The Skeleton Keeps the Score: The comparison of entheseal changes between urban and rural populations in the Dutch Post-Medieval Society

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1. Introduction

The daily activities and labour of the average person in the past is something that is of great interest to both historians and archaeologists. The daily labour that people were engaging in, would have undeniably affected how they lived their lives and how they saw the world that they lived in, but how can this labour be researched and studied? Historians are limited to written sources, but archaeologists have access to a wide range of mediums, such as material culture, architecture, and the use of space within settlements to answer these questions. Bioarchaeology, and more specifically osteoarchaeology is one line of research that can be used to explore daily labour and the effect it has on people's lives. It is indisputable that labour changes the human body, the skeleton is after all an adaptable organ. One way to look at this is through embodiment theory, which encapsulates how experiences, labour, activities; the physical world as a whole affects the body (Krieger, 2001). While embodiment theory does focus on how this affects the mind; a person's mental and emotional state, it is undeniable that the physical outside world also affects the physical body, such as the skeleton. It is essentially a record of a person's live, an embodiment of the experiences and activities that have shaped and moulded the skeleton through an individual's life. Therefore, this thesis aims to study how the physical world affects the skeleton in the form of daily activities and labour.

One way that this change can be tracked and investigated is via entheseal changes. Entheseal changes are muscle, ligament, and tendinous attachment to bone. The more exercise, or labour, that a person does the more their muscles should grow. These muscles are attached to the bone via tendons or ligaments, and the areas where they attach can be affected by the continued use of said muscles. The changes caused to entheses by this are called entheseal changes. As a result, they can provide a window into regular activity performed by past populations, particularly strenuous regular activity, such as daily labour, as this can cause more change (Schrader, 2019), due to the excess strain on the bones. These changes can be used to reconstruct the past activities of everyday people. While exercise, physical activity, is undoubtedly beneficial to the human body, evidence of regular, or even extreme physical activity in the past is linked to people of a lower class, the working classes. Entheseal changes can therefore be used to determine the amount of labour performed within these populations, by analysing their development. An example of degrees of this development is pictured below in Figure 1.1. The purpose of this thesis will be to use entheseal changes to determine the difference in labour performed in rural compared to urban settlements in the post medieval period in the Netherlands. Specifically, the labour performed in Middenbeemster compared to Arnhem.

1.1. Introducing Entheses

Entheseal changes have been used for over a century not just a representative of regular physical activity or labour, but as markers for specific activities (Lane, 1887). Unfortunately, entheseal changes are not only affected by regular physical activity, but like with most other bone formations, they are also affected by age, sex, pathology, body mass and genetics (Schlecht, 2012, p. 1245). This means that entheseal changes have a multi- factored aetiology.

Alongside the issues of a multi-factored aetiology, one of the main issues plaguing the study of entheseal changes is the lack of standardisation in the methods of recording. Previous methods have lacked clear classification criteria and detailed reference photographs (Hawkey and Merbs, 1995; Robb, 1998), and as a consequence did not produce results with low inter- observer error, which were not repeatable (Mariotti et al., 2007). This is changing with the introduction of methods such as the Mariotti method (Mariotti et al., 2004; 2007) and the Coimbra method (Henderson et al., 2016), which will be elaborated on in Chapter 3.

As a result, what is needed in this field of study is more standardised methods of measurement, but also strong a statistical framework to examine said measurements (Van der Pas and Schraeder, 2022). Progress has been made in recent years, but as always multiple studies are needed to truly solidify entheseal changes as linked to specific forms of labour. Simply put, the hypothesis that entheseal changes can be linked to specific forms of labour must continue to be tested, and applied to different populations.

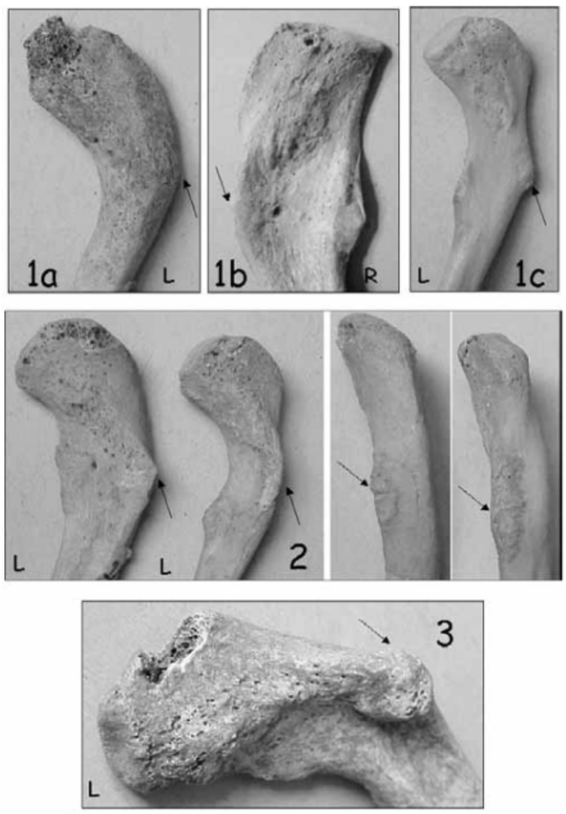

Fig 1.1- Example of the different stages of entheseal development for the conoid ligament entheses on the clavicle (Mariotti et al., 2007, p. 303)

1. 2. Research Questions

The main purpose of this study is to examine the daily activities of non- elites, specifically in post medieval Dutch settlements, and to ascertain whether entheseal changes can offer an insight into the labour of these non- elites. Within this, I will be comparing an urban settlement and a rural settlement to see how labour differs in an urban compared to a rural setting. The aim will not only be to examine how labour differed in these two communities, for example farming versus working in a factory, and whether this is supported by the entheseal changes, but whether the average individual was doing more or less gruelling labour if they were living in a rural or urban environment. There is a popular idea that moving to the city leads to more opportunities and a better life. Urbanisation is often seen as a progress of civilisation, but it is debatable whether it actually benefitted the majority of the population, which is of course the non-elites, or the working class.

Secondly, within this I will be examining how much labour women specifically were doing and whether this differs significantly in rural settlements compared to urban settlements. I will also be examining whether there is a divide on the basis of sex within the labour performed and whether this differs significantly between the two sites. During this era, roughly 16th to 19th century, historical literature suggests that there is a belief that women's work should be restricted to the home (Schmidt, 2011), whether this is reflected in the osteological record will be investigated here. It should be mentioned here that it will only be possible to determine the biological sex of the individuals examined in this thesis, not the gender that they identified with. All though I will be connecting the entheseal changes of female individuals with theories about the labour that women were performing, and male individuals with theories about the labour men were performing, gender is not the same as sex. Unfortunately, it is not possible to determine individual gender based on osteological remains, so this thesis will investigating the difference on a basis of sex, and connecting it to historical beliefs about gendered labour.

Research Questions:

Was there a significant difference in labours performed in rural settlements compared to urban settlements in the Dutch post medieval era?

Is there a difference between entheseal changes of men and women at Middenbeemster and Arnhem?

1. 3. Methods

The majority of methods undertaken for entheseal changes rely on macroscopic inspection of the bone, and then an evaluation of the extent of entheseal development. There are several different methods for this with their own differing scales of measurement. I, however, will be using the Mariotti method, for several reasons. Firstly, with 5%, it has a low rate of inter- observer error, which is key in not only the accuracy, but the repeatability of the method. Secondly, the Mariotti method covers twenty-three entheses, covering the entire post cranial body, and all the movement that is done by the body. Lastly, unlike other methods, the Mariotti method is applicable to both fibrous and fibrocartilaginous entheses (Mariotti et al., 2007). The definitions for both of these entheses and the distinction between them will be given in Chapter 2. Both the use of twenty- three entheses and the use of the two different types, mean that this method allows for a nuanced interpretation of a broad range of different movements and how the repeated movements may affect the entheses. The Mariotti method uses macroscopic evaluation on a simple numeric scale, resulting in data that can be easily used in statistical models.

Each individual will need to be sexed and aged before being selected for the sample. For this I will be using the aging and sexing data that has already been done on these collections by the University of Leiden Osteoarchaeology Lab.

1. 4. Materials

There are two key benefits to studying the post- medieval era. One, the bones tend to be better preserved, allowing for easier analysis, and two, the post-medieval era is a historical era, meaning that historical sources can be used as a reference and for comparison. As the purpose of this thesis will be the comparison of the daily labour and activities performed in rural compared to urban settlements, I will be using samples from two sites that represent rural and urban settlements respectively. Arnhem, an urban settlement, and Middenbeemster, a rural settlement. Middenbeemster is a rural settlement that mainly engaged in dairy farming. Within dairy farming there has been a debate as to the extent that women were involved, along with the possibility of hidden labour (van Nederveen Meerkerk & Paping, 2014). Arnhem is a newly urbanised settlement at the time. A variety of labours were performed in Arnhem, almost all of them wage labour, including shoemaking, the tobacco industry and typography (Baetsen et al., 2018). Like many other towns during the post medieval era in the Netherlands, Arnhem was engaged in the biggest production in the Netherlands at the time, textile production. Like within dairy farming, there has long been a debate about the involvement of women in the textile industry, for example the extent to which married women were involved with what could be called their husband's profession (Schmidt, 2011; Schmidt and van Nederveen Meerkerk, 2012; van Nederveen Meerkerk, 2008). The location of these two settlements within the Netherlands is illustrated in Figure 1.2 below.

One key difference between the Arnhem and Middenbeemster collections is that the Middenbeemster collection comes from a cemetery that serviced the entire rural population, while the Arnhem collection comes from a cemetery that appears to be located in a poorer area of town, and as a result is most likely only comprises of non- elite, working class individuals. This means that while it will be possible to examine social and class dynamics within Middenbeemster, it will not be possible to compare this between rural and urban contexts. Furthermore, according to the information from the Leiden University Osteology Lab, both cemeteries date to the post medieval period, but both are in use over a long time period, with Arnhem roughly in used between 1350 to 1829, and Middenbeemster between 1617 and 1866. This means that any conclusions drawn on a comparison between these two populations will be broad. A detailed exploration of the labour performed at both of these settlements, and an in-depth review of the extent to which women were involved in this labour will be presented in Chapter 2.

As has been mentioned above entheseal changes have a multi-factored aetiology, however age seems to be a dominant factor in entheseal development (Mariotti et al., 2007; Schlecht, 2012). As a result, I have excluded older adults from the sample. This includes the category 'old adults' and individuals who have been identified as 60 or older based on archival data, as in the case of Middenbeemster. While age will naturally still affect the entheseal changes, hopefully this criteria will exclude entheseal changes that have been dramatically affected by age. Similarly, I will not be examining non-adults as entheseal changes do need time and repeated activities to develop, and as a result the study of entheseal changes in non- adults is very different to the study of entheseal changes in adults. Furthermore, the labour realities of children are not being investigated in this thesis, as focus is placed on young, to middle adults A more detailed discussion for this is seen in Chapter 2.

Fig 1.2- Map showing location of Middenbeemster and Arnhem within the Netherlands (Felt. com, Leah Purcell).

1. 5. Reading Guide

This thesis will consist of six chapters as follows:

The next chapter, Chapter 2 will present a background of entheseal changes and labour in post medieval Dutch society. This will entail a detailed explanation of formation of entheseal changes and a brief overview of the past literature relating to them. Furthermore, it will contain a detailed overview of labour and the ideologies relating to it in post medieval Dutch society, including the labour that women performed and the ideologies surrounding their labour. This will include a brief overview of the assumed labours performed at both Middenbeemster and Arnhem.

Chapter 3 will cover the Materials and Methods used in this thesis. This will principally be an overview of the excavations that resulted in the collections the samples have been taken from, and a detailed explanation of the Mariotti et al. method, and how it has been adapted for this thesis.

Chapter 4 will present the processed data. This will consist of graphs and tables, alongside a brief summarisation of the results.

Chapter 5 will be an in-depth discussion of these results, and an attempt to relate to movement and labour within its proper historical context. This chapter will also consist of a comparison with other similar research, finding the similarities, but also analysing why there may be conflicts. Lastly, this chapter will include a summary of any limitations that were encountered during the research undertaken, during both the data collection and data analysis.

Chapter 6, the final chapter, will be a conclusion, which will comprise of a summary of the thesis and the results to the research questions that were proposed in the introduction. Whether the research questions were answered to a satisfying extent or not will lead to possible recommendations for future research.

2. Methodological and Historical Background

The following chapter will provide a background to both entheseal changes and labour in post medieval society in the Netherlands. This will include explaining how entheseal changes form, what affects this formation, and the challenges that come with studying them. Essential to understanding entheseal changes, is understanding how the body moves, which muscles are used in certain movements, and how these muscles then have an effect in the skeleton via entheseal changes. To understand the movements that people were most likely performing in the 16^{th} to 19^{th} centuries in the Netherlands, an understanding of the society and the labour performed in it is necessary. This section will include not just an explanation of the labours performed, but also the attitude towards labour, so as to understand the gendered divide within society and how that was translated to daily labour. To conclude the chapter, the specific labours performed in both Middenbeemster and Arnhem will be investigated, along with a brief history of each settlement.

2. 1. Entheseal Changes

Entheseal changes are changes to the attachment sites of muscles on bones, and as such have been and continue to be used by archaeologists to reconstruct physical activity in the past. Medically, entheseal changes are now known to be the cause of sports injuries such as 'the tennis elbow' (Benjamin et al., 2006), so it is evident not only that entheseal changes have a correlation with physical activity, but because these changes still continue to be present on contemporary skeleton and living people, comparisons of modern problems caused by these changes can be held within proxy to assume problems experienced by people of the past. Namely, that pain experienced by certain changes in the present also would have caused pain to people in the past. Still however, entheseal changes come with complications, with a multi-factored aetiology, as well how the two different types behave differently and produce different results

Fibrous vs Fibrocartilaginous

Entheseal changes can be divided into two different types, fibrous and fibrocartilaginous. Fibrous attachment sites are when the muscle attaches to the bone, via connective tissue, such as tendons. They tend to appear on the shafts of long bones and the cranium (Jurmain et al. , 2012, p. 540) . On the other hand, fibrocartilaginous attachment sites as the name suggests have an intermediary layer of cartilage, and tend to appear on the epiphysial ends of long bones, on some short bones and some parts of the vertebrae (Jurmain et al., 2012, p. 540). An example of a fibrocartilaginous entheses is the *costoclavicular* entheses, pictured in Figure 2.1. Fibrous entheses form as part of intramembranous ossification and fibrocartilaginous entheses from as part of endochondral ossification (Becker, 2020, pp. 2-3). This means that in the former the bone develops directly from sheets of connective tissue, and in the latter the bone develops by replacing cartilage.

Recent studies suggest that fibrocartilaginous joints show more significant changes related to repeated activity (Henderson et al., 2016). Studies suggest that as the attachment site tends to be at the diaphysis of long bones, the biomechanical force pulling on the bone and creating the change, is spread over a wider area, and therefore causes less of a visible change on the skeleton (Karakostis and Harvati, 2021, p. 186). This is also evident in the clinical record, as fibrocartilaginous entheses have simply been studied more in clinical literature, possibly due to the lack of symptoms produced by fibrous entheses (Henderson, 2013). However, this is not to say that fibrous entheseal changes are not indicative of daily activities, especially as some studies have suggested that some entheses are both fibrous and fibrocartilaginous (Karakostis & Harvati, 2021, p. 186).

Fig 2.1- Example of the degrees of change to the costoclavicular entheses (Stirland, 1998, p. 355, fig 1)

Multi-factored aetiology

There is not only evidence for a correlation between physical activity and entheseal changes, but both age and sex. Age has a positive correlation with entheseal changes, and this has been evidenced by many different studies (Jurmain, 1999; Mariotti et al., 2004; 2007; Villotte, 2009; Villotte et al,. 2010). Particularly after sixty, there is a deterioration of the physical properties of the entheses, and there is less chance that damage to the enthesis can be repaired (Schrader, 2020). The increase with age could simply be because entheseal changes develop over one’s life. The more physical activity, the more they develop, and the more time lived the more chance for physical activity. However, another possibility is that as bones age, they become more vulnerable which results in more dramatic entheseal changes (Schrader, 2020). Unfortunately, the current state of both clinical and bioarchaeological research on the matter is inconclusive, and as a result, older individuals, especially those above the age of sixty, will be excluded from this study investigating entheseal changes.

Sex also appears to have an effect on entheseal changes, with is credited to the male ability to develop more muscle mass, which would then create a larger force on entheses, producing more dramatic entheseal changes (Weiss et al., 2012). Evidently it is not just sex, but also size that affects the development of entheseal changes. This however is not always conclusive, as multiple studies have found evidence for more developed entheseal changes in female individuals over male individuals (Caballo- Perez and Schrader, 2022; Eshed et al., 2014). These studies however can be used as evidence for the gendered division of labour, rather than evidence that the male sex does not have a positive correlation with entheseal changes.

2. 3. Understanding Movement

To understand how entheseal changes can be used to reconstruct the labour of past populations, it is essential to understand movement, and how the muscles attached to the entheses result in movement. The main types of movement are rotation, flexion/ extension , and abduction/ adduction, which can be seen illustrated in Figure 2.2. These movements are carried out within six functional complexes: the shoulder, the elbow, the forearm, the hip, the knee and the foot. The neck is also crucial for the movement of the human body, but as this thesis does not look at the spine, it will not be examined here.

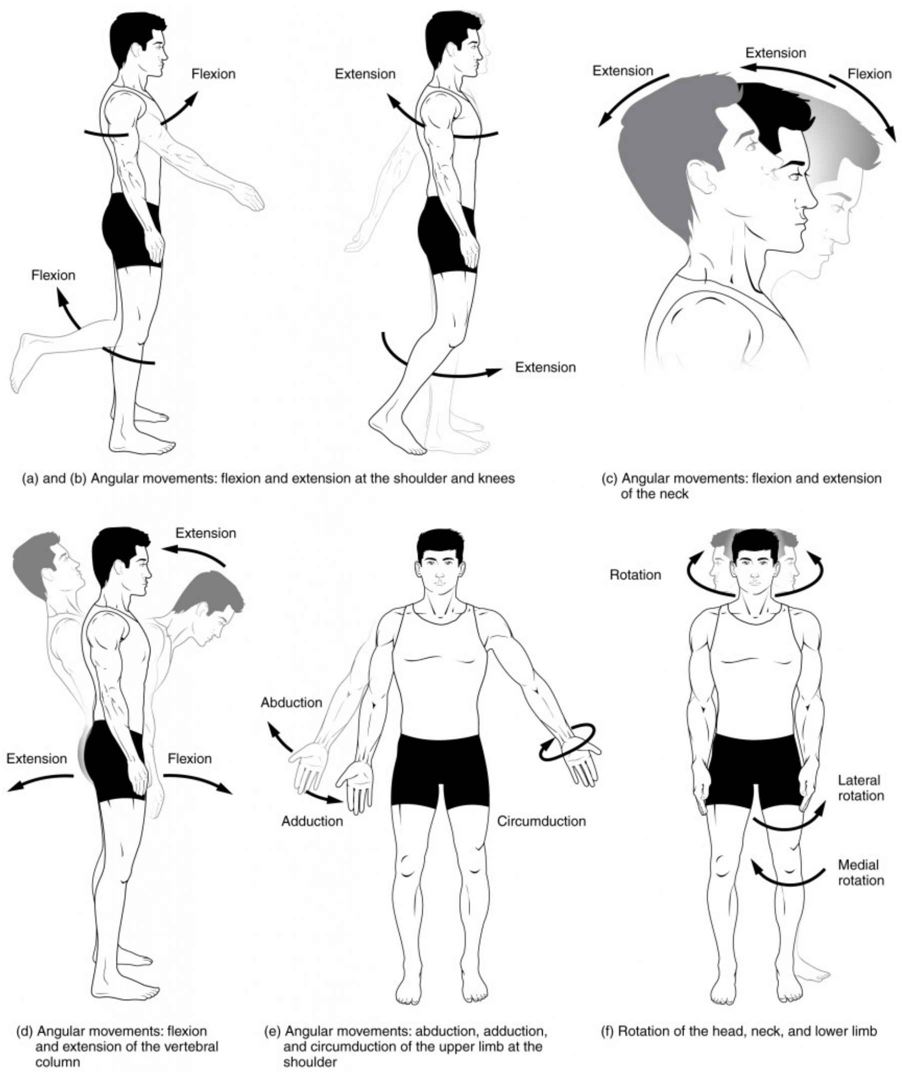

Fig 2.2- Diagram showing the main movements of the human body (Oregon State University, fig 9.5.1, https://open.oregonstate.education/aandp/chapter/9-5-types-of-body-movements/).

Movement depends on the muscles exerted on the bones, but also on the joints present. All the functional complexes mentioned above are joints. Different types of joints allow different types of movement. There are three categories of joints; fibrous, cartilaginous, and synovial. The joints that allow the most movement, and therefore are the focus of this thesis, are synovial joints. Synovial joints are when the bones involved exist within a joint cavity filled with synovial fluid, which allows for freer movements by the bones involved. Within the upper body, the shoulder, elbow and forearm all represent different forms of synovial joints. The shoulder primarily consists of a spheroidal joint, otherwise known as a ball and socket joint, the glenohumeral joint, and in this case the ball of the humerus fits into the socket of the glenoid fossa on the scapula. The elbow is a primarily a hinge joint, and allows for flexion and extension, as the ulnar hinges on the distal end of the humerus. The forearm is a pivot joint, as the radius and ulnar pivot on each other, allowing for pronation and supination, which is essentially twisting the forearm back and forth. In the lower body, the hip like the shoulder is a ball and socket joint. The knee, while similar to the elbow is a different type of joint, a bicondylar joint. The tibiofemoral joint within the knee does not just allow for flexion and extension, but a small degree of rotation. Lastly there are several joints within the feet. The toes, like the fingers, will not be elaborated on here, as due to their delicate nature, they do not survive well in the archaeological record. However the main movement in the foot is provided by the ankle, which like the elbow is a hinge joint. To summarise the synovial joints of interest are the ball and socket joint, the hinge joint, the pivot joint and the bicondylar joint. These joints and the movements they allow are illustrated below (fig 2.3).

