de leeftijd waarop men in het verleden stierf, of het skelet mannelijk of vrouwelijk was, aan welke ziekten de persoon leed, en nog veel meer. Zo kunnen wetenschappers de menselijke beenderen ook gebruiken om te achterhalen welke fysieke activiteiten mensen in het verleden zoal deden, en of iemand al dan niet hard gewerkt heeft.

Dit proefschrift onderzocht een kenmerk van fysieke activiteit op het menselijk skelet, namelijk de veranderingen die we kunnen waarnemen aan de spieraanhechtingen op menselijk bot. Wanneer een bepaalde spier veel gebruikt wordt, gaat het lichaam de aanhechting van deze spier op bot veranderen om zo de extra spierspanning op te vangen. Aan de hand van de veranderingen die we dan zien op het bot kunnen we dus achterhalen of de persoon veel fysiek werk verricht heeft. De samenlevingen van Middenbeemster en Aalst werden op deze manier onderzocht.

Middenbeemster was een landbouwgemeenschap waar voornamelijk vee werd geteeld en kaas geproduceerd (de nog steeds befaamde Beemsterkaas). Skeletmateriaal uit de 17e tot 19e eeuw uit het kerkhof naast de kerk werd onderzocht. Hieruit bleek dat de vrouwen ander, maar geen lichter werk dan de mannen.

Aalst werd onderzocht door de analyse van drie skeletcollecties uit de stad, allen te dateren tussen de 16e en 18e eeuw. De skeletten die werden opgegraven aan de huidige Louis D'Haeseleerstraat vertegenwoordigen de armere klasse. Deze individuen werden begraven naast het huidige toendertijdse klooster van de grauwzusters van de orde van Sint-Franciscus en later van het Annonciadenklooster. De individuen die werden opgegraven op de huidge Hopmarkt komen uit het toendertijdse Karmelietenklooster, en werden oorspronkelijk begraven in de kloostertuin en pandgangen. Deze mensen zijn zowel paters als burgers van een meer gegoede middenklasse, daar begravingen binnen het klooster al wat meer geld kostte. De laatste collectie tenslotte komt uit de Sint-Martinuskerk. Dit zijn de rijkste mensen binnen ons onderzoek, daar begraving in de kerk duur was. Stabiele isotopenonderzoek van koolstof en stikstof op de menselijke beenderen toonde aan dat de mensen uit de Louis D'haeseleerstraat inderdaad een armer dieet hadden met minder consumptie van vlees. Enkel twee oude dames die in een afzonderlijke hoek van het opgegraven gebied lagen hadden wel een rijk dieet, met ook veel visconsumptie. Zij waren dus hoogstwaarschijnlijk oudere nonnen. Qua fysieke activiteit was echter geen onderscheid te maken tussen de groepen op basis van hun spieraanhechtingen. Dit betekent dat zij allen een complexe waaier aan fysieke taken verrichten. Rijk zijn in post-Middeleeuws Aalst betekende dus niet dat je de hele dag stil kon zitten.

Naast deze onderzoeken heeft deze doctoraatsthesis nog twee bijdragen geleverd aan het wetenschappelijke vakgebied. Een probleem in het onderzoeksveld is dat er verschillende methodes bestaan om naar spieraanhechtingen te kijken. In hoofdstuk drie werden twee zulke methodes met elkaar vergeleken. Hieruit bleek dat beide methoden heel gelijkaardige resultaten opleveren. Dit is goed nieuws voor verder onderzoek, want het betekent dat we onderzoek dat is gedaan met de verschillende methodes met elkaar kunnen vergelijken, waardoor we veel meer inzicht kunnen krijgen in welke gemeenschappen er nu meer en minder fysiek actief waren. Een ander probleem is dat geen van de bestaande methoden om naar spieraanhechtingen te kijken kan worden toegepast op skeletten van individuen die overleden voor ze volgroeid waren. Een groeiende mens steekt namelijk anatomisch anders in mekaar dan een volwassene. Om dit op te lossen is in dit proefschrift een nieuwe methode ontwikkeld om naar spieraanhechtingen op kinderen van twee tot zeventien jaar oud te kijken. Hiermee is een heel nieuw onderzoeksgebied gecreeerd wat in de toekomst tot dieper inzicht in het leven van kinderen in het verleden gaat leiden.

Dit proefschrift heeft op deze manier ons een glimp gegeven in het dagelijkse leven van de kaasboeren van Middenbeemster en de stedelingen van Aalst. Daarnaast voorziet het toekomstige wetenschappers van een methode om ook over de kinderen uit deze en andere archeologische collecties meer te weten te komen.

Curriculum vitae

Jessica Lisbeth Antonia Palmer was born in Ghent (Belgium) on July 16th 1988. She obtained a bachelor in archaeology at the university of Ghent (grote onderscheiding) with a BA thesis on the different levels of information rock art can provide archaeologists, ranging from very direct data to abstracted interpretations. She went on to obtain a master of arts in North-West European prehistory (onderscheiding), with a dissertation on the elite painted ceramics of the iron age hillsite of the Kemmelberg. Following this masters', she completed the first year of a bachelor in Journalism at Artevelde Hogeschool.

Jessica then returned to archaeology, and obtained a Master of Science in human osteoarchaeology from the Leiden University (cum laude) with the thesis "Busy bones: osteoarthritis and musculoskeletal markers as evidence of physical activity and social differentiation in the post-medieval Netherlands". After finishing this degree, she returned to Belgium as a field archaeologist for a year.

In the fall of 2013, Jessica started her PhD research at Leiden University. Combining her research first with ongoing field excavations, and later with her simultaneous positions as lab assistant, stable isotope archaeologist, teaching assistant, and freelance copy-editor, she completed her PhD in august 2018. During this five year-period, Jessica was involved in numerous research projects on both light and heavy stable isotopes, including provenance research into the Roman soldier popularly known as 'the man in the well' from Velsen using strontium and oxygen stable isotopes, and the dietary research into the post-medieval skeletal collection of the Louis D'haeseleerstraat from Aalst using stable carbon and nitrogen isotopes which is integrated into this PhD. By completing these projects from start to finish, Jessica developed an interest in chemical processes and experience with laboratory protocols.

During her PhD, Jessica taught a host of guest lectures, and presented at the main conferences in her field on a yearly basis. She co-directed and taught a field school on human remains near Naples in Italy. She was instrumental in the development of the state-of-the-art chemical laboratory and laboratory for human osteology at the faculty of archaeology of Leiden University. Within her research group, Jessica co-supervised several master students, and was involved in the creation of the MOOC 'The truth in our bones', for which she also provided a lecture. For her own research, Jessica instigated collaborations with the Flemish

Heritage Agency, various archaeological companies, and the University of Saskatchewan. Her passion lies in the combination of different osteoarchaeological, biochemical, archaeological, and historical datasets to reconstruct the lives of people in the pasts, and she believes strong collaboration between fields and specialisms form the basis hereof.
Jessica is currently a researcher at the Center for People and Buildings at the University of Delft, focusing on how to integrate different datasets and draw overarching conclusions from diverse data contexts. She is actively investigating how to optimally utilize the remaining data collected during her PhD.