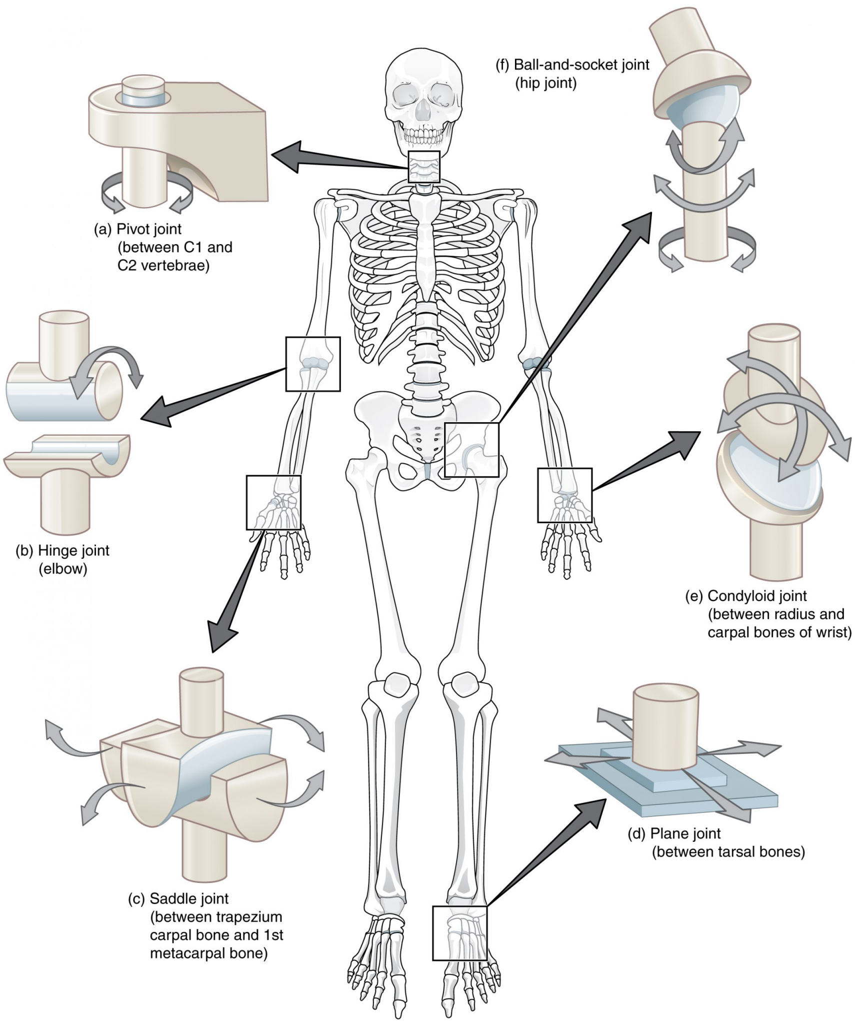

Fig 2.3- Diagram showing different forms of synovial joints and their location on the body (Oregon State University, fig 9.4.3, https://open.oregonstate.education/aandp/chapter/9-4-synovial-joints/)

Muscles attach to bones via tendons or ligaments at the entheses, and move bones through the movements allowed by these joints. Usually, muscles attach at least two different sites, which have previously been referred to as the origin and the insertion. The origin is traditionally the entheses where the muscle is inactive, and the insertion is the entheses where movement happens. These terms can be misleading, however as with different movements, the two can swap roles. (Kingston, 2005, pp. 11-12). Nonetheless, each entheses can be directly related to a movement, although not always a very specific movement.

To sum up, muscles attach to bones via tendons or ligaments, each muscle has multiple attachment sites, and each bone has several different muscles attached to it, allowing muscles to move bones through a range of joints, resulting in the full range of movement employed by people in daily life. The specific movements that will be examined by this thesis will be detailed in Chapter 3, when the specific entheses and the muscles that attach via them that are being studied here, are expanded on in detail.

2. 4. Labour in Post Medieval Dutch Society

To understand how labour was carried out and perceived in post medieval Dutch society, it is essential to first define both labour and the exact period that is the post medieval era in the Netherlands. Then it is possible to examine the labours performed and how they were perceived, in what was a time of changing attitudes. This can then be used to examine the issue of gender within society and how it translates to the labours performed.

Definitions

Post medieval society in the Netherlands, but also in the rest of Europe in general was undergoing rapid urbanisation and industrialisation, which was naturally affecting ideas around labour and the labour that was performed. To address this a definition of this specific time period, and the labour being referred to must be provided. Post-medieval in this case primarily refers to the 16th to 19th centuries, as that is when the majority of the sample from both Middenbeemster and Arnhem date to.

Labour in the context of this thesis does not only refer to wage labour, that was emerging quickly in this period as the primary form of labour, but to all the forms of labour that are needed to drive an economy, including the labour required to run a household, and the unpaid labour performed by household members within family enterprises, both in agriculture and production.

Urbanisation and Industrialisation

During this period the Netherlands experienced large scale urbanisation with the urbanisation rate going from 10% in the 1300s to 50-60% in the 1700s (van Bavel, 2010, p. 2). While the Netherlands definitely experienced large-scale urbanisation during this period, becoming one of the most urbanised countries in Europe (de Vries, 1984), industrialisation came later to the Netherlands compared to the rest of Europe, (Drukker & Tassenaar 1997, pp. 332-333). As a result, agriculture in the Netherlands did not experience large scale mechanisation until late into the 19th century (Bieleman, 2010), and was mainly driven by manual labour. However, this is not to say that it was not a successful field, as The Netherlands were able to rely almost exclusively on domestic production well into the 19th century (Winde, 2006). This is not only due to the hard labour of the average rural citizen, but the reclamation of large amount of agriculturally viable land from the sea and various lakes during this period, Middenbeemster being one of these (Jong et al., 1998). It is however during this period that a lack of stability in grain markets resulted in a change towards pastoral farming, such as dairy farming (Bieleman, 2010). It is this booming agricultural industry that was able to support the urban centres such as Amsterdam, Utrecht, and even Arnhem. Across the Netherlands there is a flourishing textile industry during this period, which is focused in urban centres, but declines after the 17th century, only to experience industrialisation in the 19th century. Across this period both urban and rural settlements experience decline, after the Dutch Golden Age of the 17th century, and then revitalisation in the 19th century.

Capitalism, Protestantism And A Lack of Aristocrats

The Dutch Golden Age has been credited as the beginning of a new form of state. This state was a Protestant state that broke away from the feudal medieval world with the invention of capitalism.

The early modern world has often been characterised by the rise of capitalism and the resulting emergence of wage labour as the primary form of labour. One of the primary changes resulting from this new system was the movement of production from the domestic sphere to the economic sphere, from the home to the factory. However, during the early modern period much of production is still in part controlled by guilds.

It should also be noted that this period is not only post medieval, but Post Reformation, as Protestantism was now the dominant religion in the Netherlands. A change in religion, particularly the adoption of Protestantism undoubtedly had an effect on the ideologies surrounding labour during this period. Manual labour had previously been seen as degrading (Wood, 2002, p. 52), however with the emergence of Calvinist thought in the Netherlands, work ethic became something that was admired and prized, and some have credited this with the emergence of capitalism, at least in the Netherlands (Ter Voert, 1997). However, it should be remembered that whether or not it was admired or looked down on, since the emergence of structured society, the lower classes have always had to engage in manual labour.

The Netherlands differed from the rest of Europe as a Protestant country, but also as a country without an aristocratic elite. In part linked to the transition to capitalism, the Dutch elite mostly comprised of those who has made their money in trade, as merchants or investors. With administrative power out of the hands of the noble classes, who had little to no knowledge of industry, the move from feudalism to capitalism, has been linked to a higher standard of living and less strict social classes. Essentially there was a rising middle class. However, the lower classes, the working class were still very much in existence, in urban and rural settlements, and did not have access to this social mobility or higher quality of life. With this claim of a more equal society compared to the rest of Europe, a lack of social hierarchy on the basis of labour should be evident in the results, with a lack of an elite group that is clearly not engaging in labour.

2. 5. Women and Labour in Post Medieval Dutch Society

A gendered division of labour is something that has been argued for in many different societies across time and geography. It must be noted that is not possible to truly define what gender the individuals used in this study identified as, and it must be acknowledged that gender is a social construct, very different to biological sex. It is however possible to use biological sex to attempt to define whether there was a division of labour based on sex in the post-medieval era Netherlands. Biological sex however does not equate to gender.

Women have always performed some form of labour, but often in the past they have worked along strict gendered divisions, so to what extent did this occur in post-medieval Dutch society? The main industries examined by this paper are farming and production, and these are most definitely fields that women played a valuable role in. It has even been suggested that the gendered divisions of labour became more ‘articulated’ during this period, in particular with the concept of women belonging in the domestic sphere (Schmidt, 2011, p. 44).

Production

Schmidt (2011) argues that during this period the norms for women narrowed, and that there is increasing literature warning of the dangers of a seductive women or mocking the reversal of gender roles. She does not blame this on the Protestant Reformation however, saying that the adoption of Protestantism did not radically change gender roles, but that it did ‘intensify the debate’ (p. 49). Rather the blame could be placed on the emergence of capitalism, as the movement of production from the home to the factory, excluded women from production (Clark, 1919, p. 299), except for the lower-class women who were forced to find work in factories. While this ideology may have been comforting to and popular with men during this period, and has been propagated by historians such as Jan de Vries and Aan van der Woude (1997), does it have a factual basis? Yes, women were encouraged to stay at home, but does this indicate that women were actually staying at home, or were they being told do so because they were not obeying this demand? While census records do not represent an accurate image of the full extent of women’s participation in the labour market, they can be in part used to debunk this theory. The number of women household heads with a registered household occupation actually increases from the 15th century to the 17th century (Schmidt & van Nederveen Meerkerk, 2012, p. 72). Furthermore, even if women did remain within the household, it should not be assumed that the labour required to run a household is less physically demanding or less economically important than wage labour. While production had moved out of the domestic sphere, women moved with it, and many were employed in early factories, especially within textile production, which is illustrated in Figure 2. 4 below.

Fig 2.4 - *Het spinnen, het scheren van de ketting, en het weven*, 1594-1596, painting by Isaac Claesz. van Swanenburg, depicting the spinning process for textile production

Agriculture

Women are often excluded from historical census registration, and as a result their labour can go ignored. This is mainly because women's, and especially married women's, labour has been seen as part of domestic sphere, and therefore of little economic importance, a view that is not only simplistic but very inaccurate (van Nederveen Meerkerk & Paping, 2014). This is exacerbated in agriculture due to the seasonal nature of many tasks, which were therefore not seen as worth recording (Cunningham, 2005). Predictably many of these seasonal tasks were undertaken by women, excluding them even further from the historical record of labour. The 1899 census, slightly outside of the time period, but relevant nonetheless, even states in its introduction that married women's work had not been accurately recorded as married women were ashamed to admit that they had undertaken wage labour (Centraal Bureau voor de Statistiek, 1902, pp. 185- 189). Whether or not the men writing this introduction had an accurate insight into how the average Dutch married woman viewed wage labour, this introduction does show that the recording of women's labour was highly inaccurate, and it is unlikely that this poor record keeping is exclusive to 1899, and much more likely that it was present in the decades before. The 19th century census' and census' before that primarily show roughly 50 % of women, and regularly less, as unemployed, and therefore not performing labour (Schmidt, 2011; Schmidt & van Nederveen Meerkerk, 2012; Van Nederveen Meerkerk & Paping, 2014).Whether this will be reflected in the osteological record, however, is yet to be seen. Nonetheless, as has been mentioned previously, whether or not women were contributing to the labour market, during this period, they were unlikely to be completely free of the demands of labour. Many 'unemployed' women were often 'housewives' and housewives would have performed extensive amounts of daily labour required to run a home in the post medieval era.

The exclusion of women, especially married women, from the historical image of the Dutch labour market, both in production and agriculture, has led to the belief that the Netherlands in the 17th century became 'the first male breadwinner society' (Schmidt & van Nederveen Meerkerk, 2012, p. 69). Apparently due to the prosperity of the Dutch Golden Age, women withdrew to the domestic sphere in middle class comfort much earlier in the Netherlands than in other European countries (de Vries & van der Woude, 1997). Multiple historians in the last few decades however have argued against this theory (Schmidt & van Nederveen Meerkerk, 2012; Van Nederveen Meerkerk and Paping, 2014), and as has been shown above it is a theory that quite simply relies on ignoring women's many labour contributions. Osteological remains offer a chance to study the labour performed by women, outside of the historical records, that can be tainted by ideological sentiment. In this thesis, I hope to discover whether this labour is reflected in the osteological record through the medium of entheseal changes.

2. 6. Middenbeemster

Middenbeemster was and still is an agricultural settlement, and was part of a region reclaimed from a lake in the early 1600s (Jong et al., 1998, p. 11) Like the majority of the Netherlands, it experienced mechanisation later than the rest of Europe, and possibly even later than the rest of the Netherlands. It seems that mechanisation does not come to Middenbeemster until the late 19th century, with the steam powered water pumps and a steam tram only appearing at the end of the 19th century (Jong et al., 1998, p. 32). The main industry in Middenbeemster, and the Beemster polder in general was cattle breeding, and as a natural consequence various forms of dairy production. This is because, despite extensive draining, the groundwater level was not suitable for large scale arable farming, but rather suited for pastoral farming. While the land had originally been drained for arable farming, specifically grain, 72% of this arable land was used as pastureland for cattle. This would not change until the 1880s, when steam powered drainage systems could drain further, allowing for land that was suited for arable farming (Jong et al., 1998, p. 26). Middenbeemster has been engaging in since is foundation, and is still famous for it today. Evidence of this is exemplified in the existence of 'Beemster' cheese and with the Beemster polder farmhouses even being protected by UNESCO (Jong et al., 1998).

Furthermore, Middenbeemster was most definitely a rural settlement, with the entire Beemster polder counting less than 3,000 inhabitants in 1840 (Falger et al., 2012, p. 127). Middenbeemster in the time period explored in this thesis, can therefore be characterised as a rural site with a main labour industry of non-mechanised dairy farming.

2. 7. Arnhem

Arnhem is first mentioned in historical records in 893, but it is not until 1233 that it is granted the title of civitas, and officially became a city (Erven Orens, 1915, p. 77). Arnhem however was never a commercial hub nor an urban centre on the scale of other cities in the Netherlands. In 1670 the city only had 6,500 inhabitants (Lourens and Lucassen, 1997, p. 17), and by the 1800s this would only increase to 9,500 (Erven Orens, 1915, p. 78), hardly indicative of a massive urban centre. In contrast Amsterdam has a population of 221,000 in 1795 (Lourens and Lucassen, 1997, p. 57), and Leiden had a population 30,955 in 1795 (Lourens and Lucassen, p. 114). While Arnhem was definitely an urban settlement in this period, it is not necessarily representative of the urban realities of people living in the bigger cities in the Netherlands during this period. Nonetheless, the labour that occurred in Arnhem did reflect its urban reality, even if on a smaller scale. Arnhem was a centre for small scale industry such as the tobacco industry, shoemaking, typography, paper production and even the textile industry (Baesten et al., 2018; Jan de Vries & Aan van der Woude, 1997). In the case of paper and textile production this work took place in mills, which were essentially factories, which entailed notoriously long hours and hard work for very little pay. Both paper and textile production required several steps in long and complicated process. This was often facilitated by machinery such as looms in the case of textile production, if not fully mechanised machinery, at least at the start of the time period being examined.

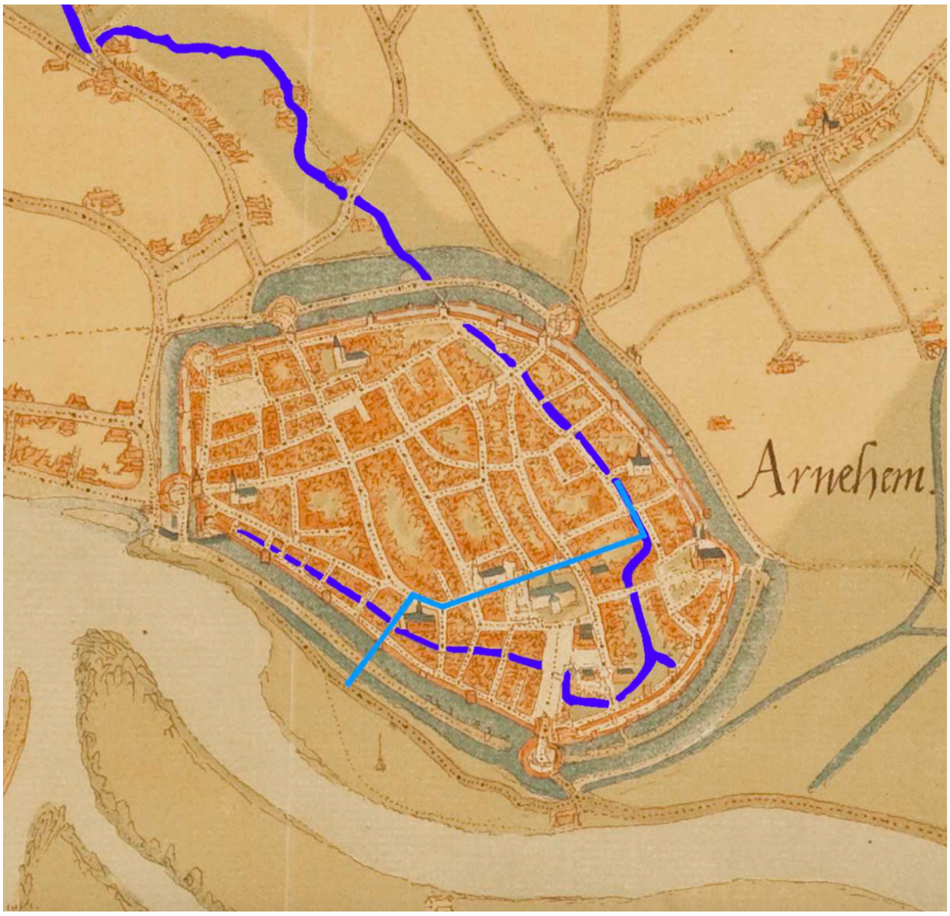

Fig 2.5- Map of Arnhem, 1558-1570, (Baesten et al., 2018, p. 9)

3. Methods and Materials

This chapter will comprise of an introduction to the materials used in this thesis, and the methods used to examine them. Beginning with the materials, the excavations that resulted in the Middenbeemster and Arnhem collections will be examined. The process by which the two samples that were used for this thesis were selected will then be explained. For the methods, both age and sex estimation were necessary, which will be explained in detail. The method used to record the entheseal changes will be explained, along with why it was chosen and any modifications. This will be followed by the methods by which the resulting data will then be analysed. This includes that statistical methods that will be used, alongside how these statistics will then be analysed. Lastly, the ethical considerations involved with studying human skeletal material, that must be considered at every step of the data collection, will be detailed.

3. 1 Materials

The two settlements examined in this thesis are Middenbeemster and Arnhem. Each of the settlements were excavated at an earlier date, and the skeletal collections were moved the Laboratory for Human Osteoarchaeology at Leiden University, where they were able to be examined for this thesis. This section will cover those excavations, and what they can reveal about the populations that each sample comprises of.

Middenbeemster

The Middenbeemster sample comes from a collection that was excavated from the Keyserkerk in Middenbeemster in June to August 2011. The church was consecrated in 1623; however, the graveyard was in use from 1615 to 1866 (Hakvoort at al., 2013). When excavated, over 400 primary coffin burials were discovered, and the skeletons were then transferred to the Laboratory for Human Osteoarchaeology at Leiden University. The majority of the burials at this churchyard were clearly carefully and purposefully buried in coffins, however there were a few bone pits (Hakvoort et al., 2013). The remains from the bone pits will not be examined here, and all the individuals examined here, were buried within the church cemetery (Hakvoort et al., 2013). As it was the only church in the Beemster Region, it is likely that both Catholics and Protestants, along with other faiths were also buried here.

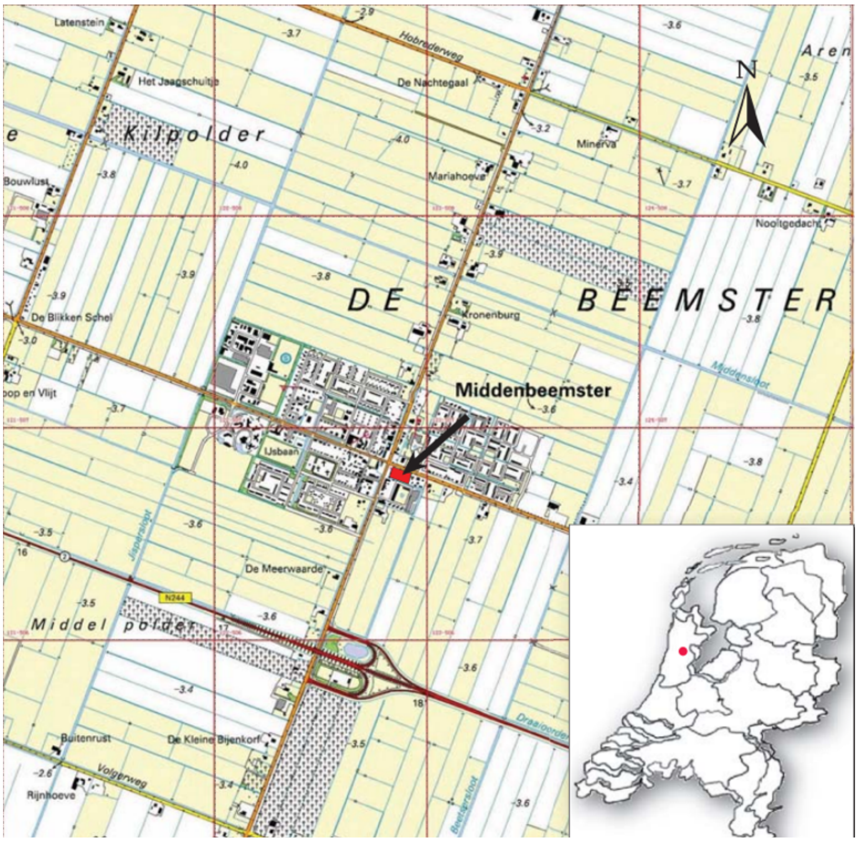

Fig 3.1- Map of modern Middenbeemster, showing its location within the Netherlands (Hakvoort et al., 2013, 11)

Arnhem

The Arnhem sample comes from a collection that was excavated in 2017, and from an area near the Eusebius Kerk in Arnhem, which is the successor of St Martin's Church. The cemetery in question is one that was moved outside of the city walls in 1626, and was then in use until 1829. The individuals excavated were all buried to the north of the cemetery, which was the cheapest place to be buried, suggesting that the collection is representative of a low-income population (Zielman and Baetsen, 2020). All the burials followed Christian practice with the bodies facing the east, ready for resurrection, according to the belief that on the Day of Judgement all those of good Christian faith would be resurrected. They also appear to follow Post- reformation norms, with a distinct lack of grave goods, this could be however due to the low-income nature of the population (Baetsen et, 2018, Zielman and Baetsen, 2020).

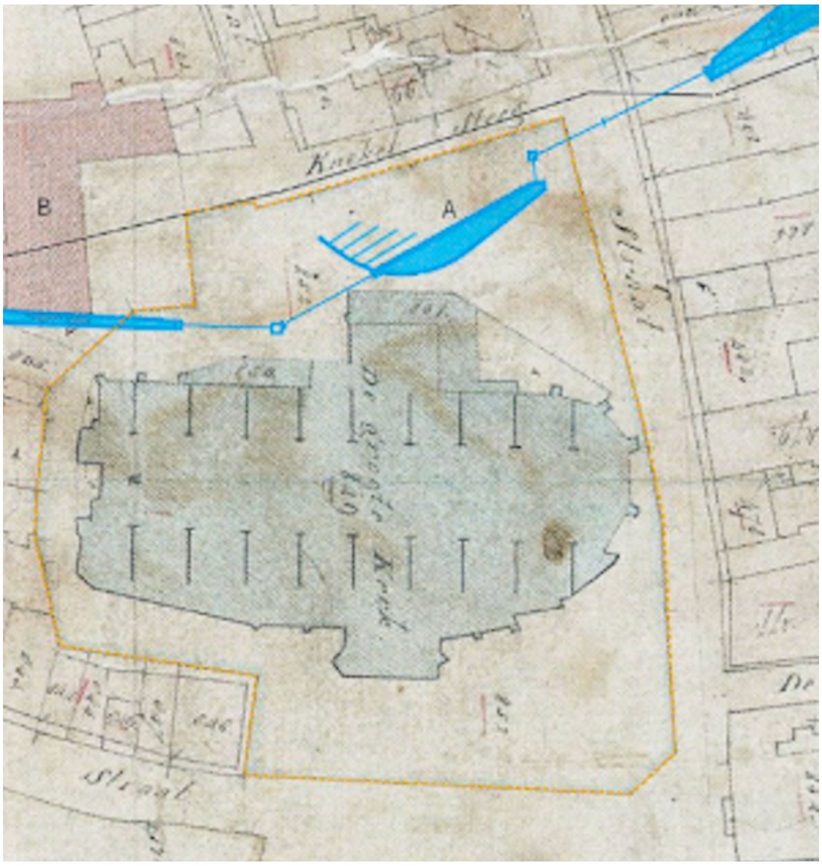

Fig 3.2- Map of St Eusebius Kerk graveyard, construction that resulted in the excavation highlighted in blue, in the north of the graveyard (Zielman and Baesten, 2020, p.39)

An important note about the Middenbeemster and Arnhem populations is that the Middenbeemster population had one church, which is where all the individuals in this sample came from, while Arnhem had multiple churches, and the individuals in the sample only come from an area that has been associated with the lower classes. As a result, the Middenbeemster sample could contain individuals from across different social classes, while the Arnhem sample will most likely only contain individuals from the lower classes. This may have an effect on the entheseal changes recorded here, and means it is not possible to do any analysis on the different lass stratifications in urban vs rural communities in this time period.

3.1.1. Sample selection

For both the Middenbeemster and Arnhem collections 50 individuals were used, equally divided by sex with 25 male and 25 female individuals. As entheseal changes have been shown to be heavily affected by age (Jurmain, 1999; Mariotti et al., 2004; 2007; Villotte, 2009; Villotte et al., 2010), the age group of Old Adults was excluded, and instead this thesis focused on Middle Adults and Young Adults. In a similar line of reasoning, Non-Adults have also not been included in the sample from either population, seeing as entheseal changes have a strong positive correlation with age and the labour realities of children are not being investigated within this thesis.

The Young Adult group for this thesis comprises of both ‘Early Young Adults’ (18-25) and ‘Late Young Adults’ (25-35), meaning that this group represents an age range of 18- 35 years old. Middle Adults on the other hand represent an age range of roughly 35-50 years old.

Entheseal changes require high levels of preservation to be examined on the skeleton, and as I will be looking at entheses all across the post cranial skeleton, a high level of completeness as well as preservation was required in all individuals. This required each individual to have the majority of the appendicular skeleton complete, two complete arms and two complete legs with only one or two bones missing, meaning at a maximum no more than 10 entheses were missing out of a total of 54. However, the sample selection will be based on the digital and paper records that exist of both collections and there is every chance that it will not be possible to examine every entheses that records show is present when it comes to the actual collection, due to degradation. As a result, there are less Young Adults included in the Arnhem sample than in the Middenbeemster sample, with 30 Young Adults and 20 Middle Adults in the Middenbeemster sample and 16 Young Adults and 34 Middle Adults in the Arnhem sample (see Table 1).

	MIDDENBEEMSTER	ARNHEM
MALE YOUNG ADULTS	15	8
MALE MIDDLE ADULTS	10	17
FEMALE YOUNG ADULTS	15	8
FEMALE MIDDLE ADULTS	10	17
TOTAL	50	50

Table 1- table showing the age and sex of individuals used in each population sample

3. 2. Methods

This section will examine the methods used in this thesis. This includes not only the methods used to collect data, but also the methods used to analyse the data.

3. 2. 1. Sex and Age estimation

The sex and age estimation used in this paper is the same sex and age estimation that was done by previous researchers at Leiden University Osteological Lab. For the individuals from Middenbeemster sex determination was done based on the guidelines of the *Workshop of European Anthropologists* (1980), using features on the skull, mandible and pelvis. The same features were also scored according to Buikstra & Ubelaker (1994), and then, the morphological features of the pubis used by Phenice (1969) were used. The combination of all these methods, and other methods, allowed for each individual to be assigned as sex, which has been used for this thesis. For Arnhem sex estimation was done using similar methods, using the morphology of the pelvis and the skull (Brickley & McKinley 2004; Buikstra & Ubelaker 1994; White & Folkens 2005). For both populations this produced ‘possible male’ and ‘possible female’ estimations, so for the purpose of the data collection done here, it has been assumed that the male or female designation is the correct designation for these skeletons. The age estimation for Middenbeemster was done via several methods. Age estimations for adult individuals were based on the wear of several skeletal features, such as the pubis symphysis (Brooks & Suchey, 1990; Todd, 1920) and the articular surface of the ilium (Buckberry & Chamberlain, 2002; Lovejoy et al., 1985). The closure of cranial sutures (Meindl & Lovejoy 1985) and the ossification of the medial ends of ribs (Iscan et al., 1984) were also used. Age estimation for the Arnhem collection was done using the same methods; the morphology of the pubic symphysis (Brooks & Suchey, 1990), the morphology of the auricular surface of the ilium (Lovejoy et al., 1985), and the closure of the cranial sutures (Meindl & Lovejoy 1985).

3. 2. 2. Entheseal Changes Recording Methods

The method used to record the entheseal changes in this paper is the Mariotti et al. (2004, 2007) method. This is due to the low intra observer error, the fact that it uses both fibrous and fibrocartilaginous entheses, and that it encompasses the majority of the post cranial skeleton. The Mariotti et al. method uses a simple scale that grades entheseal changes on a scale from 1-3, including a subsection of 1a-c. In the 2007 paper expanding on the method, images were included in the scale, alongside textual descriptions of each stage, which allowed for better repeatability, and will be heavily referred to for the data collection for this paper. In the Mariotti et al. method, twenty three entheses are studied across the post cranial skeleton, which are separated into the different spheres of movement that muscles involved operate within. These spheres of movement will be expanded on below.

Shoulder

The principle joint within the shoulder is the glenohumeral joint, which is a ball and socket joint, and comprises primarily of the humerus, scapula and clavicle. This joint allows for a wide range of motion, and it is no coincidence that it is the functional complex with the most entheses that will be examined, a total of eight, which are: the *costoclavicular* ligamen*t*, the *conoid* ligament, the *trapezoid* ligament, *pectoralis major* (clavicle), *deltoideus* (clavicle), *pectoralis* (humerus), *teres major*, *deltoideus* (humerus). These entheses are named after the ligament or muscle that is attached at the entheses, so the movement involved with the shoulder is characterised by the *costoclavicular ligament*, the *conoid ligament*, the pectorals, the deltoids and the *teres major* muscles. The primary movement facilitated by these muscles in the shoulder in rotation, a motion that is valuable in most manual labour tasks. Any task that requires the movement of the upper limbs will use this joint. Specifically, the *teres major* muscles are responsible for the rotation of the upper limbs, and the pectoralis major muscles are responsible for the elevation of the arm. The clavicular attachment for the deltoid is used for flexion and medial rotation, while the humeral attachment is used for the abduction of the shoulder, flexion, extension, and medial and lateral rotation (Kingston, 2005, pp. 21-

45). The use of one entheses over the others in this case can reveal exactly how the shoulder was being predominantly moved.

Elbow

The elbow is a hinge joint, that is operated primarily by the humerus and ulna. To examine this joint, five entheses will be examined, which are: *triceps brachii* (scapula), *brachioradialis, biceps brachii, triceps brachii* (ulna), *brachialis*, so in this case the movement involved with the elbow is characterised by the *triceps brachii, brachioradialis, biceps brachii* and *brachialis* muscles. The primary movement facilitated by these muscles in the elbow is flexion and extension, a motion that, again, is valuable in most manual labour tasks, such as lifting. Exactly how much the elbow is extended and flexed is determined by what muscles are in use. Flexion, lifting the forearm towards the body, is characterised by the *biceps brachii*, *brachialis* and *brachioradialis* muscles. Extension, the opposite, on the other hand, is characterised by the *triceps brachii* muscles. This movement is usually very much assisted by gravity, along with simply relaxing the muscles used for flexing. However, when it is done intentionally, for activities such as throwing an object, the *triceps brachii* muscle is essential (Kingston, 2005, pp. 45-52)

Forearm

The forearm encompasses the radius and the ulnar, which together create a pivot joint, with the radius pivoting around the ulna. Only three entheses relevant in this movement will be studied here, which are: the *pronator teres*, *interosseus membrane*, the *supinator* so in this case the movement involved with the elbow is characterised by the muscles, *pronator teres* and *supinator*, and the connective tissue between the two bones that is the interosseus membrane. As these muscles all work around the pivot joint of the radius and the ulna, the primary movement facilitated by these in the forearm is pronation and supination. This is the motion of twisting the forearm which results in the palm being up or down. Supination, turning the palm up, is facilitated by the *supinator* muscle and the *biceps brachii* muscle (discussed above). Pronation, turning the palm down, on the other hand, primarily relies on the *pronator teres* muscle (Kingston, 2005, pp. 52-57). In this case however both muscles will likely be in use in tandem, with the interosseus membrane keeping the two bones connected and facilitating both movements.

Hip

The activity that will be most represented by the lower body in general is walking. The lower body in general can therefore be used to establish which population was more mobile. For the hip in particular only two entheses will be studied, the *gluteus maximus*, and the *iliopsoas,* which both attach onto the femur. These muscles are both responsible for hip extension and therefore play a key role in the upward and forward movement of the body, and are therefore crucial for movements such as jumping, running and standing up (Kingston, 2005).

Knee

For the knee, which is a bicondylar joint, only three entheses will be focused on, the *vastus medialis* and the *quadriceps tendon* (both the attachment sites on the tibia and the patella). This predictably facilitates the movement of bending of the knee, which is also crucial in the motions mentioned above.

Foot

For the foot, two entheses will be focused on, the *soleus* and the Achilles tendon. These entheses are involved with the elevation of the foot, which operates on a hinge joint. The elevation of the foot is obviously crucial in walking.

One of the issues with the lower body is that the majority of motions that rely on the lower body; walking, jumping, standing up, all require the use of all three functional complexes. Any specific motion, and chance of bilateral asymmetry tends to be obscured by the motion of walking, which is undoubtedly required in daily life. Nonetheless, the lower body entheses are included in this thesis to study the mobility of the populations in rural compared to urban settlements, and for the comparison between the sexes.

3. 2. 3. Data Recording and Analysis

For data collection I will be using two Excel Spreadsheets, one for each sample. For easier statistical analysis however, I will be adapting the scale used by Mariotti et al. The scale used by Mariotti et al. includes the subsection of 1a, b, c, which will cause problems when attempting to do statistical analysis. To negate this, I will be adapting the scale to a scale that only uses numerical values, as can be seen below in Table 2.

Mariotti et al. scale	Modified scale
1a	0
1b	1
1c	2
2	3
3	4

Table 2- table showing modified scale used to record entheseal changes

Data will be collected from both left and right sides of the body for each entheses when possible. It is simply unavoidable that some data will be missing due to the preservation of the skeletal material. When data was unable to be recorded, the entheses will be marked as non-observable, or N/O. When statistically methods are performed, these entheses will be omitted, and the statistics will be performed on the data that is present.

Statistical Methods

For all the statistical methods that I will be using, I will be looking at an overall comparison between Arnhem and Middenbeemster, using the means of each functional complex. I will then examine each individual entheses. The use of an overall comparison with the means of the functional complexes is so that the difference will be more easily visualised, while the purpose of examining each entheses individually is to be able to determine more specific differences in motion, and therefore daily labour. The aim will be to see if there is a difference between left and right, age, and sex, across both populations, and across the multiple spheres of movement. Looking at the spheres of movement should hopefully show what movements were being carried out in each population and therefore allow for an estimation of which labours were being carried out in each population.

This will be done firstly by examining the mean of each enthesis across these multiple factors, and then through the use of T-tests to see if any difference is statistically significant. T-tests use a null hypothesis and an alternate hypothesis, with the null hypothesis being that the means in the two groups compared are equal, so there is no difference, and the alternate hypothesis being that the mean value in the two samples are not equal, so there is a difference (Tello & Crewson, 2003). I will be using a 5% significance level, meaning that I will be looking for a p-value of less than 0.05 to confirm a statistical difference between the two samples. I will be using T- tests on ordinal entheseal data, which can cause some issues. This has been done by previous studies (Karakostis & Havarti, 2019; Nolte & Wilczak, 2013), but to ensure that t-test can be performed on the data, I will be testing the data to ensure that it is normally distributed (van der Pas & Schrader, 2022). The graphs produced from this will be located in the appendix (see Appendix C).

I will also be using a machine learning technique, and Random Forest. Random Forest is a predictive modelling technique that comprises of multiple Decision Trees, which is why it’s called a forest. Decision Trees are essentially decision-making processes for predicting a certain outcome. With complex data sets, say a data set looking at 100 individuals across two populations, and twenty thee entheses, left and right, producing 46 variables for 100 individuals, one decision tree can result in overgeneralisation and errors, hence the need for a forest of Decision Trees (Biau & Scornet, 2016). Random forest looks at a percentage of the data, and analyses the patterns, and attempts to predict classifications, say if an entheses is likely to be lower on the basis of sex. It the validates how accurate its predictions are on the rest of the data. This will allow the identification of which entheseal changes scores are more associated with different aspects, such as sex, age and settlement, allowing to identify what movements these groups were doing and therefore what labours they were partaking in. It is not guaranteed however that Random Forest will generate a result that is accurate, especially if there is a not a clear difference. Random forest uses a random sample to generate its decision. The sample that it learns from is therefore not always representative of the larger data set. The accuracy score will therefore reflect how different each group is.

I will also be generating a scatter plot of the mean entheseal scores of each individual for both Middenbeemster and Arnhem, to illustrate the range of the mean scores for each population. This will show whether the entire population in each settlement was engaging in equal amounts of labour, or if there are outliers. Outliers could be representative of a class hierarchy, as a small group of individuals that have low entheseal scores, are likely to not be performing regular intensive labour. Not performing labour is traditionally indicative of being from a higher class.

Analysis

The analysis of the results produced by the methods above will of course focus on the comparison between the two settlements and the two sexes examined. However, the effect of age will also be discussed, and the prevalence of bilateral asymmetry within the data will also be examined. The hope is that the effect of age will be minimised, however it is unlikely that it will be completely removed, and so it will be crucial to not only acknowledge the effect, but to investigate how it differs across the different entheses, settlements, and sexes. Bilateral asymmetry refers to the preference for one side of the body, left or right, otherwise known as handedness. This can be linked to specific tasks, and it is therefore important to investigate its prevalence within the data produced.

3. 2. 4. Ethical Considerations

When using human remains, certain ethical considerations must always be met, and this is of course the case for this thesis. In particular that the human remains are always treated with respect during the research carried out. During the data collection for this thesis, the skeletal materials will be treated with care and sensitivity at all times, always remembering that the skeletons examined were and are people. Following this, all rules and regulations set forth by the Leiden University Osteoarchaeology Lab and Leiden University will be followed, a long side the regulations set forth by international bodies such as the British Association for Biological Anthropology and Osteoarchaeology. Furthermore, the research method being used, Mariotti et al. (2007), only uses macroscopic investigation, which isa non-invasive method. This will prevent any further damage to the bones from both Middenbeemster and Arnhem collections.

To ensure that this research remains open to review and repeatable, all methods and decisions have been communicated in this chapter, and any limitations that are encountered will be detailed in Chapter 5. To further ensure this, the raw data collected will be included in the appendix (see Appendix A and B), allowing a full and complete understanding of the research process undertaken in this thesis.

4. Results

This chapter will present the data resulting from the methods discussed above. This will begin with a broad overall comparison of the two settlements, grouping the entheses into the functional complexes and comparing those. Each functional complex will then be investigated to see if and how each individual entheses varies between the two settlements, but also on the basis of bilateral asymmetry, sex and age.

4.1. Overall Comparison

To begin, the average mean scores for both Middenbeemster and Arnhem suggest that both populations consist of individuals who were consistently working. Middenbeemster has only four individuals that have an average score of less than 1.5, and Arnhem has only one (fig 4.1, 4.2). For Middenbeemster, the majority of individuals have a mean score of between 1.5 and 3 (fig 4.2), while for Arnhem, the majority have a mean score of between 1.5 and 3.5 (fig 4.2).

The overall mean scores for the entheses across the body and across both samples show that Arnhem had a higher entheseal change score for both sexes and age groups (fig 4.3, 4.4). It also illustrates that while there is a divide on the basis of sex for both settlements, it is not dramatic. Age does not appear to have dramatically affected the entheseal changes either, most likely due to the exclusion of Older Adults. The Arnhem female population appears to have a higher scores in general than both the female and male populations of Middenbeemster, but this score is never higher than their male counter parts. The female population of Middenbeemster has higher scores than their male counterparts in both forearm and foot functional complexes, however of both these differences are minimal.

Each functional complex will now be investigated to see in more detail how movement, and therefore how labour differed across age and sex for both populations. Random Forest for the overall comparison had an accuracy of 85%, which is reasonably accurate, and the highest accuracy managed by Random Forest in this thesis. It identifies the right interosseus membrane as the key entheseal change that differs between the two populations. It also identifies the *teres major*, both left and right, the left *brachioradialis*, and the left *deltoideus*. This would suggest that it is movements using the upper body that differ between the two settlements, as these entheses cover the forearm, elbow and shoulder functional complex. On the basis of sex however, Random Forest only produces a 55% accuracy rate, suggesting little difference on the basis of sex in either sample, however this could change when each functional complex is examined individually.

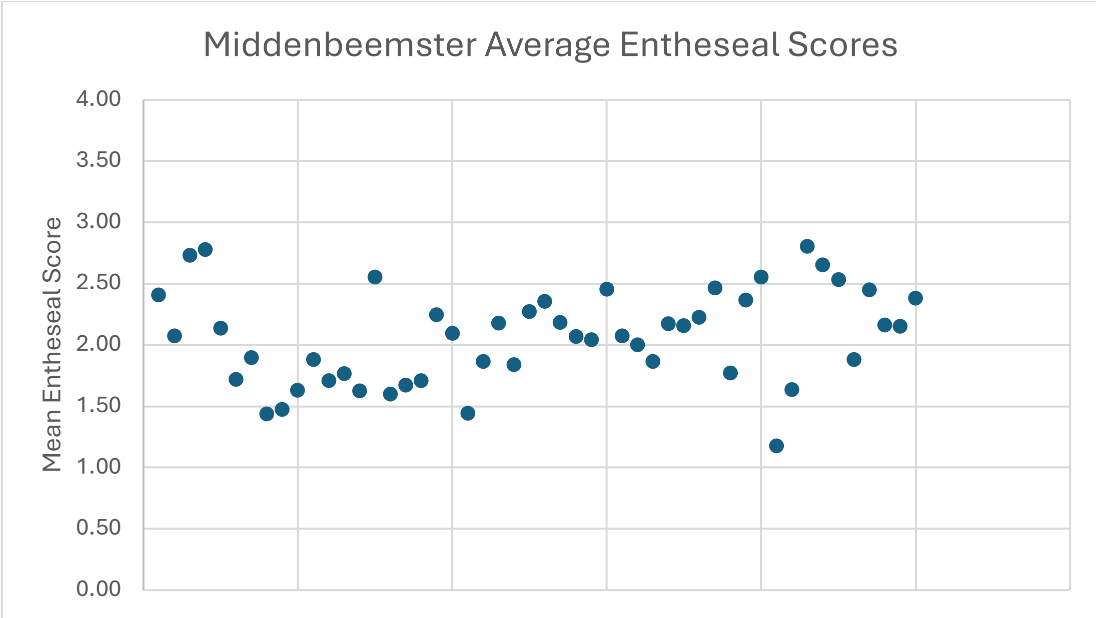

Fig 4.1- Scatter plot showing average entheseal scores for Middenbeemster

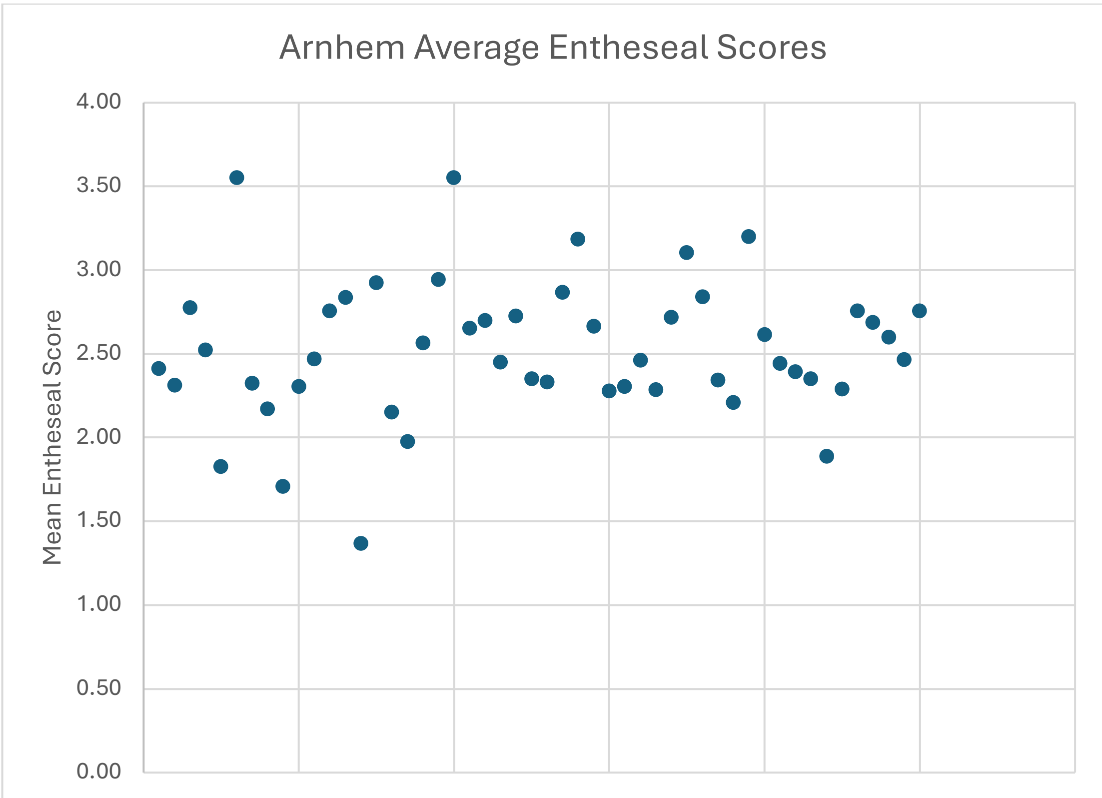

Fig 4.2- Scatter plot showing average entheseal scores for Arnhem

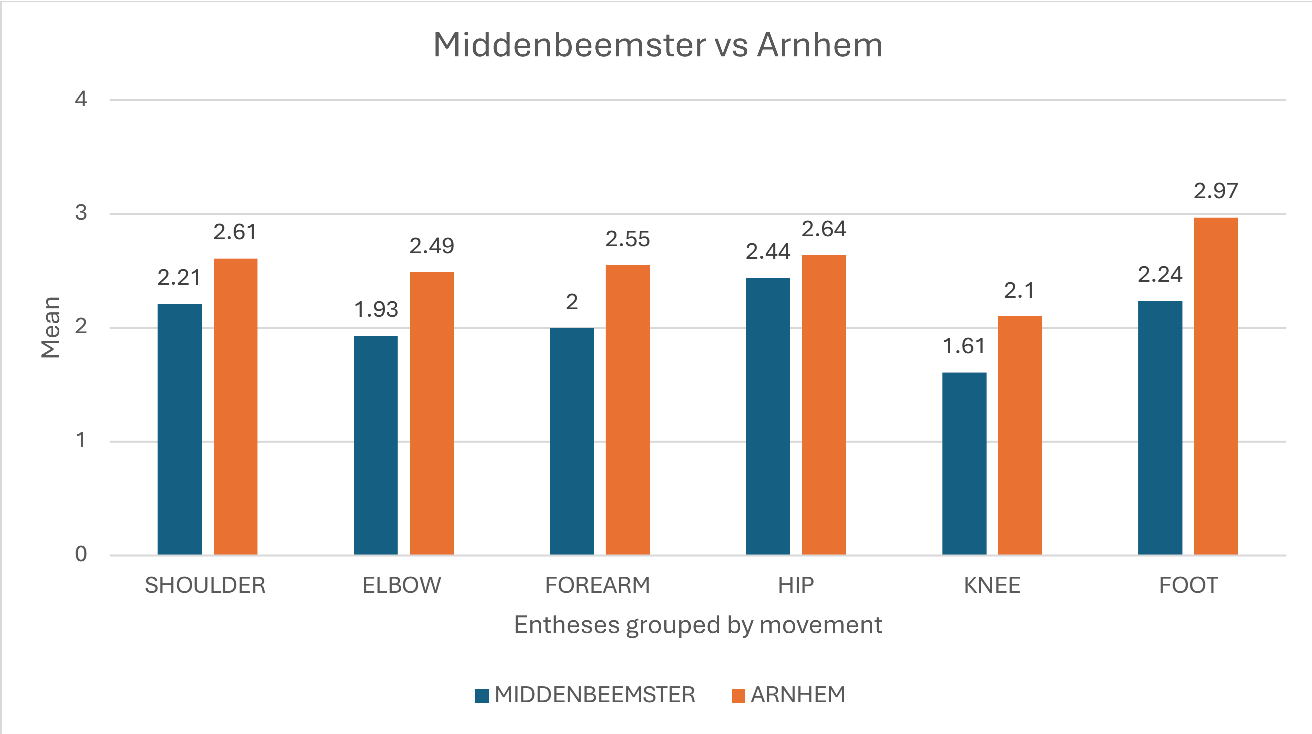

Fig 4.3- Bar chart showing the means of the different functional complexes, Middenbeemster vs Arnhem

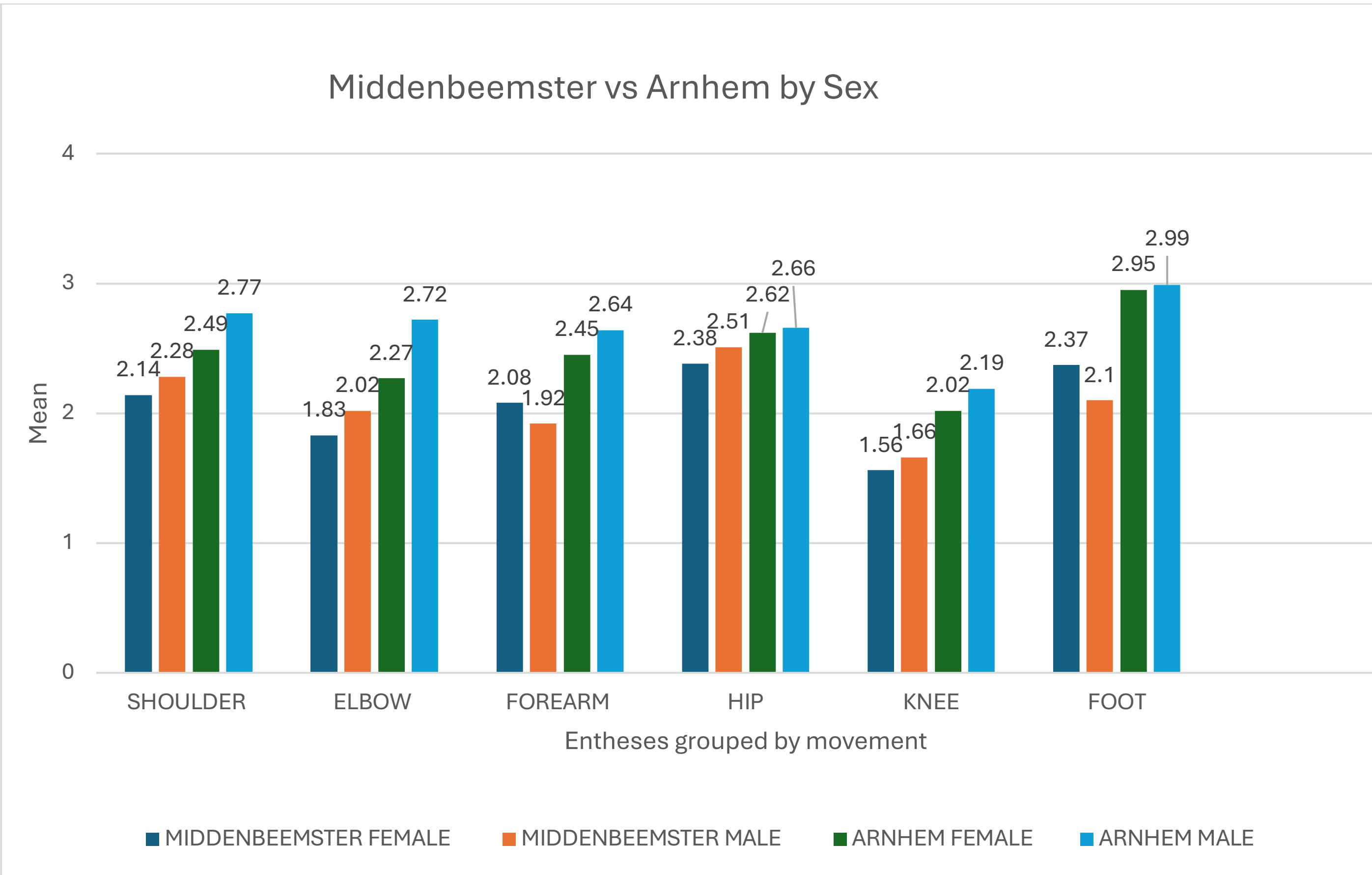

Fig 4.4- Bar chart showing the means of the different functional complexes, Middenbeemster vs Arnhem, divided by sex

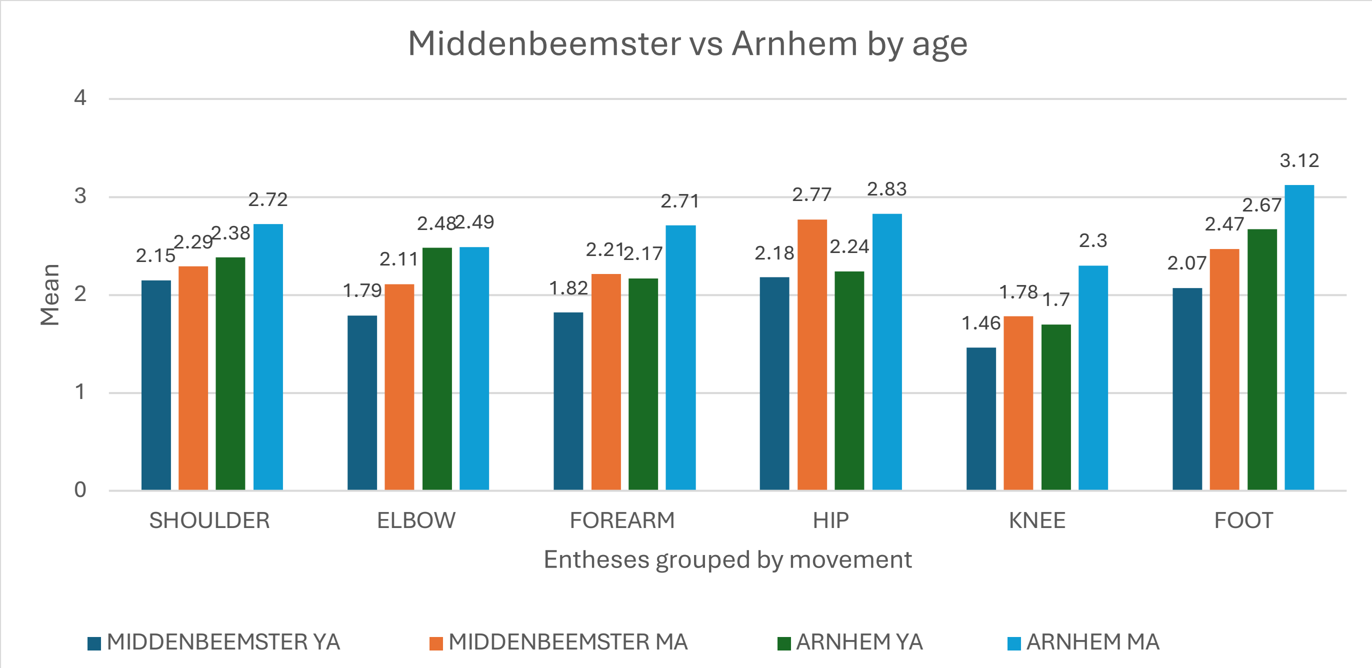

Fig 4.5 – Bar chart showing the means of the different functional complexes, Middenbeemster vs Arnhem

Feature	Importance
INTEROSSEUS MEMBRANE R	0.087
11 TERES MAJOR L	0.067
15 M. BRACHIORADIALIS L	0.057
8 M. DELTOIDEUS L	0.053
12 TERES MAJOR R	0.042

Table 3- Random forest generation of entheses most crucial for distinguishing between two populations

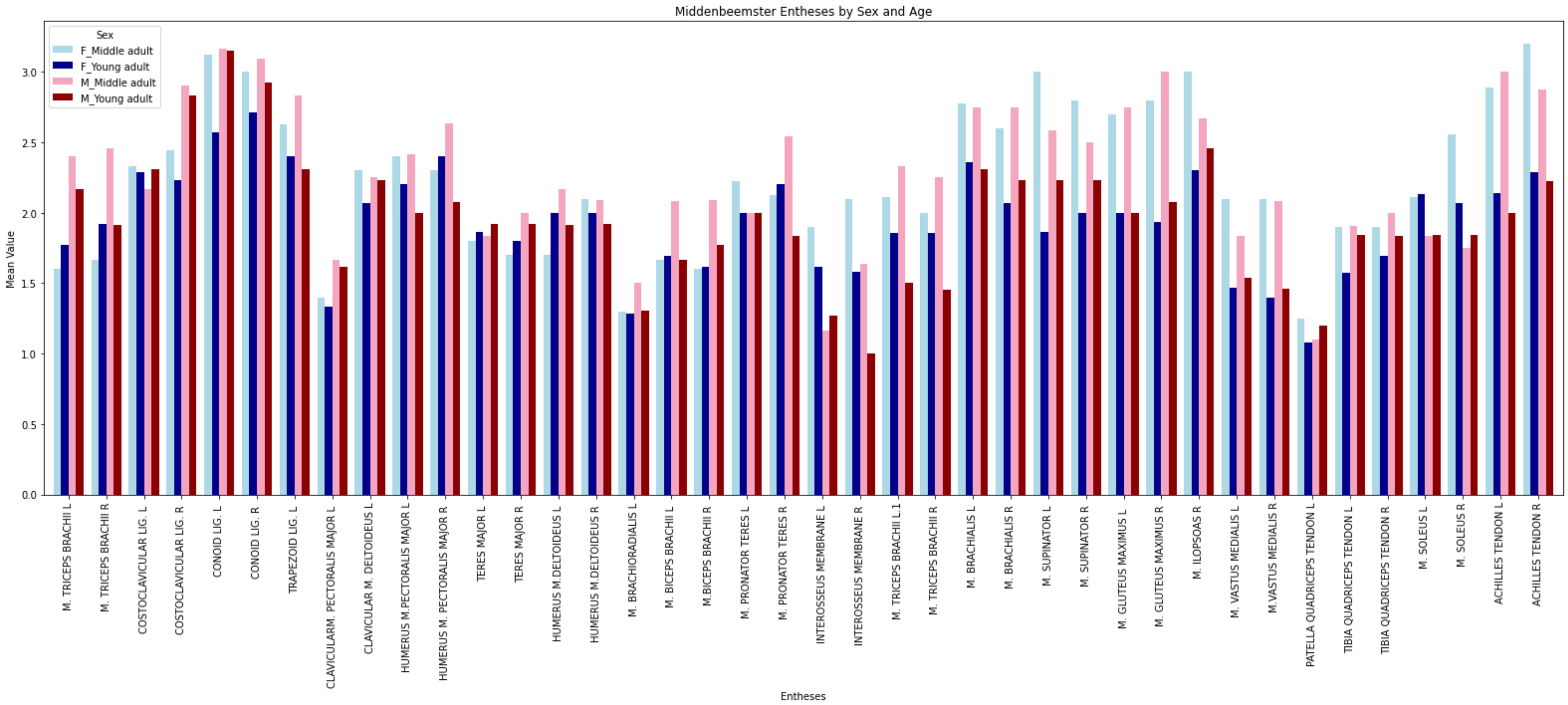

Fig 4.6- Bar chart showing the mean of Middenbeemster entheses, divided by sex and age

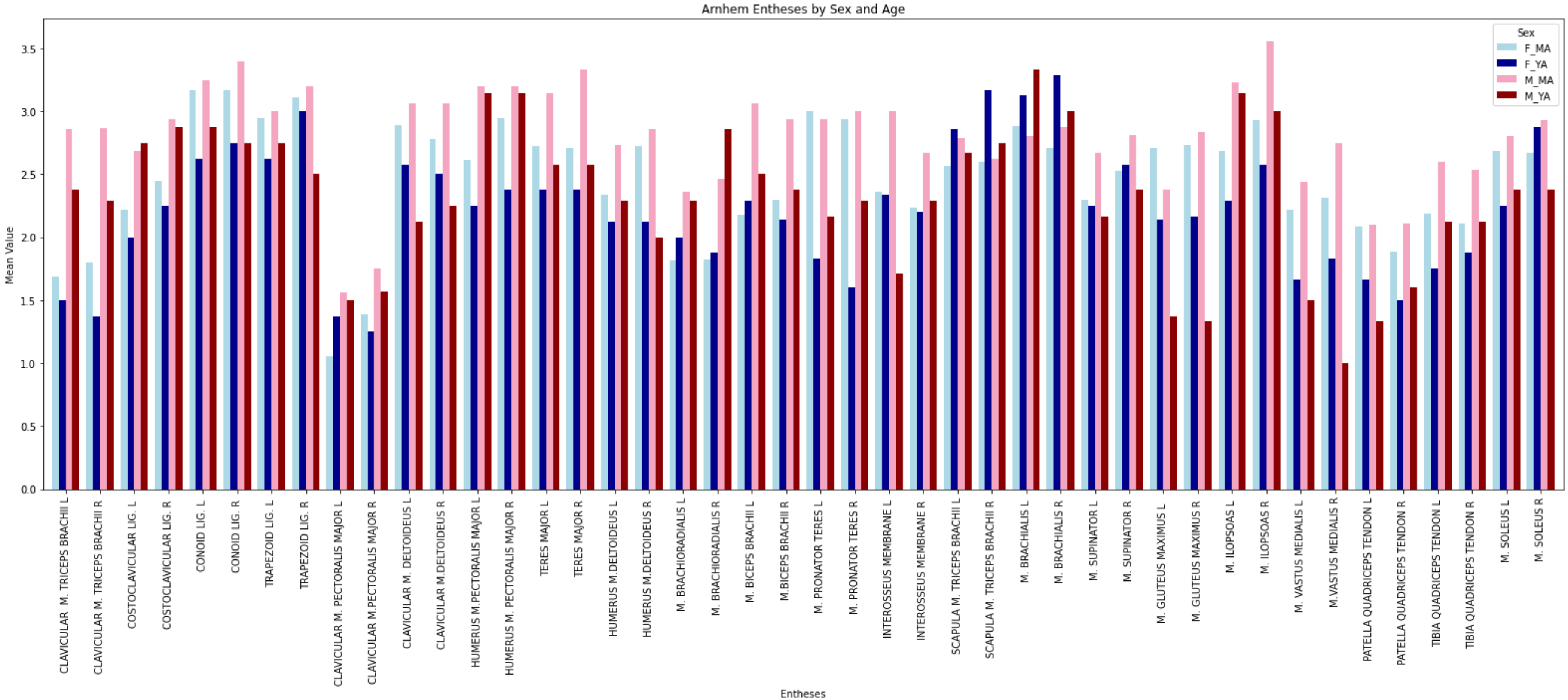

Fig 4.7- Bar chart showing the mean of Arnhem entheses, divided by sex and age

4. 2. Individual Entheses Results

4. 2.1. Handedness

The T-tests used present very little evidence for bilateral asymmetry in the results presented here. Middenbeemster only shows evidence of bilateral asymmetry with two entheses, the *achilles tendon* (0.031) and the *brachioradialis* (0.002). The results from the Arnhem sample only result in a statistical difference on the basis of handedness for three entheses; the *deltoideus* attachment on the humerus (0.033), the *pectoralis* attachment on the humerus (0.027) and the *supinator* entheses (0.018). Therefore, there appears to be some bilateral asymmetry in the movement produced by the foot and the elbow in Middenbeemster, and some bilateral asymmetry in the movement produced in the shoulder and forearm in Arnhem. However, overall bilateral asymmetry is not common in either population (4.35% in Middenbeemster and 8.70% for Arnhem) (see Tables 4 and 5).

Variable	t_stat	p_value	Comparison	Settlement	Functional Complex
COSTOCLAVICULAR LIG.	-1.372	0.117	Handedness	Middenbeemster	Shoulder
CONOID LIG.	0.467	0.642	Handedness	Middenbeemster	Shoulder
CLAVICLE M. PECTORALIS	-0.227	0.821	Handedness	Middenbeemster	Shoulder
CLAVICLE M. DELTOIDEUS	-0.184	0.855	Handedness	Middenbeemster	Shoulder
HUMERUS M. PECTORALIS	-1.769	0.083	Handedness	Middenbeemster	Shoulder
HUMERUS M. DELTOIDEUS	0.375	0.710	Handedness	Middenbeemster	Shoulder
TERES MAJOR	0.375	0.710	Handedness	Middenbeemster	Shoulder
TRAPEZOID	0.0	1.0	Handedness	Middenbeemster	Shoulder
SCAPULA M. TRICEPS BRACHII	0.227	0.822	Handedness	Middenbeemster	Elbow
M. BRACHIORADIALIS	-3.288	0.002	Handedness	Middenbeemster	Elbow
M. BICEPS BRACHII	-0.903	0.372	Handedness	Middenbeemster	Elbow
ULNA M. TRICEPS BRACHII	0.813	0.421	Handedness	Middenbeemster	Elbow
M. BRACHIALIS	1.288	0.204	Handedness	Middenbeemster	Elbow
M. PRONATOR TERES	-1.275	0.210	Handedness	Middenbeemster	Forearm
INTEROSSEUS MEMBRANE	-0.780	0.439	Handedness	Middenbeemster	Forearm
M. SUPINATOR	0.240	0.811	Handedness	Middenbeemster	Forearm
M. GLUTEUS MAXIMUS	-1.159	0.252	Handedness	Middenbeemster	Hip
M. ILOPSOAS	0.329	0.744	Handedness	Middenbeemster	Hip
M. VASTUS MEDIALIS	-0.299	0.766	Handedness	Middenbeemster	Knee
PATELLA QUADRICEPS TENDON	-1.139	0.263	Handedness	Middenbeemster	Knee
TIBIA QUADRICEPS TENDON	-1.000	0.323	Handedness	Middenbeemster	Knee
M. SOLEUS	-0.573	0.569	Handedness	Middenbeemster	Foot
ACHILLES TENDON	-2.249	0.031	Handedness	Middenbeemster	Foot

Table 4- T -tests for Middenbeemster entheses on the basis of handedness, with the statistically different entheses highlighted

Variable	t_stat	p_value	Comparison	Settlement	Functional Complex
COSTOCLAVICULAR LIG.	-1.596	0.117	Handedness	Arnhem	Shoulder
CONOID LIG.	-0.423	0.674	Handedness	Arnhem	Shoulder
CLAVICLE M. PECTORALIS	-2.274	0.027	Handedness	Arnhem	Shoulder
CLAVICLE M. DELTOIDEUS	0.423	0.674	Handedness	Arnhem	Shoulder
HUMERUS M. PECTORALIS	-2.197	0.033	Handedness	Arnhem	Shoulder
HUMERUS M. DELTOIDEUS	-2.668	0.011	Handedness	Arnhem	Shoulder
TERES MAJOR	-0.298	0.767	Handedness	Arnhem	Shoulder
TRAPEZOID	-1.062	0.294	Handedness	Arnhem	Shoulder
SCAPULA M. TRICEPS BRACHII	-0.374	0.710	Handedness	Arnhem	Elbow
M. BRACHIORADIALIS	0.255	0.800	Handedness	Arnhem	Elbow
M. BICEPS BRACHII	0.573	0.569	Handedness	Arnhem	Elbow
ULNA M. TRICEPS BRACHII	1.0	0.0	Handedness	Arnhem	Elbow
M. BRACHIALIS	0.530	0.599	Handedness	Arnhem	Elbow
M. PRONATOR TERES	0.298	0.767	Handedness	Arnhem	Forearm
INTEROSSEUS MEMBRANE	0.198	0.844	Handedness	Arnhem	Forearm
M. SUPINATOR	-2.453	0.018	Handedness	Arnhem	Forearm
M. GLUTEUS MAXIMUS	-1.959	0.058	Handedness	Arnhem	Hip
M. ILOPSOAS	-1.968	0.058	Handedness	Arnhem	Hip
M. VASTUS MEDIALIS	-0.829	0.412	Handedness	Arnhem	Knee
PATELLA QUADRICEPS TENDON	0.826	0.418	Handedness	Arnhem	Knee
TIBIA QUADRICEPS TENDON	0.330	0.743	Handedness	Arnhem	Knee
M. SOLEUS	-0.892	0.377	Handedness	Arnhem	Foot
ACHILLES TENDON	-1.882	0.070	Handedness	Arnhem	Foot

Table 5- T-tests for Arnhem entheses on the basis of handedness, with the statistically different entheses highlighted

4. 2. 2. Sex

Overall, the males produce higher entheseal scores than females, across both populations, however this is not always true for individual entheses across the functional complexes. Crucially, there are not always statistical differences between males and females across the board. The means of the entheseal scores within the shoulder, show female Young Adults having higher scores than male Young Adults for the humerus *pectoralis major*, the humerus *deltoideus* and the *trapezoid* entheses (fig 4.6). This does not however result in statistical differences, as the T tests show Middenbeemster in particular as having no statistical differences on the basis of sex for any of the entheses located in the shoulder functional complex (see Table 6). For Arnhem, males exhibit higher means for all the entheses in the shoulder, and results in statistical differences on the basis of sex, with both attachment sites for the left *pectoralis major* muscle, on the clavicle and humerus (0. 027 and 0.001, respectively), and the right *teres major* entheses all showing a statistical difference within the shoulder. When it comes to the elbow, there are more instances where females have a higher mean than males. The Middenbeemster sample shows female Young Adults having higher scores for the triceps brachii on the ulna (fig 4.6), however again this is not supported by the T-tests. The Middenbeemster sample, however, does show some statistical difference on the basis of sex, with the *triceps brachii* entheses on the left scapula

(0.024). Within the Arnhem sample, female Young Adults, also have a higher mean for the *triceps brachii* entheses on the ulna, and the right brachialis (fig 4.7) which again is not supported by the T-tests. Arnhem, however, again has more entheses that display a statistical difference on the basis of sex, with the left *biceps brachii* (0.007), right *brachioradialis* (0.010), and both *triceps brachii* entheses on the scapula (both 0.000) . Within the forearm, females have higher means than males for several entheses. For the Middenbeemster sample, female Middle Adults have higher scores than their male counterparts for the *supinator* and left *pronator teres* entheses (fig 4.6). The right pronator teres on the other hand, shows female Young Adults as having a higher mean entheseal score, and the interosseus membrane shows higher mean entheseal scores for both female age groups for their respective male counterparts (fig 4.6). However yet again this is not supported by the T-tests. For the forearm, the Middenbeemster sample, again has no entheses with statistical differences on the basis of sex (Table 6). However, neither does the Arnhem sample (Table 7). But the Arnhem sample, does show female Young Adults having a higher mean entheseal score for the right supinator (fig 4.7). It appears that movement constrained to the forearm functional complex does not differ on the basis of sex in either population.

For the lower body, Middenbeemster continues to lack entheses that differ on the basis of sex. Within the hip functional complex, Middenbeemster again has no entheses with a statistical difference on the basis of sex, but female Middle Adults exhibit a higher mean entheseal score for the right *iliopsoas* entheses. Arnhem, again, does have entheses that differ on the basis of sex, with the left *gluteus maximus* entheses (0.040), and both *iliopsoas* entheses (left, 0.006; right, 0.033), 3 out of 4 of the entheses studied within the hip functional complex (table 7). For once this appears to coincide with female Middle Adults having a higher mean entheseal score for the left *gluteus maximus* entheses (fig 4.7). For the knee functional complex, the left *vastus medialis* and the left patella *quadriceps tendon*, both show a higher mean entheseal score for female Middle Adults compared to male Middle Adults within the Middenbeemster sample (fig 4.6). For Arnhem, the *vastus medialis* and the left patella *quadriceps tendon* exhibits a higher mean entheseal score for female Young Adults (fig 4.7). This is again not reflected by the T-tests, as Middenbeemster again produces no entheses with a statistical difference on the basis of sex (table 6), while Arnhem produces two, both *quadriceps tendon* entheses on the tibia (left, 0.014; right, 0.43). For the foot, the soleus entheses exhibits a higher mean entheseal score for both female age groups compared to their male counterparts, and the right achilles tendon exhibits a higher score for female Middle Adults within the Middenbeemster sample (Table 6). This is at least in part supported by the T-test, as the right soleus entheses differs on the basis of sex in the Middenbeemster sample (0.041). Within the Arnhem sample, the right soleus and the right achilles exhibit a higher score for female Middle Adults, and the left achilles for female Young Adults (fig 4.7), however, has no entheses that statistically differ on the basis of sex for this functional complex.

Sex does not appear to dramatically affect the entheseal scores, at least in the case of Middenbeemster. Sex has a much more of an effect on the entheseal scores in Arnhem, suggesting that movement differed on the basis of sex dramatically more in Arnhem compared to Middenbeemster. Furthermore, when the female individuals have higher mean entheseal scores than male individuals, this does not, most of the time, result in statistical differences. The statistical differences mostly only occur when the male individuals have a higher mean score, suggesting not only is it more common that male individual will have a higher score, but that there is a larger gap between female and male entheseal scores when male individuals score higher.

Variable	t_stat	p_value	Comparison	Settlement	Functional Complex
CLAVICLE M. DELTOIDEUS L	-0.240	0.812	Sex	Middenbeemster	Shoulder
CLAVICLE M. PECTORALIS MAJOR L	-1.120	0.268	Sex	Middenbeemster	Shoulder
CLAVICLE M.DELTOIDEUS R	-1.069	0.291	Sex	Middenbeemster	Shoulder
CLAVICLE M.PECTORALIS MAJOR R	-0.496	0.622	Sex	Middenbeemster	Shoulder
CONOID LIG. L	-1.457	0.152	Sex	Middenbeemster	Shoulder
CONOID LIG. R	-0.715	0.479	Sex	Middenbeemster	Shoulder
COSTOCLAVICULAR LIG. L	0.176	0.861	Sex	Middenbeemster	Shoulder
COSTOCLAVICULAR LIG. R	-1.316	0.195	Sex	Middenbeemster	Shoulder
HUMERUS M. PECTORALIS MAJOR R	0.128	0.899	Sex	Middenbeemster	Shoulder
HUMERUS M.DELTOIDEUS L	-0.835	0.408	Sex	Middenbeemster	Shoulder
HUMERUS M.DELTOIDEUS R	0.200	0.842	Sex	Middenbeemster	Shoulder
HUMERUS M.PECTORALIS MAJOR L	0.408	0.685	Sex	Middenbeemster	Shoulder
TERES MAJOR L	-0.219	0.828	Sex	Middenbeemster	Shoulder
TERES MAJOR R	-1.026	0.310	Sex	Middenbeemster	Shoulder
TRAPEZOID LIG. L	-0.377	0.708	Sex	Middenbeemster	Shoulder
TRAPEZOID LIG. R	0.486	0.630	Sex	Middenbeemster	Shoulder
M.BICEPS BRACHII L	-0.710	0.482	Sex	Middenbeemster	Elbow
M.BRACHIALIS L	0.007	0.994	Sex	Middenbeemster	Elbow
M.BRACHIALIS R	-0.762	0.450	Sex	Middenbeemster	Elbow
M.BRACHIORADIALIS L	-0.467	0.643	Sex	Middenbeemster	Elbow
M.BRACHIORADIALIS R	-0.553	0.583	Sex	Middenbeemster	Elbow
SCAPULA M.TRICEPSBRACHII L	-2.347	0.024	Sex	Middenbeemster	Elbow
ULNA M.TRICEPSBRACHII L	0.008	0.994	Sex	Middenbeemster	Elbow
SCAPULA M.TRICEPSBRACHII R	-1.370	0.178	Sex	Middenbeemster	Elbow
ULNA M.TRICEPSBRACHII R	0.129	0.898	Sex	Middenbeemster	Elbow
M.BICEPS BRACHII R	-1.265	0.212	Sex	Middenbeemster	Elbow
INTEROSSEUS MEMBRANE L	1.654	0.105	Sex	Middenbeemster	Forearm
INTEROSSEUS MEMBRANE R	1.392	0.171	Sex	Middenbeemster	Forearm
M. PRONATOR TERES L	0.333	0.741	Sex	Middenbeemster	Forearm
M. PRONATOR TERES R	-0.025	0.980	Sex	Middenbeemster	Forearm
M. SUPINATOR L	-0.320	0.750	Sex	Middenbeemster	Forearm
M. SUPINATOR R	-0.189	0.852	Sex	Middenbeemster	Forearm
M. GLUTEUS MAXIMUS L	-0.365	0.717	Sex	Middenbeemster	Hip
M. GLUTEUS MAXIMUS R	-1.019	0.313	Sex	Middenbeemster	Hip
M. ILOPSOAS L	-0.480	0.634	Sex	Middenbeemster	Hip
M. ILOPSOAS R	0.209	0.836	Sex	Middenbeemster	Hip

M. VASTUS MEDIALIS L	0.172	0.864	Sex	Middenbeemster	Knee
M.VASTUS MEDIALIS R	-0.358	0.722	Sex	Middenbeemster	Knee
PATELLA QUADRICEPS TENDON L	-0.026	0.980	Sex	Middenbeemster	Knee
PATELLA QUADRICEPS TENDON R	-0.609	0.547	Sex	Middenbeemster	Knee
TIBIA QUADRICEPS TENDON L	-0.746	0.460	Sex	Middenbeemster	Knee
TIBIA QUADRICEPS TENDON R	-0.547	0.587	Sex	Middenbeemster	Knee
ACHILLES TENDON L	-0.047	0.963	Sex	Middenbeemster	Foot
ACHILLES TENDON R	0.410	0.684	Sex	Middenbeemster	Foot
M. SOLEUS L	1.341	0.186	Sex	Middenbeemster	Foot
M. SOLEUS R	2.097	0.041	Sex	Middenbeemster	Foot

Table 6- T-tests for Middenbeemster entheses on the basis of sex, with the statistically different entheses highlighted

Variable	t_stat	p_value	Comparison	Settlement	Functional Complex
CLAVICLE M. DELTOIDEUS L	0.242	0.810	Sex	Arnhem	Shoulder
CLAVICLE M. PECTORALIS MAJOR L	-2.279	0.027	Sex	Arnhem	Shoulder
CLAVICLE M.DELTOIDEUS R	-0.433	0.667	Sex	Arnhem	Shoulder
CLAVICLE M.PECTORALIS MAJOR R	-1.561	0.125	Sex	Arnhem	Shoulder
CONOID LIG. L	-0.617	0.540	Sex	Arnhem	Shoulder
CONOID LIG. R	-0.659	0.514	Sex	Arnhem	Shoulder
COSTOCLAVICULAR LIG. L	-1.642	0.107	Sex	Arnhem	Shoulder
COSTOCLAVICULAR LIG. R	-1.535	0.131	Sex	Arnhem	Shoulder
HUMERU S M.DELTOIDEUS R	-0.263	0.794	Sex	Arnhem	Shoulder
HUMERUS M. PECTORALIS MAJOR R	-1.976	0.054	Sex	Arnhem	Shoulder
HUMERUS M.DELTOIDEUS L	-1.412	0.165	Sex	Arnhem	Shoulder
HUMERUS M.PECTORALIS MAJOR L	-3.421	0.001	Sex	Arnhem	Shoulder
TERES MAJOR L	-1.603	0.116	Sex	Arnhem	Shoulder
TERES MAJOR R	-2.412	0.020	Sex	Arnhem	Shoulder
TRAPEZOID LIG. L	-0.344	0.733	Sex	Arnhem	Shoulder
TRAPEZOID LIG. R	0.422	0.675	Sex	Arnhem	Shoulder
M. BICEPS BRACHII L	-2.832	0.007	Sex	Arnhem	Elbow
M. BRACHIALIS L	0.038	0.970	Sex	Arnhem	Elbow
M. BRACHIALIS R	-0.190	0.850	Sex	Arnhem	Elbow
M. BRACHIORADIALIS L	-1.378	0.175	Sex	Arnhem	Elbow
M. BRACHIORADIALIS R	-2.702	0.010	Sex	Arnhem	Elbow
SCAPULA M. TRICEPS BRACHII L	-4.457	0.000	Sex	Arnhem	Elbow
ULNA M. TRICEPS BRACHII L	-0.427	0.671	Sex	Arnhem	Elbow
SCAPULA M. TRICEPS BRACHII R	-4.441	0.000	Sex	Arnhem	Elbow
ULNA M. TRICEPS BRACHII R	0.417	0.679	Sex	Arnhem	Elbow
M.BICEPS BRACHII R	-1.931	0.060	Sex	Arnhem	Elbow
INTEROSSEUS MEMBRANE L	-0.766	0.448	Sex	Arnhem	Forearm
INTEROSSEUS MEMBRANE R	-1.099	0.279	Sex	Arnhem	Forearm
M. PRONATOR TERES L	-0.156	0.877	Sex	Arnhem	Forearm
M. PRONATOR TERES R	-0.470	0.641	Sex	Arnhem	Forearm
M. SUPINATOR L	-1.109	0.274	Sex	Arnhem	Forearm
M. SUPINATOR R	-0.636	0.528	Sex	Arnhem	Forearm
M. GLUTEUS MAXIMUS L	2.113	0.040	Sex	Arnhem	Hip
M. GLUTEUS MAXIMUS R	0.865	0.392	Sex	Arnhem	Hip

M. ILOPSOAS L	-2.911	0.006	Sex	Arnhem	Hip
M. ILOPSOAS R	-2.219	0.033	Sex	Arnhem	Hip
M. VASTUS MEDIALIS L	-0.150	0.881	Sex	Arnhem	Knee
M.VASTUS MEDIALIS R	0.045	0.964	Sex	Arnhem	Knee
PATELLA QUADRICEPS TENDON L	0.365	0.717	Sex	Arnhem	Knee
PATELLA QUADRICEPS TENDON R	-0.500	0.621	Sex	Arnhem	Knee
TIBIA QUADRICEPS TENDON L	-2.545	0.014	Sex	Arnhem	Knee
TIBIA QUADRICEPS TENDON R	-2.084	0.043	Sex	Arnhem	Knee
ACHILLES TENDON L	0.570	0.573	Sex	Arnhem	Foot
ACHILLES TENDON R	-0.109	0.914	Sex	Arnhem	Foot
M. SOLEUS L	-0.441	0.661	Sex	Arnhem	Foot
M. SOLEUS R	-0.037	0.971	Sex	Arnhem	Foot

Table 7- T- tests for Arnhem entheses on the basis of sex, with the statistically different entheses highlighted

4. 2. 3. Age

There is a clear progression on the basis of age. Across both populations, and functional complexes, the older group (Middle Adults) tend to have higher average entheseal scores (fig 4.6, fig 4.7). However, there is not always a statistical difference on the basis of age across the functional complexes for either populations. Within the shoulder, like with sex, Middenbeemster exhibits no entheses with statistical differences on the basis of age (table 8). Again, Arnhem exhibits more entheses with statistical differences; the *deltoideus* (left, 0.003; right 0.026) and *conoid* ligament on both clavicles (left, 0.033; right, 0.015) and the *pectoralis major* (0.003) and *teres major* (0.018) on the right humerus. This theme does not continue with the elbow, with Middenbeemster exhibiting three entheses (and the right *brachialis* entheses, the right *brachioradialis* entheses and the *triceps brachii* on the left ulna, see Table 8), and Arnhem with two (both *triceps brachii* entheses on the scapula, see table 9). For the forearm, the supinator entheses (left, 0.002; right, 0.011) differ on the basis of age for Middenbeemster, and the *pronator teres* (left, 0.003; right 0.003)for Arnhem.

For the hip, the gluteus maximus entheses differ on the basis of age for both populations (Tables 8, 9). For the knee, the vastus medialis entheses also differs on basis of age for both populations (Tables 8, 9), and the left quadriceps tendon entheses on the tibia differs on the basis of age for Arnhem (0.008) . For the foot, the achilles tendon, both left (0.006) and right (0.014), differs on the basis of age for Middenbeemster, but only the right achilles tendon differs on the basis of age for Arnhem (0.000).

Unlike with sex, there is not one population that is more affected by age; however, it clearly is a prominent factor in entheseal development, across both populations, and all functional complexes.

Variable	t_stat	p_value	Comparison	Settlement	Functional Complex
CLAVICLE M. DELTOIDEUS L	0.780	0.439	Age group	Middenbeemster	Shoulder
CLAVICLE M. PECTORALIS MAJOR L	0.412	0.682	Age group	Middenbeemster	Shoulder
CLAVICLE M.DELTOIDEUS R	0.949	0.348	Age group	Middenbeemster	Shoulder
CLAVICLE M.PECTORALIS MAJOR R	0.455	0.651	Age group	Middenbeemster	Shoulder
CONOID LIG. L	1.100	0.277	Age group	Middenbeemster	Shoulder
CONOID LIG. R	0.960	0.342	Age group	Middenbeemster	Shoulder
COSTOCLAVICULAR LIG. L	-0.257	0.799	Age group	Middenbeemster	Shoulder
COSTOCLAVICULAR LIG. R	0.335	0.739	Age group	Middenbeemster	Shoulder
HUMERUS M. PECTORALIS MAJOR R	0.942	0.351	Age group	Middenbeemster	Shoulder
HUMERUS M.DELTOIDEUS L	-0.053	0.958	Age group	Middenbeemster	Shoulder
HUMERUS M.DELTOIDEUS R	0.659	0.513	Age group	Middenbeemster	Shoulder
HUMERUS M.PECTORALIS MAJOR L	1.398	0.169	Age group	Middenbeemster	Shoulder
TERES MAJOR L	-0.193	0.848	Age group	Middenbeemster	Shoulder
TERES MAJOR R	0.215	0.830	Age group	Middenbeemster	Shoulder
TRAPEZOID LIG. L	1.851	0.071	Age group	Middenbeemster	Shoulder
TRAPEZOID LIG. R	0.701	0.487	Age group	Middenbeemster	Shoulder
M.BICEPS BRACHII L	0.825	0.414	Age-group	Middenbeemster	Elbow
M.BRACHIALIS L	1.830	0.074	Age-group	Middenbeemster	Elbow
M.BRACHIALIS R	2.246	0.029	Age-group	Middenbeemster	Elbow
M.BRACHIORADIALIS L	0.484	0.631	Age-group	Middenbeemster	Elbow
M.BRACHIORADIALIS R	2.101	0.041	Age-group	Middenbeemster	Elbow
SCAPULA M.TRICEPSBRACHII L	0.152	0.880	Age-group	Middenbeemster	Elbow
ULNA M.TRICEPS BRACHII L	2.168	0.036	Age-group	Middenbeemster	Elbow
SCAPULA M.TRICEPSBRACHII R	0.678	0.501	Age-group	Middenbeemster	Elbow
ULNA M.TRICEPSBRACHII R	1.800	0.079	Age-group	Middenbeemster	Elbow
M.BICEPS BRACHII R	0.665	0.509	Age-group	Middenbeemster	Elbow
INTEROSSEUS MEMBRANE L	0.128	0.899	Age group	Middenbeemster	Forearm
INTEROSSEUS MEMBRANE R	1.528	0.134	Age group	Middenbeemster	Forearm
M. PRONATOR TERES L	0.302	0.764	Age group	Middenbeemster	Forearm
M. PRONATOR TERES R	1.290	0.205	Age group	Middenbeemster	Forearm
M. SUPINATOR L	3.228	0.002	Age group	Middenbeemster	Forearm
M. SUPINATOR R	2.640	0.011	Age group	Middenbeemster	Forearm
M. GLUTEUS MAXIMUS L	3.740	0.0005	Age group	Middenbeemster	Hip
M. GLUTEUS MAXIMUS R	4.530	0.00004	Age group	Middenbeemster	Hip
M. ILOPSOAS L	0.632	0.531	Age group	Middenbeemster	Hip
M. ILOPSOAS R	1.385	0.174	Age group	Middenbeemster	Hip
M. VASTUS MEDIALIS L	2.020	0.049	Age group	Middenbeemster	Knee
M.VASTUS MEDIALIS R	3.242	0.002	Age group	Middenbeemster	Knee
PATELLA QUADRICEPS TENDON L	0.129	0.898	Age group	Middenbeemster	Knee
PATELLA QUADRICEPS TENDON R	1.185	0.244	Age group	Middenbeemster	Knee
TIBIA QUADRICEPS TENDON L	0.895	0.376	Age group	Middenbeemster	Knee
TIBIA QUADRICEPS TENDON R	0.795	0.431	Age group	Middenbeemster	Knee
ACHILLES TENDON L	2.875	0.006	Age group	Middenbeemster	Foot
ACHILLES TENDON R	2.579	0.014	Age group	Middenbeemster	Foot
M. SOLEUS L	-0.218	0.829	Age group	Middenbeemster	Foot
M. SOLEUS R	0.580	0.565	Age group	Middenbeemster	Foot

Table 8- T-tests for Middenbeemster entheses on the basis of age, with the statistically different entheses highlighted

Variable	t_stat	p_value	Comparison	Settlement	Functional Complex
CLAVICLE M. DELTOIDEUS L	3.128	0.003	Age group	Arnhem	Shoulder
CLAVICLE M. PECTORALIS MAJOR L	-0.752	0.456	Age group	Arnhem	Shoulder
CLAVICLE M.DELTOIDEUS R	2.298	0.026	Age group	Arnhem	Shoulder
CLAVICLE M.PECTORALIS MAJOR R	0.642	0.524	Age group	Arnhem	Shoulder
CONOID LIG. L	2.193	0.033	Age group	Arnhem	Shoulder
CONOID LIG. R	2.534	0.015	Age group	Arnhem	Shoulder
COSTOCLAVICULAR LIG. L	0.178	0.859	Age group	Arnhem	Shoulder
COSTOCLAVICULAR LIG. R	0.300	0.765	Age group	Arnhem	Shoulder
HUMERUS M. PECTORALIS MAJOR R	3.105	0.003	Age group	Arnhem	Shoulder
HUMERUS M.DELTOIDEUS L	1.431	0.159	Age group	Arnhem	Shoulder
HUMERUS M.DELTOIDEUS R	1.283	0.206	Age group	Arnhem	Shoulder
HUMERUS M.PECTORALIS MAJOR L	0.892	0.377	Age group	Arnhem	Shoulder
TERES MAJOR L	1.989	0.053	Age group	Arnhem	Shoulder
TERES MAJOR R	2.453	0.018	Age group	Arnhem	Shoulder
TRAPEZOID LIG. L	1.309	0.197	Age group	Arnhem	Shoulder
TRAPEZOID LIG. R	1.343	0.186	Age group	Arnhem	Shoulder
M.BICEPS BRACHII L	0.753	0.455	Age group	Arnhem	Elbow
M.BRACHIALIS L	-1.780	0.082	Age group	Arnhem	Elbow
M.BRACHIALIS R	-1.497	0.141	Age group	Arnhem	Elbow
M.BRACHIORADIALIS L	-0.185	0.854	Age group	Arnhem	Elbow
M.BRACHIORADIALIS R	-0.653	0.517	Age group	Arnhem	Elbow
SCAPULA M.TRICEPSBRACHII L	0.998	0.323	Age group	Arnhem	Elbow
ULNA M.TRICEPSBRACHII L	-0.413	0.682	Age group	Arnhem	Elbow
SCAPULA M.TRICEPSBRACHII R	1.868	0.069	Age group	Arnhem	Elbow
ULNA M.TRICEPSBRACHII R	-1.305	0.199	Age group	Arnhem	Elbow
M.BICEPS BRACHII R	1.187	0.242	Age group	Arnhem	Elbow
INTEROSSEUS MEMBRANE L	1.984	0.054	Age group	Arnhem	Forearm
INTEROSSEUS MEMBRANE R	0.664	0.511	Age group	Arnhem	Forearm
M. PRONATOR TERES L	3.332	0.002	Age group	Arnhem	Forearm
M. PRONATOR TERES R	3.217	0.003	Age group	Arnhem	Forearm
M. SUPINATOR L	1.068	0.291	Age group	Arnhem	Forearm
M. SUPINATOR R	0.949	0.348	Age group	Arnhem	Forearm
M. GLUTEUS MAXIMUS L	3.397	0.001	Age group	Arnhem	Hip
M. GLUTEUS MAXIMUS R	4.143	0.0002	Age group	Arnhem	Hip
M. ILOPSOAS L	0.858	0.396	Age group	Arnhem	Hip
M. ILOPSOAS R	1.620	0.114	Age group	Arnhem	Hip
M. VASTUS MEDIALIS L	2.645	0.011	Age group	Arnhem	Knee
M.VASTUS MEDIALIS R	3.426	0.001	Age group	Arnhem	Knee
PATELLA QUADRICEPS TENDON L	1.626	0.114	Age group	Arnhem	Knee
PATELLA QUADRICEPS TENDON R	1.151	0.260	Age group	Arnhem	Knee
TIBIA QUADRICEPS TENDON L	2.795	0.008	Age group	Arnhem	Knee
TIBIA QUADRICEPS TENDON R	1.655	0.104	Age group	Arnhem	Knee
ACHILLES TENDON L	1.841	0.075	Age group	Arnhem	Foot
ACHILLES TENDON R	4.589	0.000	Age group	Arnhem	Foot
M. SOLEUS L	1.671	0.102	Age group	Arnhem	Foot
M. SOLEUS R	0.678	0.501	Age group	Arnhem	Foot

Table 9- T- tests for Arnhem entheses on the basis of age, with the statistically different entheses highlighted

4. 2. 4. Rural vs Urban

As has been mentioned previously, Arnhem produces higher scores than Middenbeemster and this does not change when each functional complex is examined. The T- tests used to establish whether there was a statistical difference in the basis of urban vs rural settlement, overall produces much more entheses with statistical differences than with sex or age. For the shoulder, there appears to be a significant difference in the use of the *deltoideus* muscles, as all four entheses associated with it differ (see Table 10). The *pectoralis major* entheses on the humerus (both 0.000) and the *teres major* entheses (both 0.000), also exhibit a statistical difference between the two populations. This theme continues with the elbow, as only the *triceps brachii* entheses on the scapula do not differ on the basis of settlement type (see Table 10). The forearm functional complex has less entheses that differ on the basis of settlement type, however the *pronator teres* (left, 0.000; right, 0.001) and the *interosseous membrane* entheses (left, 0.003; right, 0.015) both show a statistical difference. This coincides with the Random forest test performed that identified the interosseous membrane as the entheses that differed between the two populations the most.

The lower body is no different, the majority of entheses differing on the basis of settlement type. For the hip, the right iliopsoas entheses differs (0.037), for the knee, all of the entheses differ on the basis of settlement type, and the same is true for the foot (see Table 10). Overall, the T-tests for settlement type, suggest that the two settlements are highly statistically different, suggesting a definite difference in the movement and labour performed by the two populations.

The Random forest tests performed however, do not agree across the board. For the upper body, Random forest is able to distinguish much more easily between the two populations. It identifies the *teres major* entheses as the main entheses that differs between the two populations, with an accuracy rate of 80% for the shoulder functional complex. For the elbow functional complex, it does not perform as well, only producing an accuracy rate of 65% and naming the *triceps brachii* entheses as the principally differing entheses. However, it goes downhill from here, with none of the other entheses resulting in more than a 55% accuracy rate for Random Forest. It is within the forearm functional complex that the interosseous membrane entheses is located, which is identified as the most relevant entheses for differing between the two populations. However, when only focusing on the functional complex, Random Forest only produces an accuracy of 55%, suggesting that it cannot tell the two populations apart on the forearm alone. The lack of accuracy for the functional complexes other than the shoulder and the elbow, directly contradict the T-test results, especially for the lower body, for which the majority of entheses as statistically different on the basis of settlement type.

Variable	t_stat	p_value	Comparison	Functional Complex
CLAVICLE M. DELTOIDEUS L	-0.599282	0.550	Settlement	Shoulder
CLAVICLE M. PECTORALIS MAJOR L	-0.181134	0.857	Settlement	Shoulder
CLAVICLE M.DELTOIDEUS R	-0.488168	0.627	Settlement	Shoulder
CLAVICLE M.PECTORALIS MAJOR R	-1.186004	0.239	Settlement	Shoulder
CONOID LIG. L	-2.432419	0.017	Settlement	Shoulder
CONOID LIG. R	-2.838636	0.006	Settlement	Shoulder
COSTOCLAVICULAR LIG. L	1.042	2.998	Settlement	Shoulder
COSTOCLAVICULAR LIG. R	0.000	1.000	Settlement	Shoulder
HUMERUS M. PECTORALIS MAJOR R	-3.128	0.002	Settlement	Shoulder
HUMERUS M.DELTOIDEUS L	-2.553	0.012	Settlement	Shoulder
HUMERUS M.DELTOIDEUS R	-3.909	0.000	Settlement	Shoulder
HUMERUS M.PECTORALIS MAJOR L	-4.108	0.000	Settlement	Shoulder
TERES MAJOR L	-6.519	0.000	Settlement	Shoulder
TERES MAJOR R	-6.763	0.000	Settlement	Shoulder
TRAPEZOID LIG. L	-3.057	0.003	Settlement	Shoulder
TRAPEZOID LIG. R	-3.609	0.0005	Settlement	Shoulder
M.BICEPS BRACHII L	-0.797	0.427	Settlement	Elbow
M.BRACHIALIS L	-0.816	0.417	Settlement	Elbow
M.BRACHIALIS R	-3.701	0.000	Settlement	Elbow
M.BRACHIORADIALIS L	-2.744	0.007	Settlement	Elbow
M.BRACHIORADIALIS R	-4.109	0.000	Settlement	Elbow
SCAPULA M.TRICEPSBRACHII L	-4.053	0.000	Settlement	Elbow
ULNA M.TRICEPSBRACHII L	-4.352	0.000	Settlement	Elbow
SCAPULA M.TRICEPSBRACHII R	-4.697	0.000	Settlement	Elbow
ULNA M.TRICEPSBRACHII R	-2.812	0.006	Settlement	Elbow
M.BICEPS BRACHII R	-3.094	0.003	Settlement	Elbow
INTEROSSEUS MEMBRANE L	-3.095	0.003	Settlement	Forearm
INTEROSSEUS MEMBRANE R	-2.497	0.015	Settlement	Forearm
M. PRONATOR TERES L	-4.351	0.000	Settlement	Forearm
M. PRONATOR TERES R	-3.478	0.001	Settlement	Forearm
M. SUPINATOR L	-0.188	0.851	Settlement	Forearm
M. SUPINATOR R	-1.835	0.070	Settlement	Forearm
M. GLUTEUS MAXIMUS L	0.173	0.863	Settlement	Hip
M. GLUTEUS MAXIMUS R	-0.342	0.733	Settlement	Hip
M. ILOPSOAS L	-1.702	0.093	Settlement	Hip
M. ILOPSOAS R	-2.124	0.037	Settlement	Hip
M. VASTUS MEDIALIS L	-2.263	0.026	Settlement	Knee
M.VASTUS MEDIALIS R	-2.374	0.020	Settlement	Knee
PATELLA QUADRICEPS TENDON L	-3.321	0.001	Settlement	Knee
PATELLA QUADRICEPS TENDON R	-2.351	0.022	Settlement	Knee
TIBIA QUADRICEPS TENDON L	-3.195	0.002	Settlement	Knee
TIBIA QUADRICEPS TENDON R	-2.373	0.020	Settlement	Knee
ACHILLES TENDON L	-3.768	0.000	Settlement	Foot
ACHILLES TENDON R	-4.528	0.000	Settlement	Foot
M. SOLEUS L	-3.988	0.000	Settlement	Foot
M. SOLEUS R	-4.347	0.000	Settlement	Foot

Table 10- T-test results comparing Middenbeemster and Arnhem entheses, with the statistically different entheses highlighted

Middenbeemster Female Population vs Arnhem Female Population

As is illustrated in table 11, the female populations of Middenbeemster and Arnhem statistically differ on several entheses. Within the shoulder functional complex, the *teres major* entheses (left, 0.002; right, 0.000) and *deltoideus* on the clavicle (left, 0.019; right, 0.032), both differ on a statistically level, with the p- values of the former suggesting a very high level of difference between the two populations. Crucially there are several entheses within the shoulder functional complex that only differ on one side of the body. Only the right *deltoideus* on the humerus (0.017) and *trapezoid* ligament (0.04). In both of these cases the respective left entheses is close to or on the cusp of being statistically different, so this may not represent a clear case of difference in bilateral asymmetry between the two populations. Within the elbow functional complex there is a total of five entheses with a statistical difference. This includes both of the triceps brachii entheses on the ulna (left, 0.002; right, 0.001); and both of *biceps brachii* entheses (left, 0.027; right, 0.01). The right brachialis also differs in a statistical level (0.015), and again the counterpart left entheses is close to being statistically relevant.

The forearm and hip functional complexes however do not differ at all between the female populations of the two settlements. The lower body does show statistical differences in the knee and foot entheses with both the *quadriceps tendon* entheses on the patella (left, 0.005; right, 0.009), the right *vastus medialis* (0.037), the left *achilles tendon* (0.001) and the right *soleus* entheses (0.027). Like in the upper body, any entheses that is only statistically relevant on one side of the body, the respective entheses is close to being relevant.

Variable	t-stat	p-value	Comparison	Functional Complex
CLAVICLE M. DELTOIDEUS L	-2.423	0.019	Settlement	Shoulder
CLAVICLE M. PECTORALIS MAJOR L	0.954	0.345	Settlement	Shoulder
CLAVICLE M.DELTOIDEUS R	-2.213	0.032	Settlement	Shoulder
CLAVICLE M.PECTORALIS MAJOR R	0.391	0.698	Settlement	Shoulder
CONOID LIG. L	-0.843	0.404	Settlement	Shoulder
CONOID LIG. R	-0.869	0.389	Settlement	Shoulder
COSTOCLAVICULAR LIG. L	0.418	0.678	Settlement	Shoulder
COSTOCLAVICULAR LIG. R	-0.173	0.863	Settlement	Shoulder
HUMERUS M. PECTORALIS MAJOR R	-2.162	0.036	Settlement	Shoulder
HUMERUS M.DELTOIDEUS L	-1.917	0.061	Settlement	Shoulder
HUMERUS M.DELTOIDEUS R	-2.471	0.017	Settlement	Shoulder
HUMERUS M.PECTORALIS MAJOR L	-1.313	0.195	Settlement	Shoulder
TERES MAJOR L	-3.996	0.0002	Settlement	Shoulder
TERES MAJOR R	-5.056	0.000	Settlement	Shoulder
TRAPEZOID LIG. L	-2.117	0.085	Settlement	Shoulder
TRAPEZOID LIG. R	-2.117	0.04	Settlement	Shoulder
M.BICEPS BRACHII L	-2.289	0.027	Settlement	Elbow
M.BRACHIALIS L	-1.857	0.07	Settlement	Elbow
M.BRACHIALIS R	-2.52	0.015	Settlement	Elbow

M.BRACHIORADIALIS L	-1.987	0.053	Settlement	Elbow
M.BRACHIORADIALIS R	-0.916	0.364	Settlement	Elbow
SCAPULA M.TRICEPS BRACHII L	0.378	0.707	Settlement	Elbow
ULNA M.TRICEPS BRACHII L	-3.323	0.002	Settlement	Elbow
SCAPULA M.TRICEPSBRACHII R	0.806	0.424	Settlement	Elbow
ULNA M.TRICEPSBRACHII R	-3.614	0.001	Settlement	Elbow
M.BICEPS BRACHII R	-2.693	0.01	Settlement	Elbow
INTEROSSEUS MEMBRANE L	1.792	0.081	Settlement	Forearm
INTEROSSEUS MEMBRANE R	1.026	0.312	Settlement	Forearm
M. PRONATOR TERES L	1.956	0.058	Settlement	Forearm
M. PRONATOR TERES R	1.528	0.135	Settlement	Forearm
M. SUPINATOR L	0.172	0.864	Settlement	Forearm
M. SUPINATOR R	1.099	0.277	Settlement	Forearm
M. GLUTEUS MAXIMUS L	1.208	0.233	Settlement	Hip
M. GLUTEUS MAXIMUS R	1.230	0.225	Settlement	Hip
M. ILOPSOAS L	0.429	0.670	Settlement	Hip
M. ILOPSOAS R	0.565	0.576	Settlement	Hip
M. VASTUS MEDIALIS L	1.435	0.158	Settlement	Knee
M.VASTUS MEDIALIS R	-2.149	0.037	Settlement	Knee
PATELLA QUADRICEPS TENDON L	-3.005	0.005	Settlement	Knee
PATELLA QUADRICEPS TENDON R	2.757	0.009	Settlement	Knee
TIBIA QUADRICEPS TENDON L	1.963	0.056	Settlement	Knee
TIBIA QUADRICEPS TENDON R	1.410	0.165	Settlement	Knee
ACHILLES TENDON L	3.411	0.001	Settlement	Foot
ACHILLES TENDON R	1.826	0.077	Settlement	Foot
M. SOLEUS L	1.831	0.074	Settlement	Foot
M. SOLEUS R	2.325	0.024	Settlement	Foot

Table 11- T-tests results comparing the female populations of Middenbeemster and Arnhem, with the statistically different entheses highlighted

Middenbeemster Male Population vs Arnhem Male Population

Just like the female population, the male populations of the two settlements differ significantly on several entheses, but unlike the female population, they differ across all of the functional complexes. The deltoideus on the humerus (left, 0.016; right, 0.16) and the teres major differ on a statistical level, just like between the two female populations, however the pectoralis entheses also both differ (left, 0.000, right 0.000). Similarly to the female populations, the male populations also differ statistically within the elbow functional complex; with both triceps brachii entheses on the ulna (left, 0.007, right, 0.004), both *brachioradialis* entheses (left, 0.001; right, 0.001), the right *biceps brachii* (0.003) and the left *brachialis* (0.041). Unlike the female populations, the male populations do differ statistically within the forearm functional complex, with both interosseous membrane entheses (both 0.000)and left pronator teres (0.024); and within the hip functional complex with both iliopsoas entheses (left, 0.016; right 0.004). In the lower body the male population also differs in both the knee and foot functional complex, with the quadriceps tendon entheses on the tibia (left, 0012; right, 0.050) and all four entheses within the foot functional complex (table 12).

Variable	t-stat	p-value	Comparison	Functional Complex
CLAVICLE M. DELTOIDEUS L	1.958	0.056	Settlement	Shoulder
CLAVICLE M. PECTORALIS MAJOR L	0.465	0.644	Settlement	Shoulder
CLAVICLE M.DELTOIDEUS R	-1.397	0.169	Settlement	Shoulder
CLAVICLE M.PECTORALIS MAJOR R	-0.405	0.688	Settlement	Shoulder
CONOID LIG. L	0.179	0.859	Settlement	Shoulder
CONOID LIG. R	0.866	0.391	Settlement	Shoulder
COSTOCLAVICULAR LIG. L	1.367	0.178	Settlement	Shoulder
COSTOCLAVICULAR LIG. R	0.142	0.888	Settlement	Shoulder
HUMERUS M. PECTORALIS MAJOR R	-3.697	0.000	Settlement	Shoulder
HUMERUS M.DELTOIDEUS L	-2.505	0.016	Settlement	Shoulder
HUMERUS M.DELTOIDEUS R	-2.579	0.014	Settlement	Shoulder
HUMERUS M.PECTORALIS MAJOR L	-4.314	0.000	Settlement	Shoulder
TERES MAJOR L	5.429	0.000	Settlement	Shoulder
TERES MAJOR R	4.919	0.000	Settlement	Shoulder
TRAPEZOID LIG. L	0.179	0.859	Settlement	Shoulder
TRAPEZOID LIG. R	0.866	0.391	Settlement	Shoulder
M.BICEPS BRACHII L	-3.658	0.001	Settlement	Elbow
M.BRACHIALIS L	-2.105	0.041	Settlement	Elbow
M.BRACHIALIS R	-1.85	0.071	Settlement	Elbow
M.BRACHIORADIALIS L	-3.454	0.001	Settlement	Elbow
M.BRACHIORADIALIS R	-3.407	0.001	Settlement	Elbow
SCAPULA M.TRICEPSBRACHII L	-1.406	0.167	Settlement	Elbow
ULNA M.TRICEPS BRACHII L	-2.847	0.007	Settlement	Elbow
SCAPULA M.TRICEPSBRACHII R	-1.81	0.077	Settlement	Elbow
ULNA M.TRICEPS BRACHII R	-3.057	0.004	Settlement	Elbow
M.BICEPS BRACHII R	-3.162	0.003	Settlement	Elbow
INTEROSSEUS MEMBRANE L	-4.453	0.000	Settlement	Forearm
INTEROSSEUS MEMBRANE R	-4.135	0.000	Settlement	Forearm
M. PRONATOR TERES L	-2.347	0.024	Settlement	Forearm
M. PRONATOR TERES R	-1.969	0.056	Settlement	Forearm
M. SUPINATOR L	-0.513	0.610	Settlement	Forearm
M. SUPINATOR R	-1.469	0.149	Settlement	Forearm
M. GLUTEUS MAXIMUS L	1.335	0.188	Settlement	Hip
M. GLUTEUS MAXIMUS R	0.681	0.5	Settlement	Hip
M. ILOPSOAS L	-2.518	0.016	Settlement	Hip
M. ILOPSOAS R	-3.031	0.004	Settlement	Hip
M. VASTUS MEDIALIS L	-1.730	0.090	Settlement	Knee
M.VASTUS MEDIALIS R	-1.284	0.206	Settlement	Knee
PATELLA QUADRICEPS TENDON L	-1.799	0.081	Settlement	Knee
PATELLA QUADRICEPS TENDON R	-1.445	0.160	Settlement	Knee
TIBIA QUADRICEPS TENDON L	-2.612	0.012	Settlement	Knee
TIBIA QUADRICEPS TENDON R	-2.015	0.050	Settlement	Knee
ACHILLES TENDON L	-2.219	0.033	Settlement	Foot

ACHILLES TENDON R	-3.353	0.002	Settlement	Foot
M. SOLEUS L	-3.448	0.001	Settlement	Foot
M. SOLEUS R	-3.996	0.000	Settlement	Foot

Table 12- T test results comparing the male populations of Middenbeemster and Arnhem , with the statistically different entheses highlighted

Middenbeemster Young Adult population vs Arnhem Young Adult population

When only the young adult groups of the two populations are compared, there are several significant differences in entheseal scores. Within the upper body this includes entheses within the shoulder functional complex with both *teres major* entheses (left, 0.020; right 0.015) and the left *pectoralis major* entheses on the humerus (0.012). Within the elbow functional complex, all but two entheses differ on a statistical level, the *triceps brachii* entheses on the scapula (table 13). Within the forearm only one entheses differs on a statistical level, the right *interosseous membrane* entheses (0.011). The lower body is a very different story, with only two entheses differing statistically, both within the foot, the left *achilles tendon* (0.005) and the right *soleus* entheses (0.016).

Variable	t-stat	p-value	Comparison	Functional Complex
CLAVICLE M. DELTOIDEUS L	-0.678	0.501	Settlement	Shoulder
CLAVICLE M. PECTORALIS MAJOR L	0.116	0.908	Settlement	Shoulder
CLAVICLE M.DELTOIDEUS R	-0.776	0.442	Settlement	Shoulder
CLAVICLE M.PECTORALIS MAJOR R	0.207	0.837	Settlement	Shoulder
CONOID LIG. L	0.343	0.734	Settlement	Shoulder
CONOID LIG. R	0.253	0.802	Settlement	Shoulder
COSTOCLAVICULAR LIG. L	0.253	0.802	Settlement	Shoulder
COSTOCLAVICULAR LIG. R	0.093	0.927	Settlement	Shoulder
HUMERUS M. PECTORALIS MAJOR R	-2.054	0.046	Settlement	Shoulder
HUMERUS M.DELTOIDEUS L	-1.117	0.271	Settlement	Shoulder
HUMERUS M.DELTOIDEUS R	-0.489	0.627	Settlement	Shoulder
HUMERUS M.PECTORALIS MAJOR L	-2.638	0.012	Settlement	Shoulder
TERES MAJOR L	-2.426	0.020	Settlement	Shoulder
TERES MAJOR R	-2.534	0.015	Settlement	Shoulder
TRAPEZOID LIG. L	1.461	0.151	Settlement	Shoulder
TRAPEZOID LIG. R	-1.139	0.261	Settlement	Shoulder
M.BICEPS BRACHII L	-2.364	0.023	Settlement	Elbow
M.BRACHIALIS L	-3.702	0.001	Settlement	Elbow
M.BRACHIALIS R	-3.467	0.001	Settlement	Elbow
M.BRACHIORADIALIS L	-2.846	0.007	Settlement	Elbow
M.BRACHIORADIALIS R	-3.115	0.003	Settlement	Elbow
SCAPULA M.TRICEPSBRACHII L	0.080	0.936	Settlement	Elbow
ULNA M.TRICEPSBRACHII L	-3.779	0.001	Settlement	Elbow
SCAPULA M.TRICEPSBRACHII R	0.460	0.648	Settlement	Elbow
ULNA M.TRICEPSBRACHII R	-4.609	0.000	Settlement	Elbow
M.BICEPS BRACHII R	-2.073	0.045	Settlement	Elbow
INTEROSSEUS MEMBRANE L	1.760	0.087	Settlement	Forearm
INTEROSSEUS MEMBRANE R	2.676	0.011	Settlement	Forearm

M. PRONATOR TERES L	0.000	1.000	Settlement	Forearm
M. PRONATOR TERES R	0.000	1.000	Settlement	Forearm
M. SUPINATOR L	0.714	0.479	Settlement	Forearm
M. SUPINATOR R	1.592	0.119	Settlement	Forearm
M. GLUTEUS MAXIMUS L	1.145	0.259	Settlement	Hip
M. GLUTEUS MAXIMUS R	1.093	0.282	Settlement	Hip
M. ILOPSOAS L	-0.902	0.373	Settlement	Hip
M. ILOPSOAS R	-1.238	0.225	Settlement	Hip
M. VASTUS MEDIALIS L	-0.064	0.949	Settlement	Knee
M.VASTUS MEDIALIS R	0.234	0.817	Settlement	Knee
PATELLA QUADRICEPS TENDON L	-1.350	0.187	Settlement	Knee
PATELLA QUADRICEPS TENDON R	-1.757	0.091	Settlement	Knee
TIBIA QUADRICEPS TENDON L	-1.101	0.277	Settlement	Knee
TIBIA QUADRICEPS TENDON R	-0.986	0.330	Settlement	Knee
ACHILLES TENDON L	-2.955	0.005	Settlement	Foot
ACHILLES TENDON R	-1.889	0.068	Settlement	Foot
M. SOLEUS L	-1.246	0.220	Settlement	Foot
M. SOLEUS R	-2.508	0.016	Settlement	Foot

Table 13- T test results comparing the Young Adult populations of Middenbeemster and Arnhem, with the statistically different entheses highlighted

Middenbeemster Middle Adult Population vs Arnhem Middle Adult Population

The two Middle Adult groups from the two different settlements differ on even more entheses than their younger counterparts. They differ within every fictional complex excluding the hip, and a total of twenty-two entheses out of fifty-four. For the shoulder: the *deltoideus* entheses on the humerus and clavicle; the *pectoralis major* entheses on the humerus; the *teres major* entheses and the right *trapezoid ligament*. For the elbow, there are less statistically different entheses than the comparison between the two Young Adult groups, but there are several. The biceps brachii (left, 0.006; right, 0.005) and the left brachioradialis (0.027) entheses are all statistically different. For the forearm all but the supinator entheses differ (table 14). For the knee, the left quadriceps tendon entheses on the patella (0.008) and on the tibia (0.012) both differ, and all the entheses differ within the foot functional complex (table 14).

Variable	t-stat	p-value	Comparison	Functional Complex
CLAVICLE M. DELTOIDEUS L	-2.784	0.007	Settlement	Shoulder
CLAVICLE M. PECTORALIS MAJOR L	1.149	0.256	Settlement	Shoulder
CLAVICLE M.DELTOIDEUS R	-2.016	0.049	Settlement	Shoulder
CLAVICLE M.PECTORALIS MAJOR R	0.053	0.958	Settlement	Shoulder
CONOID LIG. L	-0.291	0.772	Settlement	Shoulder
CONOID LIG. R	-1.112	0.272	Settlement	Shoulder
COSTOCLAVICULAR LIG. L	-0.645	0.522	Settlement	Shoulder
COSTOCLAVICULAR LIG. R	0.022	0.983	Settlement	Shoulder
HUMERUS M. PECTORALIS MAJOR R	-2.899	0.005	Settlement	Shoulder
HUMERUS M.DELTOIDEUS L	-2.574	0.013	Settlement	Shoulder

HUMERUS M.DELTOIDEUS R	-3.340	0.002	Settlement	Shoulder
HUMERUS M.PECTORALIS MAJOR L	-2.237	0.029	Settlement	Shoulder
TERES MAJOR L	-6.336	0.000	Settlement	Shoulder
TERES MAJOR R	-6.408	0.000	Settlement	Shoulder
TRAPEZOID LIG. L	-1.092	0.280	Settlement	Shoulder
TRAPEZOID LIG. R	-2.170	0.035	Settlement	Shoulder
M.BICEPS BRACHII L	-2.876	0.006	Settlement	Elbow
M.BRACHIALIS L	-0.393	0.696	Settlement	Elbow
M.BRACHIALIS R	-0.547	0.587	Settlement	Elbow
M.BRACHIORADIALIS L	-2.271	0.027	Settlement	Elbow
M.BRACHIORADIALIS R	-0.637	0.527	Settlement	Elbow
SCAPULA M.TRICEPSBRACHII L	-0.850	0.399	Settlement	Elbow
ULNA M.TRICEPSBRACHII L	-1.976	0.054	Settlement	Elbow
SCAPULA M.TRICEPSBRACHII R	-0.840	0.405	Settlement	Elbow
ULNA M.TRICEPSBRACHII R	-1.916	0.061	Settlement	Elbow
M.BICEPS BRACHII R	-2.969	0.005	Settlement	Elbow
INTEROSSEUS MEMBRANE L	-4.351	0.000	Settlement	Forearm
INTEROSSEUS MEMBRANE R	-3.478	0.001	Settlement	Forearm
M. PRONATOR TERES L	-3.095	0.003	Settlement	Forearm
M. PRONATOR TERES R	2.497	0.015	Settlement	Forearm
M. SUPINATOR L	-0.188	0.851	Settlement	Forearm
M. SUPINATOR R	-1.835	0.070	Settlement	Forearm
M. GLUTEUS MAXIMUS L	0.900	0.372	Settlement	Hip
M. GLUTEUS MAXIMUS R	0.693	0.492	Settlement	Hip
M. ILOPSOAS L	-1.084	0.284	Settlement	Hip
M. ILOPSOAS R	-1.372	0.177	Settlement	Hip
M. VASTUS MEDIALIS L	-1.522	0.134	Settlement	Knee
M.VASTUS MEDIALIS R	-1.792	0.079	Settlement	Knee
PATELLA QUADRICEPS TENDON L	-2.823	0.008	Settlement	Knee
PATELLA QUADRICEPS TENDON R	-1.706	0.097	Settlement	Knee
TIBIA QUADRICEPS TENDON L	-2.623	0.012	Settlement	Knee
TIBIA QUADRICEPS TENDON R	-1.810	0.076	Settlement	Knee
ACHILLES TENDON L	-1.910	0.064	Settlement	Foot
ACHILLES TENDON R	-3.793	0.001	Settlement	Foot
M. SOLEUS L	-3.960	0.000	Settlement	Foot
M. SOLEUS R	-3.304	0.002	Settlement	Foot

Table 14- T test results comparing the Middle Adult populations of Middenbeemster and Arnhem, with the statistically different entheses highlighted

5. Discussion

This chapter will attempt to provide a summary of the processed data, and link the data to possible movements, and therefore labour performed by each population. This will then be placed within its proper historical context, and used to compare the two populations, and therefore answer the research questions set out in the introduction. There will also be a comparison to other similar studies, to further establish the results in the wider historical record. And lastly, there will be a discussion of the limitations of the methods and results produced here.

5. 1. Was there a significant difference in labours performed in rural settlements compared to urban settlements in the Dutch post medieval era?

The data overall does suggest that there is some difference in the entheseal scores between the two populations, and therefore movement and labours performed in the two settlements. Arnhem has higher entheseal scores overall, which could suggest that Arnhem residents were engaging in more intensive daily labour, however, as has been mentioned, entheseal changes have a multi-factored aetiology. For both populations, there is clearly some difference between the two age groups, which is to be expected as age is one of the many factors that contribute to the development of entheseal changes.

Handedness

Bilateral asymmetry could not be established conclusively in either population. This could be due to the need for muscles in both sides to be used to complete many daily labours. Pushing, pulling, lifting, walking, and many other actions require both the left and right muscles to be engaged, while only more delicate tasks, like writing, which can be difficult to examine in this context, require the dominant muscle, or dominant hand, to pull the weight.

Bilateral asymmetry, or a dominant hand, can therefore be made invisible by the larger force required for non-delicate tasks. This ensures that there is little difference between the left and the right evident when examining entheses, at least the entheses studied by this thesis. There are some indications that bilateral asymmetry is present if only slightly in both populations in the T-tests done on other comparisons. It is common for an entheses from side of the body to statistically differ, but not the other. For example, the T-tests done on the basis of age within the Arnhem sample produced the result that the right achilles tendon differed statistically, but not the left. What is also common in this situation is that the entheses that doesn't differ is close to the standard of a p-value of 0.05. In the case of the achilles tendon, the right is statistically different with a p- value of 0.000, but the left achilles tendon is close to being statistically different with a p-value of 0.075. This indicates that there is some evidence of bilateral asymmetry, of a dominant side, but there is not enough difference in how people are moving their bodies in either Middenbeemster or Arnhem to produce a statistical difference.

Class

While the cemetery that the Arnhem sample comes through most likely only serviced lower income individuals, the assumption was that the cemetery for the Middenbeemster sample serviced the entire population for the surrounding Beemster polder. The Middenbeemster sample should therefore be representative of any class disparity for that specific region, and in general for rural settlements in the Netherlands. However, the entheseal scores collected here do not showcase an evident class disparity. The majority of individuals from Middenbeemster show average to high entheseal scores. However there are small number of outlies for both populations. This could be reflective of a small elite class who did not engage regularly in labour, or simply examples of individuals who were incapable of labour. Unfortunately, this thesis has not been able to fully investigate the class hierarchy that existed in the Netherlands at the time.

The Interosseous Membrane

Random Forest identifies the right *interosseous membrane* entheses on the radius, which is part of the forearm functional complex, as the principal entheses that differs between the two populations. The main movement this would be involved with would be pronation/supination, which requires the radius to rotate around the ulna (Kingston, 2005, p.53). Tasks that require this movement tend to be tasks that require the hand to be moved through different orientations. This could also be associated with tasks that would usually use a dominant hand, right or left. Therefore, despite the lack of regular difference between the left and right for both populations, this would suggest that one population was using their right forearm, or hand, more than the other, for tasks that require the twisting of the forearm. It is the Arnhem population that has a higher average of scores for the *interosseus membrane*, and it also has less variation for this entheses over sex and age. For the Middenbeemster population there is drastic difference between the scores of the female Middle Adults, and the rest of the sample, suggesting that the action is something that women were doing as part of their labour, not men. This illustrates the difference between the actions and movements required for labour in rural vs urban environments. Furthermore, when the t-test between the male populations of Arnhem and Middenbeemster showed both the interosseus membrane entheses as statistically different between the men of Arnhem and Middenbeemster (table 12), another indication that the men of Middenbeemster are not using the forearm in the motion of pronation and supination, and not just the right but also the left.

Presumably the rotation of the (right) forearm is not required in the dominant labour performed in Middenbeemster, dairy farming. Dairy farming seems to require labour that is not differentiated by the use of a dominant hand, for example heavy lifting, pushing and pulling, or walking long distances across the farm. Women however do seem to engage in this activity, particularly as they age. The rotations of a dominant hand, in this case the right, is something that would be useful, even required, in most domestic tasks, such as cooking. One such task would be stirring a pot of food. As women, in this period and many others, performed the majority of domestic labour, with women particularly in rural areas being designated as only housewives (Centraal Bureau voor de Statistiek, 1902, pp. 185-9), this interpretation would fit with what written sources dictate about the period. In Arnhem, the majority of lower-class individuals, like in most urban centres during this period, would have worked in factories. As the sample used is primarily made up of lower-class individuals (Baetsen et al., 2018), it makes sense to assume that this is how most of the individuals in the Arnhem sample made their livings. The pronation and supination of the right forearm is likely to have been useful when operating the machines that made up post medieval factories, such as textile looms.

The right interosseous membrane was not the only entheses that differed between the two population. Many entheses differ on the basis of settlement type across all the functional complexes, and these will be explored in more detail below.

Upper Body

For the shoulder the *teres major* entheses is identified as the entheses used to distinguish between the two populations. This muscle is used in the extension of the shoulder, particular within phase 1, extending between 0° and 20°. It is also involved in the medial rotation of the shoulder (Kingston, 2005, p. 36), and is crucial for the stabilisation of the glenohumeral joint (Drake et al., 2005, m702). The extension of the shoulder exhibited here is indicative of pulling something to the extent that shoulder extends only slightly. This could be moving product across a machine (textile loom) or the motion of using a decker, a small frame used to collect pulp to from a sheet a paper. All in all, it correlates with the actions required for the production industries that are known to operate in Arnhem.

Arnhem also has a higher mean score for all the elbow entheses (fig 4. 6, 4.7), suggesting more regular intensive labour involving flexion and extension performed by the inhabitants of Arnhem. The motion primarily used here be would flexion and extension, suggesting that there is a difference in the amount of movements, such as lifting, that Arnhem is doing compared to Middenbeemster. The entheses that show the most difference between the two populations are the attachment sites for the *biceps brachii* and *triceps brachii* muscles. The triceps brachii is the main extensor of the elbow, allowing for extension across a range of 145 ° and 0°, while the biceps brachii is crucial for flexion, but only the first phase allowing for flexion from 0° to 60°. This limited range could be associated with movements required to make a basic machine run, as would be the basic responsibility of a factory worker.

There are two possible interpretations for the higher scores within the Arnhem population. Firstly, that Arnhem populations were moving heavier loads, or performing harder labour. Secondly, that they were performing more repeated movements over time. It seems logical, that factory work, the operations of the same machine day in day out, would require more repeated movements, especially repeated movements of flexion and extension than the activities involved with dairy farming. Therefore, following the second interpretation, higher scores are evident in the Arnhem sample due to more upper body use, for a longer time, and more consistently in factory work compared to dairy farming. Dairy farming likely required more varied task across the day, rather than standing in form of machine and doing the same task all day, every day.

Lower Body

Entheseal changes are notoriously difficult to examine on the lower body due to the ability of locomotion to obscure any nuances. Predictably, therefore the lower body in particular resulted in inconclusive results. While the statistical methods used to examine the data disagreed, there does seem to nonetheless be a slight difference between the two populations. The expectation was that dairy farmers would be more mobile than factory workers, who would have predominantly stayed in one spot all day, unlike a farmer. This, however, was not true, as again Arnhem has higher scores than Middenbeemster overall in this area. The lack of clear statistical difference however does indicate that both populations were mobile, and the repeated movement of walking has unfortunately obscured any difference that labours performed by the differing populations might have had on the lower body. This includes any difference in how the lower body was used to operate machinery, such as the use of one leg to operate a lever. Levers would be required to operate both looms and spinning wheels, both tools used regularly within the textile industry. It could be expected that Arnhem would therefore have more evidence for this activity than Middenbeemster. There is some indication that the use of the right achilles tendon increased with age compared to the left, however there isn't a statistical difference compared to Middenbeemster.

Middenbeemster Women vs Arnhem Women

Women in Middenbeemster and women in Arnhem were clearly moving their bodies differently, especially within the upper body, as is illustrated in table 11. Within the shoulder functional complex, the *teres major* entheses and *deltoideus* on the clavicle both differ on a statistically level. The teres major muscle is highlighted as especially statistically different. Both the *deltoideus* entheses on the clavicle and the *teres major* muscle are principally employed in the medial rotation of the shoulder. Within the elbow functional complex there is a total of five entheses with a statistical difference; both of the *triceps brachii* entheses on the ulna, both of *biceps brachii* entheses, and the right *brachialis*. The *triceps brachii* and *biceps brachii* are respectively the extension and flexion of the elbow. This difference in movement, medial rotation and flexion and extension, is likely reflective in the difference between framing and factory work that has been elaborated on above.

The forearm and hip functional complexes however do not differ at all between the women of the two populations. As I have mentioned above and will elaborate on below, I have linked the use of pronation and supination within the forearm with traditional household tasks, and labour that is traditionally feminine such as weaving. These T-tests further support this theory, and suggest that in both urban and rural settlements women were performing these traditionally feminine labours, and most likely taking on a significant amount of the household labour tasks. The lower body does show statistical differences in the knee and foot entheses with both the *quadriceps tendon* entheses on the patella, the right *vastus medialis*, the left *achilles tendon*, and the right *soleus* entheses. The *quadriceps tendon* could suggest some difference in mobility between the two groups of women, but the lack of statistically relevant entheses in the hip does not support this. The left achilles tendon and right soleus however could be indicative of the consistent movement of one foot in a different manner by one population; of a bilateral asymmetry in the foot functional complex. This could reflect the use of a foot lever on a loom or spinning wheel by the Arnhem women. While the women of Middenbeemster likely used this equipment, and were involved in domestic textile production, the women of Arnhem were more likely to be involved in this sector in an industrial capacity, so were using the equipment for longer periods and more consistently. Overall, the Arnhem women have higher scores than the Middenbeemster women, as is consistent with the data for Arnhem overall.

Middenbeemster Men vs Middenbeemster Men

When comparing exclusively the men of Middenbeemster and Arnhem, there are more statistical differences than between their female counterparts. Not only are there more entheses that statistically differ, bit the differences are across all the functional complexes. In the shoulder, the deltoideus on the humerus and the teres major differ on a statistical level, just like between the two female populations, again reflecting the difference between farming and factory work. The pectoralis entheses also both differ, which is involved in the first phase of movement for raising the arm, 0°- 60°, (Kingston, 2005, p. 31). The clavicular attachment in particular flexes the shoulder out of its anatomical position (Kingston, 2005, p. 33) Similarly to the female populations, the male populations also differ statistically within the elbow functional complex; with both triceps brachii entheses on the ulna, both *brachioradialis* entheses, the right *biceps brachii*, and the left *brachialis*. Clearly the difference between factory work and farming is evident not only in the broader comparison between the two populations, but also when both the men and women are compared separately. Unlike the female populations, the male populations do differ statistically within the forearm functional complex, with both *interosseous membrane* entheses (both 0.000)and left *pronator teres*. As has been mentioned previously, the *interosseous membrane* is especially interesting here. This entheses is one of the key difference between Middenbeemster and Arnhem, and it is clearly the movement and labour performed by men that is creating this difference. Male labour differs within the use of the forearm, while female labour doesn't, as men are performing different labour in urban vs rural environments, while women are still performing similar labour. The men also differ within the hip functional complex with both *iliopsoas* entheses. In the lower body the men also differ in both the knee and foot functional complex, with the quadriceps tendon entheses on the tibia and all four entheses within the foot functional complex. All this does suggest some difference in mobility, and as Arnhem has consistently higher scores; (fig 4. 3, 4.7), this would suggest more mobility in Arnhem, at least among the men.

Middenbeemster Young Adults vs Arnhem Young Adults

When only the young adult groups of the two populations are compared, there are several significant differences in entheseal scores. Crucially these differences exist primarily within the upper body, which includes entheses within the shoulder functional complex with both *teres major* entheses and the left *pectoralis major* entheses on the humerus. These muscles are involved with the medial rotation of the shoulder and the raising of the arm using the shoulder respectively. However, it is within the elbow functional complex, that the most entheses differ. All but two entheses differ on a statistical level, with only the *triceps brachii* entheses on the scapula not differing(table 13). Clearly there is a difference in the flexion and extension between the Young Adults of Middenbeemster and Young Adults of Arnhem. Within the forearm only one entheses differs on a statistical level, the right *interosseous membrane* entheses, which is an entheses that has been identified as crucially differing between Middenbeemster and Arnhem, by multiple different statistical tests. The lower body is a very different story, with only two entheses differing statistically, both within the foot, the left *achilles tendon* and the right *soleus* entheses. There is clearly not a difference between the mobility of young Adults in urban vs rural environment, at least that is evident in the data presented here. However, in a similar manner to the differences within the foot between the women of the two settlements, this could indicate the use of foot lever by one population, most likely Arnhem, as foot levers are used by many different pieces of equipment used in factory work, like the equipment used in textile production which has been elaborated in previously.

Middenbeemster Middle Adults vs Arnhem Middle Adults

The differences in movement between the two settlements appear to increase with age. This is hardly surprising, as entheseal development also appears to increase with age. The two Middle Adult groups differ within every fictional complex, excluding the hip. For the shoulder, again the *deltoideus* entheses on the humerus and clavicle; the *pectoralis major* entheses on the humerus; the *teres major* entheses and the right *trapezoid ligament*. These entheses mostly differ between the two populations, whether only certain age groups and certain sexes are exclusively examined or not. Clearly these muscles are used veery differently is an individual is employed in a rural context or an urban context. Arnhem has higher scores, so it can be assumed that these muscles and the movements they allow are used more within the production and factory work, like textile production, paper production, shoe-making and the other industries that employed the people of Arnhem. The elbow differs less within the Middle Adult populations than the Young Adult populations, but the forearm differs more. With The biceps brachii and the left brachioradialis entheses are all statistically different. For the forearm all but the supinator entheses differ (table 14). The brachioradialis muscle assists both supination and pronation, so for the comparison between the Middle Adult populations, the main difference in movement that is evident, is pronation and supination, as has been illustrated by the data previously. For the knee, again there is a different quadriceps tendon entheses, with both on the tibia differing, and the eft on the patella differing. All the entheses in the foot functional complex differ. It is possible that the extended mobility as individuals age has led to an increase in the entheseal development within the foot functional complex, at least in Arnhem, which, again, has higher scores (fig 4.3, 4.7).

5. 2. Is there a difference between entheseal changes of men and women at Middenbeemster and Arnhem?

While there is definitely a difference between the two sexes, there does not appear to be dramatic difference between the entheseal scores of male individuals and female individuals in either population, Random Forest in this case only has a 55% accuracy. This reflects the difficulty to find a pattern that differentiates between the male and female populations. According to Random Forest, there is not a clear statistical difference between how males and females moved their bodies. There are however other indications of a gendered division of labour. Male individuals do have higher mean scores than female individuals overall, however this is not true in every case. If the grade of an entheseal change can be linked with the amount of hard labour performed, this would suggest that women were doing just as much hard labour as men, in both urban and rural settlements, which is hardly surprising when historical literature is examined critically. Male individuals may have performed slightly more labour, but it is only slightly more labour. But when the functional complexes are examined, some differences between the two sexes do emerge. There does appear to be some difference in how people moved their bodies on the basis of sex, if not a clear difference in how much they moved their bodies, or how much labour was performed. Furthermore, it is not uniform across the two settlements, there appears to be much more division of labour in the basis of sex in Arnhem, an urban settlement.

Upper Body

Crucially for the shoulder functional complex, the entheseal changes from the Middenbeemster sample do not differ at all on the basis of sex, while the Arnhem population does. This could suggest that there was a more gendered divide in labour in Arnhem compared to Middenbeemster, at least in the labour that required the rotation of the shoulder joint. It is both attachment sites for the left *pectoralis major* muscles and the right *teres major* entheses on the humerus that vary on the basis of sex. The distinguishing in handedness here points even more so to a difference in the specific type of labour being performed by men vs women. This could relate to that in rural areas, women, at least seasonally helped with the farming work their male relatives were doing, and therefore were performing very similar labours to their male relatives (van Nederveen Meerkerk & Paping, 2014). While in urban areas, such as Arnhem, it appears that there was a more gendered division of labour. While in Middenbeemster, dairy farming dominated the labour force, however in Arnhem, there were multiple industries that employed the work force. There is every chance that women and men, even those in the same family were employed in different industries. For example, women may have worked at a factory producing different products to their husbands, thus performed a different set of movements on a daily basis. One example is that textile production was traditionally seen as women's work, women were more likely to employed by the textile industry, while their husbands worked elsewhere.

Within the elbow functional complex, Arnhem again shows more entheses with statistical differences on the basis of sex compared to Middenbeemster. This coincides with what is mentioned above, as movements and labours that would produce a statistical difference in the shoulder functional complex are likely to produce similar differences in the elbow functional complex. This includes movements such a lifting, pulling, pushing; all movements that would not have been out of place within a factory.

While entheses within the forearm functional complex, massively differ on the basis of settlement, neither population have any entheses within this functional complex on the basis of sex. The movements of pronation and supination clearly did not differ between the two sexes in either population. The twisting of the forearm, the use of the wrist can be connected with more delicate movements, as mentioned above. Also mentioned above, Middenbeemster female Middle Adults seem to have higher scores when looking at the means for the right interosseous membrane. This difference does not translate to the T-tests. This could be because the difference between the entheseal scores is simply not big enough that both the T-tests and Random forest can agree on it. While I have previously connected the movement of pronation and supination with female population of Middenbeemster, unfortunately it seems that there is a lack of clear difference between the male and female populations in the case of this movement, at least not a clear enough difference to make any definite conclusions. This seems to be common occurrence, when comparing the samples on the basis of sex and the basis of settlement, suggesting that while there are slight differences between the two, the differences are not always obvious or dramatic.

Lower Body

For the majority of entheses, there is not a statistical difference on the basis of sex for the Middenbeemster population. There are entheses where the female individuals have higher scores, but these are never supported by T-tests. Clearly there was no division on the basis of sex for mobility in rural settlements. This is not surprising, the upper body results suggest that women and men were performing the same labour in Middenbeemster, so it follows that so would the lower body. As mobility tends to obscure any kind of evidence of specific activity in the lower body, it is not possible to tell if this reflects men and woman being equally mobile in Middenbeemster, and therefore rural settlements, or men and woman performing similar activity. The lack of difference in the lower body does suggest the former.

Arnhem, on the other hand, again shows much more of a division on the basis of sex. While it is less blatant than the upper body, it is still clearly present. As male individuals mostly have higher scores overall, this would suggest that men were more mobile than women in Arnhem, and therefore in urban settlements. However, there is one instance where female individuals have higher entheseal scores than male individuals, which is supported by the T-tests performed, the left *gluteus maximus*. It is difficult however to find a clear action that would utilise the left *gluteus maximus*, but not also use muscles within the knee. Why women were less mobile than men in urban settlements is also a hard question to answer. Crucially it is not uniform across all the entheses in the lower body, which would all be used in walking. This would suggest that rather than being less mobile, women were simply performing slightly different forms of labour, as has already been concluded above.

Women were more likely than men to work in then men to work in the textile industry (van Nederveen Meerkerk, 2006), while men in Arnhem may have worked in one of the other production industries in Arnhem, such as tobacco production, typography and shoe- making. Like in the upper body, it is likely that men and women moved their lower body different when operating the different machines used for these different forms of production. The left *gluteus maximus*, could have been employed more by women to operate the foot lever necessary for the use of a textile loom. Especially if they were standing when operating, this would explain the lack of evidence for the use for the left knee in the action.

To sum up, women and men worked in different, but often similar industries in urban environment. This is illustrated by the often only slight difference between the sexes. However, in a rural environment, there is clearly very little difference between the labour performed by men and women. Women are clearly also performing the same roles within farming as men, or there is simply too much overlap between the movements required for farming and those required for housework. They are however definitely performing labour that is mostly equally as strenuous in rural environments, and with only a slight difference in urban environments.

5. 3. Comparisons with other research

The main struggle in this section has been to connect the data collected with specific forms of activity. While some general conclusions, such as individuals in Arnhem performing more repeated actions in their daily labour, or performing more hard labour, it is hard to say with confidence what exactly this labour was. This is a common theme in other research that uses entheseal changes. In can be difficult to compare studies using entheseal changes as researchers use many different methods for the collection and analysis, so a direct comparison is hard to achieve. However, Palmer et al. have conducted research on one of the populations, Middenbeemster, that has been studied here, allowing for as direct a comparison as possible. In their 2014 study, Palmer et al. (2014)also concludes that Middenbeemster inhabitants engaged in 'generally strenuous labour' (p. 83), and that there is a lack of evidence for class hierarchy, at least on the basis of labour (p. 85). This study also looked at the severity and prevalence of osteoarthritis in the Middenbeemster population, which unsurprisingly was high, much higher than other Dutch population of the time, specifically urban elite populations (p. 83). However, Palmer et al. identified a significant difference in the labour performed by male individuals and labour performed by female individuals, which was not evident in this study. This could be due to a number of factors; different recording methods, different statistical methods, different sample selection, etc. However, it does illustrate the issue with ensuring that there are standardised methods in recording entheseal changes.

While it has been argued that men are more likely to develop dramatic entheseal changes than women due to a biological ability to develop and sustain more muscle mass (Bakirci et al., 2020), in this study there is little evidence of men doing so in Middenbeemster, and in both Arnhem and Middenbeemster, there are instances of female individuals producing higher entheseal scores than male individuals in their settlement. Caballo- Perez and Schrader (2022) find in their research into labour in the state formation of Egypt and Nubia, evidence for a gendered division in labour, however the evidence is in higher scores for female individuals. When female individuals produce higher entheseal development, they can be viewed as evidence for 'genuine sexual division of labour', as they are overcoming the 'sexual discrepancy precluding males from developing more muscle'(p. 457). In the case of the female individuals studied in Egypt, they appear to have higher scores on entheses associated forearm supination and pronation. The same appear to happen in Middenbeemster, although it is not definite, as unfortunately the statistical methods used disagree. I have associated this movement with actions required in the domestic sphere such as non-mechanised weaving and cooking, and similarly Cabello-Perez and Schrader have linked it to 'weaving, handcrafting, pottery production, planting, collecting, and processing agricultural resources' (p. 457), all activities that would not have been out of place among the rural female population of the post medieval era in the Netherlands.

5. 4. Limitations of the study

As with any study, limitations are bound to occur. Some of these like the Osteological Paradox, are long established, and were clear before the study began. Others like the methods and materials used, only became clear after data collection and analysis began. Nonetheless, it is important to acknowledge any and all limitations, to be able to properly understand the resulting conclusions of the study.

5. 4. 1. The Osteological Paradox

The Osteological Paradox has three core tenets, which are demographic non-stationary, selective mortality, and hidden heterogeneity in risks (Wood et al., 1992). The first two especially affect this thesis and contribute to the limitations of the study.

Demographic non-stationary refers to the fact populations are not stationary, they evolve over time, with emigration and immigration. A cemetery is not necessary representative of what actually made up a living population, as not everyone who lived in the settlement necessarily stayed in the settlement or was buried in the local cemetery. This means that both sample I have used to represent Middenbeemster, and therefore rural populations, and the sample I have used to represent Arnhem, and therefore urban populations, might not be accurate representations of either population.

Selective mortality refers to the fact that the sample is inherently biased, in that all the individuals are dead. This seems obvious and simplistic, but as is mentioned above this means the that the population examined is not necessarily representative of a living population. Both the samples I have used include Young Adults. These young Adults are not necessarily representative of the average alive young adult from the settlement or time period, as they died young. Something went wrong for them, whether from disease or trauma, or a multitude of other reasons, which resulted in their death. This can then skew the data, as we are not examining a healthy, living young person, but a dead one, and therefore there are complications in using the individual, and sample as a whole as a representation of a living population.

5. 4. 2. Methods

Recording method

The method used to collect data in this study was based on the Mariotti et method, and as a result the specifics given for scoring, written and pictural, provided in the Mariotti et al. 2007 paper, were used heavily when scoring the entheseal changes. However, the entheseal changes observed in both the Middenbeemster and Arnhem samples were occasionally clearly more dramatic than the photos and description provided for the highest score that Mariotti et al. provided. It is unclear as to why this occurred. This did not happen regularly, but suggests the possibility that a more extensive grading score is required, and that within this study, entheseal changes that shouldn't be grouped together, have been.

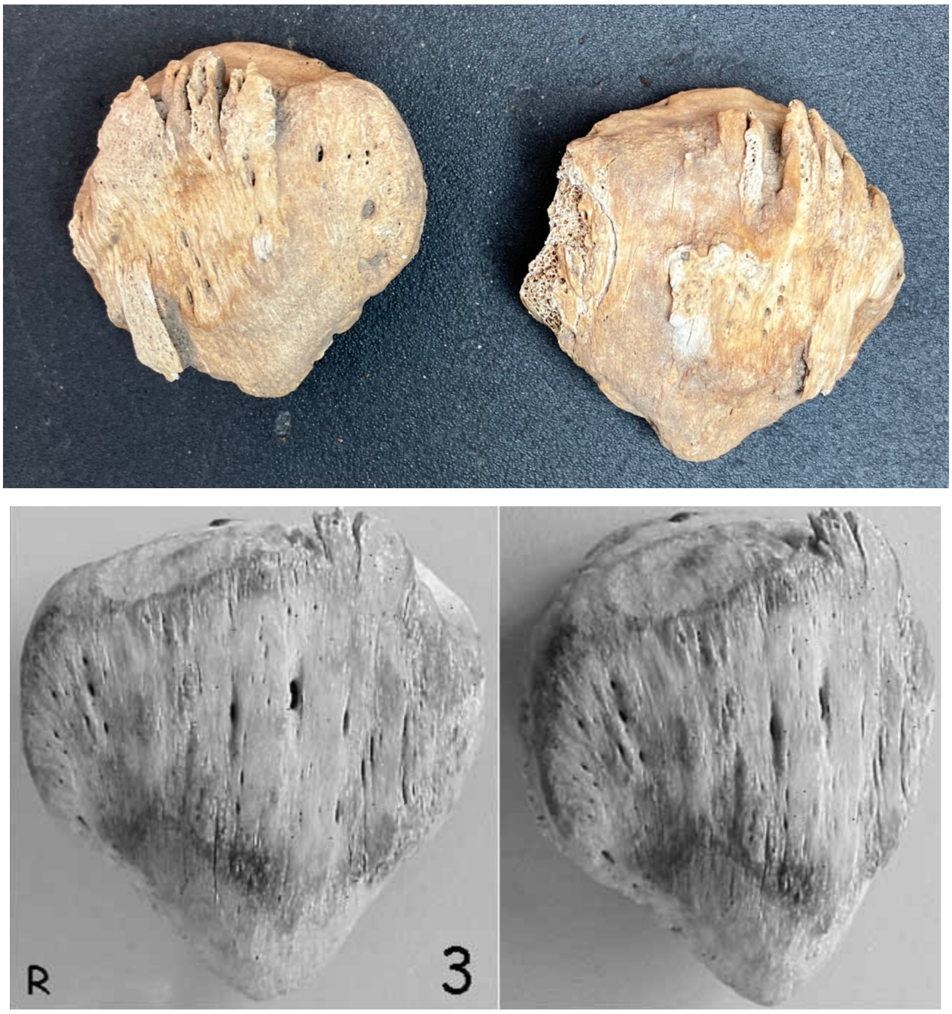

Fig 5.1- Patellas from Arnhem sample (S918), compared to reference supplied by Mariotti et al. (2007, p. 310)

Fig 5.2- right calcaneus from Middenbeemster (S174), compared to reference supplied by Mariotti et al. (2007, p. 312)

5. 4. 2. Materials

There is an imbalance within the sample on the basis of age, which detracts from any comparison between the two samples. The Arnhem sample has much less Young Adults and much more Old Adults than the Middenbeemster sample. However, the lack of consistent statistical differences on the basis of age for the Arnhem sample compared to the Middenbeemster sample, i.e. Arnhem does not consistently differ more than Middenbeemster on the basis of age. Both populations appear to differ equally on the basis of age, which would suggest that this has not affected the results dramatically.

6. Conclusion

The aim of this thesis was to answer to research questions:

Was there a significant difference in labours performed in rural settlements compared to urban settlements in the Dutch post medieval era?

Is there a difference between entheseal changes of men and women at Middenbeemster and Arnhem?

These questions have been answered by examining and grading the entheseal changes of a sample of the Middenbeemster and Arnhem collections held within the Laboratory for Human Osteoarchaeology at Leiden University. This data was then analysed using random forest and t- tests to compare the two settlements but to also examine bilateral asymmetry, age and sex. Using this I was able to answer the research questions presented in the introduction. The answers and conclusions that were reached are summed up here, alongside recommendations for future research.

6. 1. Answers

When comparing the entheseal score of Middenbeemster and Arnhem, there appears to be some difference between the labour performed in rural compared to urban settlements, however it is not a dramatic difference. Arnhem has higher scores overall; therefore, it appears that individuals in an urban settlement performed either a higher frequency or higher intensity of labour.

One definite conclusion is that the populations tested here were equally mobile, in rural settlements compared to urban settlements, and in male individuals compared to female pos.

One of the crucial differences between Arnhem and Middenbeemster is that there is a bigger difference in the labour performed by men compared to women in Arnhem. Women appear to do very similar labour to men, when in a rural environment. They may have done most of the work required within the domestic sphere, but they also clearly joined the men on the farm. This was most likely seasonal, such as during the harvest, when the need for labour was higher. While this labour was part time, clearly women were engaging in it enough that it has an effect on their muscles and therefore bones, altering their skeleton in a near identical manner to how the work affected their male counterparts. For Middenbeemster, and rural environments in general, it has been suggested that women were predominantly housewives. Either this labour produced a similar effect on the skeleton due to the use of similar movements, to that generated by dairy farming, or women were more active in the agriculture industry than previously thought. The interosseous membrane was identified as possibly being a crucial differing entheses between the male and female populations, however due to differing results from statistical methods, it cannot be used for any concrete conclusions.

However, in urban environments, while both men and women clearly worked, they appear to be employed in slightly different sectors. Women traditionally worked in the textile sector (van Nederveen Meerkerk, 2006), while men would have worked in one of the many other sectors in Arnhem, such as; shoe making, the tobacco industry, paper production and typography (Baesten et al., 2018; Jan de Vries and Aan van der Woude, 1997). Additionally, the difference in labour between the two settlements appears to be mainly driven by men. Women perform similar labours in both settlements, with some differences, while men appear to perform much more statistically different labour. One reason for this, is that whether living in the countryside or city, women were performing the majority of tasks required in the smooth running of a household. This includes, but is not limited to; cooking, cleaning and even weaving. In Arnhem, unlike in Middenbeemster, women performed production on an industrial level however, and this is reflected in their entheseal development.

Crucially this is why the data does not indicate more equality between the sexes in rural settlements than urban settlements. It can indicate a multiple things, such as a stronger prevalence of a family business in a rural compared to an urban settlement. Women were helping out on family farms in rural settlements, rather than engaging in a separate industries, as could be common in a more urban environment. Furthermore, in a rural environment, such as Middenbeemster, there is more likely to be one dominant industry, which in this case, is dairy farming.

Furthermore, as was expected, male individuals overall scored higher than female individuals, for both populations. It is an unsurprising conclusion that men were performing more labour than women in the past. However, as has been elaborated extensively above, this is a very simplistic conclusion. Women were undoubtedly performing significant levels of labour, as is clearly enumerated in their entheseal scores. The difference between men and women that has been presented here does not simply mean that men were the main breadwinners, not that they were performing the majority of the labour required to survive in this era. It should be noted here that male bodies possess an ability to create muscle at a greater rate than the female body, which naturally has an effect on the development of entheseal changes.

The differences in labour between urban and rural settlements, and the differences in labour on the basis of sex enumerated above are however mitigated by the multi-factored aetiology of entheseal changes. Entheseal changes can be affected by both genetics and sex. While the data that has been presented here could suggest that urban populations, and men performed a higher intensity or frequency of labour than rural populations, or it could simply reflect that affect that sex or different genetic pools can have on entheseal changes. Determining which interpretation is correct is only possible with further, multi-disciplinary research.

6. 2. Recommendations for future research

Firstly, as age is a large factor in the development of entheses, a more balanced sample on the basis of age could allow for more direct comparisons between the two populations. This could be achieved by excluding the lower limb entheses, as these were not useful for determining specific labours. This exclusion would allow for more older individuals to be included in the Arnhem sample. In addition, the inclusion of juveniles and old adults could be used to establish the progression of entheseal development over time. Due to the lack of labour laws, juveniles were most likely frequently performing intensive labour. It would be interesting to compare the extent entheseal changes in the juvenile populations of rural and urban settlements, to establish whether one population was beginning work at an earlier age than the other. This however would most likely need to go along side a multi-disciplinary approach to produce concrete results.

As mentioned above, a multi-disciplinary approach is essential to further research conducted on entheseal changes. This could include looking at other non-specific stress indicators to understand their relationship with entheseal changes, and to further understand the link between entheseal changes and labour. I have suggested that Arnhem has higher scores due to the higher frequency of repeated actions in factory work compared to dairy farming, therefore the higher scores are due to a higher frequency of repeated actions, rather than the performance of harder labour. Osteoarthritis, or examining the skeleton via cross-sectional geometry, could be used to establish whether it is a higher intensity of labour or a higher frequency of labour that results in a more extreme development of the entheses. This in turn can then be used to link entheseal changes to more specific actions and labours than has been possible here.

Lastly, while Arnhem was definitely an urban settlement in the post medieval period, and experience urbanisation throughout the period, it was not one of the larger centres of the Netherlands. To truly examine the difference between labour in rural settlements compared to urban settlements, it would be necessary to examine populations from larger cities of the time; such as Amsterdam, the Hague or even Leiden. These larger urban settlements can be used to examine whether there is a progression between correlation between a larger urban settlement, and if there is a more dramatic divide between urban and rural life in the Netherlands during the post medieval era.

To conclude, daily labour did differ between urban and rural settlements in post-medieval Netherlands. And furthermore, there was a difference in the labour performed by men and women in the same period. In urban populations there is ore difference in the labour performed by men compared to women, however this difference is caused by the difference in male labour. Women are performing similar labours in both the urban and rural environment, just to a higher extent in Arnhem environments. These conclusions can only be advanced upon with wider, interdisciplinary research.

Abstract

This thesis investigates the difference in daily labour between rural and urban settlements in the post-medieval Netherlands, and how this labour operates along a gendered divide. Labour in this thesis will be studied by investigating entheseal changes on the post cranial skeleton, and investigating the relationship between entheseal development, motion, and daily labour. This thesis aims to do this by studying the data from two church cemetery excavations, on rural and one urban, Keyserkerk in Middenbeemster and St Eusebius Kerk in Arnhem. Middenbeemster is rural site dating from the 17th to the 19th century, while Arnhem is an urban site, also dating from the 17th to the 19th century. The main research questions are: Was there a significant difference in labours performed in rural settlements compared to urban settlements in the Dutch post medieval era? Is there a difference between entheseal changes of men and women at Middenbeemster and Arnhem?

50 individuals from each excavation were examine, to create a sample of 100 individuals, with 25 Young Adults and 25 Middle Adults from Middenbeemster, and 16 Young Adults and 34 Middle Adults from Arnhem. The Mariotti et al method was used to evaluate 27 entheses across the post cranial skeleton, from both the left and right of the body. These results were then analysed using T-tests and Random forests, and compared with historical literature on labour during this era.

The results suggest that there was very different labour realities in urban compared to rural environments during the post- medieval era in the Netherlands. In urban environments, there is a much larger difference in movement on the basis of sex, women appear to be performing very different daily labours . On the other hand, in rural environments, there is very little differentiation on the basis of sex. This difference in labour on the basis of sex between the two settlements appears to be due to the difference in labour that men were performing. Women in both urban and rural environments were performing traditional household roles that included cooking, cleaning and weaving. Furthermore, in rural contexts they were more likely to be employed in the same industry as their male counterparts, which in the case of Middenbeemster is dairy farming. Women took on seasonal roles within farming, and as a result were performing many of the same movements as their male counterparts on a regular basis, resulting in very similar entheseal development.

In urban contexts, in Arnhem, male and female individuals could be employed in different industries, and as a result there is greater differentiation in entheseal development. The Arnhem sample overall indicates more entheseal development, with higher entheseal scores across the board. This is consistent with what historical suggests about the population examined here. The sample is from a lower-class section of the cemetery and the entheseal scores reflect the extensive labour these individuals had to perform to survive.

While the Middenbeemster sample shows lower entheseal scores, both populations clearly indicate that the majority of the population was employed in regular movement, suggesting extensive labour, with only a few outliers.

This study hopes to contribute to the study of entheseal changes, particular in their connection with labour. It demonstrates how entheseal changes can be used to study the difference in labour on the basis of both settlement and sex, as well as the nuances involved with investigating skeletal change that has such a multi-factored aetiology, and the importance of placing data in its historical context.

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Appendix

Appendix A - MIDDENBEEMSTER RAW DATA

Appendix B - ARNHEM RAW DATA

Appendix C – NORMALITY ASSUMPTION TESTS

Appendix A - MIDDENBEEMSTER RAW DATA

MIDDENBEEMSTER RAW DATA

Appendix B - ARNHEM RAW DATA

ARNHEM RAW DATA

Appendix C – NORMALITY ASSUMPTION TESTS

Normality assumption tests on raw data, showing normal distribution: