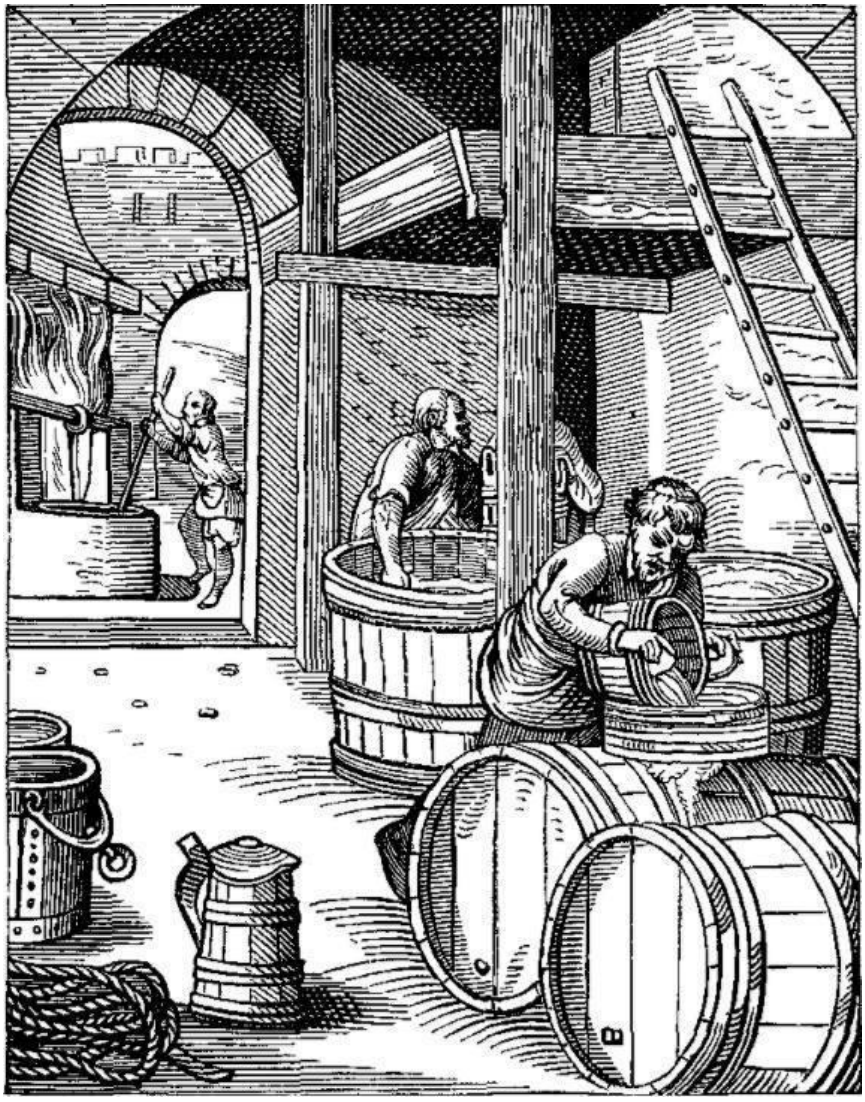
Activity patterns of a rural and urban environment in post-medieval Netherlands

A study between Middenbeemster and Arnhem using osteoarthritis



Nina Piso

Figure: Beer brewery (https://historiek.net/korte-geschiedenis-van-bier-pils-biertje/134508/

Activity patterns of a rural and urban environment in post-medieval Netherlands

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1. Introduction

1.1 Historical context

This study investigates the differences in human activity patterns between a rural environment and an urban environment in the Netherlands during the post-medieval period. These activity patterns are investigated through the use of osteoarthritis. The post-medieval period is quite a long period encompassing the late 16th century up to the end of the 19th century. Historical data shows us that the urban and rural sectors had a dependency on each other. Farming villages supplied cities with products for export, like butter and cheese, as well as raw materials for industries, like hemp, flax, and hop, at least this is the case in the silt and clay landscapes in the north of the Netherlands. The sand landscapes in the middle, east, and south of the country show something different. Here, economy based on money developed slowly (Blok 1979, 16). Much of the industries in the cities in these parts of the country were not focused on producing for export, but rather for supplying for its citizens and the occupants of its surroundings (Blok 1979, 118). Cities during that period had very specialized industries, Leiden, for example, was focused on wool industry, while Schiedam had many distilleries. This, however, does not mean that every city had only one type of industry. There were many other industries, like sugar refineries, paint production, and ship building (Blok 1979, 119-123). This difference in production between the cities is also true for the rural areas. The differences in soil play a large role in this. The provinces of Friesland, Holland and West-Utrecht were mainly focused on dairy farming, Zeeland, West-Brabant, and the Zuid-Hollandse islands cultivated multiple crops in rotation like grains, legumes, and madder. More to the east, in Gelderland, East-Utrecht, and the Veluwe, we see cultivation of potatoes, as well as a big focus on tobacco production (Blok 1979, 18, 29, 41).

Moreover, there were differences in activity between the men and women of both environments. Women´s participation in the work force has not been a heavily researched topic in the Netherlands (Dekken 2010, 18). It is known that both in the city and on the countryside women ruled the household, cleaning the house as well as taking care of the children, the old, and the sick. Besides this traditionally women's work, some females, often widows or old spinsters, were involved with more labour intensive work.

In the cities they were often a part of the production process in factories, and, in the rural sector they helped managing the land. A big farming industry in rural areas was dairy farming. In this branch it is likely that women helped with the preparation of the dairy, for example, churning butter, since this was very much a women's job (de Vries and van der Woude 1995, 690). In certain cities, the beer brewery sector was a big industry in which women played a role. Before beer brewing became an industry, it was a job which was part of the women's household. This household practice came to a stop at the end of the Medieval period, it then became an industry mainly dominated by men (van Dekken 2010, 34). However, there are still cases known where women were active in the beer brewery business, very often widows inheriting the breweries from their late husbands or less often as employees (van Dekken 2010, 36-37). The remainder of women active in the brewery sector were often more involved in selling and pouring of beer rather than its production, these women were more often unmarried women rather than widows (van Dekken 2010, 158).

This historical data does suggest a difference in labour between the city and countryside. Cities were mostly industrialised, the countryside remained liable on agriculture, although there was also a dependency between the two sectors. Moreover, there appear to be clear differences between men and women. However, what the literature fails to answer, is the physical strain and impact this labour had on the human body. This information can be vital in knowing if one environment was particularly harder or more demanding than the other environment. A way to obtain this information is through studying the skeletons of the people living and working in this period and environment. Osteoarchaeologists are able to reconstruct certain parts of the lives of past populations through their bones. These skeletal remains can give information on sex, age-at-death, stature, and pathology, and combines it with economic, social, and cultural aspects of the living environment of the individual (Schats 2016, 2). This research in particular uses specific markers on the bones in order to recognise the disease of osteoarthritis. Osteoarthritis is a degenerative joint disease affecting the synovial joints which allow movement for any mammal. Simply put, osteoarthritis development starts with the deterioration of the articular cartilage and eventually affects the underlying bone surface. This leaves markers on the bone surface that often remain observable in archaeological context. There are many factors attributing to this disease, like body weight, age, and genetics, to name a few, however, the factor that contributes most to the development of osteoarthritis is mechanical stress i.e. mechanical loading. This is due to the fact that osteoarthritis needs movement of the joints in order to develop. Therefore, it is possible for osteoarchaeologist to use this disease in order to research and make a link to activity patterns of the past (Schats 2016, 43). Which is what this research aims to do.

1.2 Research questions

As discussed, the historical literature can give us a certain level of information on activity patterns in a post-medieval Netherlands. However, this does not provide us with information on the impact on the body and the differences between rural and urban environments. In this study, the disease of osteoarthritis will be used to investigate the differences in activity patterns between a rural and an urban environment. This leads to the following research questions.

The main research question is:

- What can be concluded about differences in activity patterns between a rural environment and an urban environment through the study of osteoarthritis?

The following sub-questions have been formulated in order to distinguish these differences further:

- What are the differences between men and women in osteoarthritis prevalence, both within and between environments?
- What differences are observed in the number and type of affected joints, both within and between environments, and what does this say about specific activities?

1.3 Approach

1.3.1 Material

For this research, comparison will be made between the rural site of Middenbeemster and the urban site of Arnhem, in order to research the differences in activity between two different environments. Both these collections have been found in cemeteries adjacent to churches. The cemetery of Middenbeemster was located at the south-side of the church (Hakvoort 2013, 11), in contrast to the cemetery of Arnhem, which was located on the northside of the church (Baetsen *et al.* 2018, 38). Cemetery location can be an indication of class, but in this case, the vast majority of the Beemster municipality was middleclass, this means that it is highly likely that most of the interred individuals in this cemetery belonged to this working class (Saars *et al.* 2017, 3). The placement of the cemetery in Arnhem on the northside, however, is probably an indication that it was reserved for the lower working classes of city society (Baetsen *et al*. 2018, 38). This means that these two collections can be well compared, because these individuals come from roughly the same ranks of society.

The village of Middenbeemster, situated in the province of Noord-Holland, is known to have been a dairy farming community in which the vast majority of inhabitants was active. Here the modernization and mechanization of the Industrial Revolution arrived quite late, this means that the working class did not have machines available, but rather had to do their work with manual labour (Palmer 2019, 18). Labour of the working class in the city of Arnhem, in the province of Gelderland, is not as well-known as that of Middenbeemster, because its industry was less focused on export making it less interesting for historical research. However, there is mention of Arnhem dabbling in decorative pottery, which is much more associated with the city of Delft, and in the production of paper. These two industries, however, were not as prominent as in other cities in the Netherlands. The same goes for the tobacco industry. As mentioned, the agriculture in Gelderland had a focus on tobacco, Arnhem had only one prominent tobacco factory able to compete with the factories in Amsterdam (de Vries and van der Woude 1995, 361, 368, 384). Besides these three smaller industries, Arnhem was more known for their beer brewing industries, in which much of the working class was active (Baetsen *et al.* 2018, 34).

The cemetery of Middenbeemster was in use from AD 1615 until 1866. During excavation, the archaeologists were able to uncover well over 400 primary burials (Hakvoort 2013, 11-12). However, these graves are not all suited for this research. In total, this study uses 211 individuals based on specific criteria. The cemetery of Arnhem was in use for a longer time frame than the cemetery of Middenbeemster. Its first interment was in AD 1444 and its last was in the year 1829 (Baetsen *et al.* 2018, 38). This longer use comes with a higher number of burials, in total they uncovered over 800 burials. Here, again, the same set of criteria were used in order to create an assemblage of 230 individuals fitting the needs for this research.

1.3.2 Methods

This research into the differences in activity patterns in city and countryside, makes use of datasets procured by the osteoarchaeologists working on the skeletal remains of the sites. These analysed datasets contain extensive amounts of information not needed for this particular research. Therefore, smaller datasets have been assembled fitting the needs of this research. The following data is extracted from the datasets; individuals from the post-medieval period, the sex of the individuals, and presence of osteoarthritis, both per individual as per joint.

The analysed datasets have been procured by different osteoarchaeologists, therefore, it is possible that analysis for estimating sex and the determination of osteoarthritis, could have been done using different methods. It is necessary to explore these methods in order to see if the datasets are compatible enough to be able to make a good comparison.

The used datasets will be analysed and statistical analysis will be performed. The results of this statistical analysis will provide the answers to the aforementioned research questions.

1.4 Thesis structure

This thesis is divided into six chapters. Chapter 2 will discuss what osteoarthritis is, how it is formed, what factors are associated with its formation, and how can it be recognised in the human skeleton and how activity can be inferred from it. Chapter 3 will cover the materials and methods used in this thesis. The results of the skeletal analysis will be discussed in chapter 4. Here, tables will be presented that show the amount of women and men with osteoarthritis within and between both environments as well as tables that show in which joints are the most affected. Chapter 5 will provide a discussion on the results of the skeletal analysis. The final chapter, chapter 6, will give a conclusion on this study and will provide answers to the aforementioned research questions. Furthermore, it will discuss possibilities for future research.

2. Osteoarthritis and activity

2.1 Introduction

In this research the joint disease osteoarthritis will be used to look at the differences in activity patterns between an urban and a rural environment in the Netherlands. Therefore, this chapter will focus on explaining this disease. It will first describe the characteristics and processes of osteoarthritis and how it can be observed in the bone, then it will discuss its aetiology. Lastly, this chapter will provide examples of previous research in order to provide an understanding of how this disease can be helpful in studying activity patterns of past populations.

2.2 Osteoarthritis

2.2.1 Characteristics of osteoarthritis

Osteoarthritis is a degenerative joint disease that affects all mammals with synovial joints. The synovial joint (fig. 2.1) is characterised by holding the two ends of articulating bones in place with a capsule. The capsule consists of a inner layer, the synovial membrane, and the outer layer which is fibrous tissue. It is laced with blood vessels, nerve endings and lymphatics (Waldron 2009, 24). Covering the articular surfaces is the hyaline cartilage, in contrast to the fibrous tissue, this cartilage has no blood vessels or nerve endings. This cartilage makes it possible for the bones to move without causing any pain or discomfort (Larsen 2015, 179). A lubricating synovial fluid that fills the space between the articulating bones make the synovial joint even more mobile. All of this makes it possible for a mammal to move and have stability at the same time. Synovial joints are the most common joint type the human skeleton and are also affected by disease more than any other type of joint (Larsen 2015, 179). Examples of such joints are the knee, hip, and elbow (Schats 2016, 42).

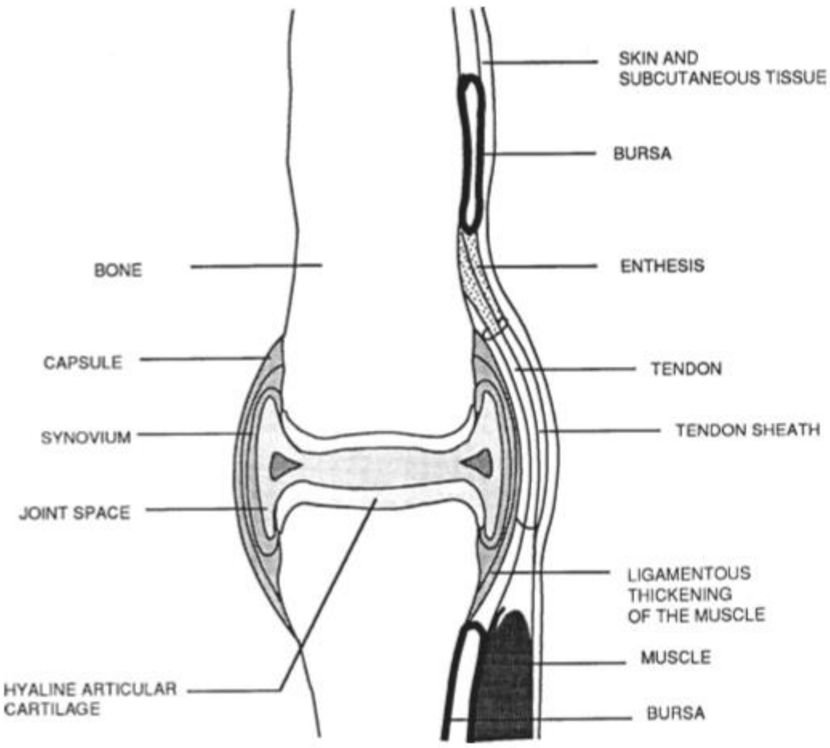

Figure 2.1: A normal synovial joint (Waldron 2009, 26).

Osteoarthritis is a process that can be broken down into a couple of different phases. It starts with the thinning and eventual loss of the hyaline cartilage covering the articular surfaces. This thinning and loss of the cartilage can be assigned to three stages. In stage one, the enzymes in the cartilage matrix break down. During stage two the cartilage starts to fibrillate both horizontally and vertically, causing the surface to become eroded. Due to the erosion, fragments of collagen and proteoglycan (protein in cartilage matrix) are released into the joint cavity and this, in turn, initiates stage three. The fragments causes the synovial membrane to become inflamed and produce inflammatory cytokines, which leads to a further breakdown of the cartilage (Waldron 2009, 27).

As a result of the loss of cartilage, some stability of the joint is lost. In an effort to stabilise the joint, the body reacts by creating new bone. This bone can be formed around the joint margin in the form of bone spurs, which are called osteophytes, or it can be formed on top of the joint surface. In addition to this, the contour of the joint can be altered, it can become more flat and wide than you would see in unaffected joints. Lastly, a phenomenon called eburnation is often produced. Now that the cartilage no longer separates the articular joints, there is bone-to-bone contact between the two bones. Eburnation leaves a highly polished area on the joint surface that can be easily differentiated from non-eburnated areas. This highly polished area can also be scored or contain some small grooves in the direction of movement due to the presence of small debris or crystals. All these reactions of the body to the loss of stability; osteophytes, new bone formation on the joint surface, joint contour alteration, eburnation, as well as pitting or porosity of the joint surface, is what can still be seen in the skeleton after burial (fig. 2.2). These processes make it possible to diagnose osteoarthritis. It is, however, not necessary to have all of them present in order to be classified as osteoarthritis. When either eburnation is present, or, two of the smaller characteristics, osteophytes, new bone formation on joint surface, contour change, and pitting of the surface occur, a joint can be said to be affected by osteoarthritis (Waldron 2009, 27-28; Schats 2006, 43).

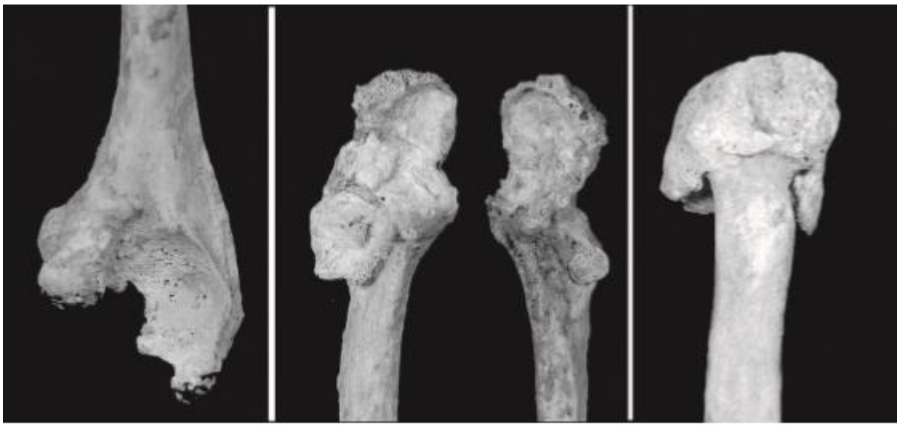

Figure 2.2: New bone growth, marginal osteophytes, and eburnation on the humerus (left), ulnae (centre), and radius (right) (Larson 2015, 182).

2.2.2 Aetiology of osteoarthritis

With the exception of dental disease, osteoarthritis is the most common pathological condition found in human skeletal remains (Waldron 2009, 26; Schats 2016, 43). A numerous amount of factors can be associated with the development of this chronic disease. These factors include age, ancestry, genetics, sex, body weight, living environment, and mechanical stress (Waldron 2009, 28). The probability of occurrence increases with age, it is highly unlikely that a person of very old age still has a healthy set of joints. Over the age of 40 years, osteoarthritis is more likely to affect the individual. There are certain studies that have shown that racial differences as well as genetics can have an influence on the occurrence of osteoarthritis. Genetics can play a role in the bone and cartilage formation as well as the joint contour and muscle strength. Racial differences can be connected to the body weight in different ethnic groups. In countries where the rate of obesity is lower, the rate of osteoarthritis is also lower (Waldron 2009, 28; Arden *et al.* 2008, 11). The factor that is most important and contributes most to the developing of the disease, however, is the mechanical stress (Larsen 2015, 179). As Waldron (2009, 28) states; "*joints that do not move, do not develop osteoarthritis.*" Movement of the joint is therefore key in the development of osteoarthritis. Consequently, the study of osteoarthritis has the ability to research past human activities and their patterns of activity. Different mechanical loading, due to the differences in occupation, can show differences in the patterns of osteoarthritis (Schats 2016, 43). When researching osteoarthritis, however, it is important to realise that a direct link between the condition and a specific physical occupation cannot be made. As stated earlier, there are numerous factors that can be the cause of osteoarthritis and it is almost never just the one factor, but a combination of factors (Waldron 2009, 28). This means that it is nearly impossible to award a specific occupation to the individual based on the joint disease, but the disease can be used to look at activity patterns in a more general sense (Schats 2016, 43) and this is also what this thesis aims to do.

2.3 Previous archaeological research

Several studies have been conducted to study the activity patterns of past populations by investigating the occurrence and distribution of osteoarthritis in skeletal human remains. These investigations have been able to support the use of osteoarthritis for research into activity patterns. For example, Schrader (2012) has used osteoarthritis to examine the impact of the Egyptian expansion by looking at the levels of activity in skeletal remains from the site of Tombos. She found a low frequency of individuals affected with osteoarthritis. This could be an indication that the residents of Tombos did not engage in much physical activity. This correlates with the hypothesis that Tombos was an administrative centre for the Egyptian state (Schrader 2012, 67-68).

Cheverko and Bartelink (2017) used differences in activity levels within hunter-gatherers to investigate the subsistence transition in North-America. Over half of the studied individuals exhibited the presence of osteoarthritis, with a high occurrence in the hips. The increase of osteoarthritis in the hip of both females and males through time, elucidates the impression that mobility increased in order to provide for food (Cheverko and Bartelink 2017, 335-337).

A study by Zhang and colleagues (2017) used the prevalence of osteoarthritis to study the division of labour between sexes and specialized occupations at Yinxu, China, during a period of early urbanization. In order to do this, they examined collections from two different sites at that region (Zhang *et al.* 2017, 2). Especially the upper limbs showed a higher prevalence of osteoarthritis in men than in women, suggesting men were more involved in heavy labour intensive work. A comparison between the two sites showed that one site might have had more strenuous activity than the other (Zhang *et al.* 2017, 13-14).

Some Dutch studies on the subject have also been conducted. Schats (2016) has used rural and urban medieval populations from the Netherlands to study the socioeconomic developments in the medieval period (Schats 2016, 1). A part of that study investigated the activity patterns, using, among others, osteoarthritis. She found that the separate comparison of specific joint groups and of men and women show significant differences, indicating that physical activity changed through the medieval period for both men and women (Schats 2016, 187).

Palmer *et al.* (2016) used osteoarthritis in order to investigate the variety in activity patterns between social status as well as between sexes. This was done with the collection of the rural village of Middenbeemster in the Netherlands (Palmer *et al.* 2016, 79). The lack of differences in prevalence of osteoarthritis between men and women suggests that they both engaged in similar strenuous activities. In addition they compared their results to similar studies in the Netherlands, of which two were studies of Dutch cities. Both showed that the prevalence of osteoarthritis in Middenbeemster was higher, suggesting more labour intensive work (Palmer *et al.* 2016, 83-84).

These studies are good examples of how, although osteoarthritis is a multifactorial disease, it is still highly usable in the reconstruction of activity. These studies used osteoarthritis to investigate a division of labour between sexes and between social status, as well as a progression of labour intensity through time. It can also be used to show the differences in activity between sites. Consequently, osteoarthritis is a good marker for this particular research into the differences in activity patterns between a rural and an urban environment in a post-medieval Netherlands.

3. Material and methods

3.1 Introduction

This chapter will discuss the skeletal collections used for this study to investigate the difference in activity patterns between a rural and an urban context and the methods used for the analysis. First, the two sites will be discussed in a historical site context and the excavation history of the sites will be addressed. The selection of the used data is also discussed. After this, the methods section will discuss the methods employed for both collections to estimate sex and age-at-death, as well as how osteoarthritis was determined. Finally, this chapter will give insights into how the selected data has been analysed.

3.2 Material

The materials will be discussed per site, first it will provide some context to the sites and then it will continue with giving some background into the particulars of the excavation. First the rural site of Middenbeemster will be discussed and next the urban site of Arnhem.

3.2.1 Middenbeemster

3.2.1.1 Site context

The small village of Middenbeemster lies in the Beemster municipality in the province of Noord-Holland, as seen on figure 3.1. This Beemster municipality is a polder with the village of Middenbeemster in the centre and the hamlets of Noord-, Zuid-, and Westbeemster, and farmsteads surrounding it in an area of around 70 km2 (Saars *et al.* 2017, 3). UNESCO has made this polder a world heritage site in 1999 due to the uniqueness of the design of the polder in to square plots. In AD 1613, the town was founded. In order to live in this polder the marshy lake was drained and the land was elevated by the settlers in the period four years prior (Palmer 2018, 17). The main kind of labour was centred around dairy farming. A sexual division of labour was in play in this region. The men would most likely work on the pastures and the women would milk the cows, churn butter, make cheese as well as manage the everyday household. It appears that besides this sexual division there was not really a large division in classes.

Although research does suggest that individuals of all classes lived in the Beemster municipality the vast majority was middle class (Saars *et al.* 2017, 3).

Figure 3.1: Location of Middenbeemster

Originally, five churches were supposed to be constructed in the Beemsterpolder, but eventually only one of those churches was build. In 1618, the build of the church in Middenbeemster commenced. The build was assigned to Hendrick de Keyser hence its final name; Keyserkerk. In the summer of 1623, the church was ready to be used. Both the church and the surrounding area were used for burial, not only for inhabitants of Middenbeemster but the deceased from the entire polder were interred here. It is highly likely that the burials inside the church were reserved for higher class people or the people that could afford it. Although the church was only ready in 1623 the cemetery was already in use before the construction in 1615. The burials inside the church stopped in 1829 and everyone had to make use of the cemetery outside of the church that was located on the southside until the year 1866 when a different cemetery in Middenbeemster was put into use due to new laws (Hakvoort 2013, 11-14).

Figure 3.2: Trench with uncovered burial on the foreground (Hakvoort 2013, 16).

3.2.1.2 Excavation history

The skeletal collection used in this research comes from the cemetery located outside of the Keyserkerk. This cemetery was in use from AD 1615 – 1866, but the majority of the skeletal remains uncovered date to the period between 1829 and 1866. The cemetery was excavated in 2011 by a collaboration between the Laboratory of Human Osteoarchaeology Leiden University and Hollandia Archeologen. The reason this excavation commenced, was that the church wanted to build an extension on the southside of the church. However, when the build started a large amount of skeletal remains in several layers was found. Therefore, it was established that archaeological research had to be conducted before construction could continue. On the 13th of June 2011, the project started and on the 5th of August the work was finished. In total, they were able to uncover well over 400 graves. With the buried individuals certain artefacts of ceramic, metal, glass and bone were found. A small portion of individuals remain in situ since they were not in the area assigned for the new construction (Hakvoort 2013, 11-12, 35; Palmer 2019, 17; van Spelde and Hoogland 2018, 309).

Figure 3.3: Uncovered burial (Hakvoort 2013, 33).

3.2.3 Arnhem

3.2.3.1 Site context

Arnhem is the capital of the province of Gelderland in the east of the Netherlands (fig.3.2). This town first appears in Dutch history under the name of 'Arneym' in 893 on a document. This document was a deed of possessions of the Sint-Salvator Abbey in Prüm. This abbey, located in Germany, owned the land the Sint-Maartenskerk, which was the predecessor of the Eusbiuschurch, was located on. The church had to pay the abbey one pound every year. Not only the church had to pay taxes, but the farmers occupying the east bank of the Sint-Jansbeek also had to pay taxes. This land was also owned by the Prüm abbey (Smit and Wientjes 2006, 337; Baetsen *et al.* 2018, 34). In 1233, this small settlement obtained its city rights granted by count Otto II. In order to protect this newly established city, walls surrounding the city were built in 1300 and in 1550, a harbour with connection to the Rijn was a fact (Haak 1933,32).

Figure 3.4: Location of Arnhem

Arnhem was able to substantially grow, with 10.000 residents at the end of the 18th century, and it became the capitol of the then-called province of Gelre (Roelofs 1995, 7; Baetsen *et al.* 2018, 34). The Sint-Jansbeek, a creek running through the town, was of significant importance for the people of Arnhem. In the 14th century it got channelized, and it was the populations main source for water. As a source of water it also powered the local work, like leather production and beer breweries. The importance of the Sint-Jansbeek however vanished when a road got build over it and it went underground. It became the first sewer of the city (Baetsen *et al.* 2018, 34).

The cemetery, called ‘Oude Kerkhof’, north of the Eusebiuschurch has been in use since around 1444 and stopped being in use in 1829 when cemeteries had to be moved outside of the city limits. Historical evidence suggests that cemeteries on the northside of churches were reserved for the lower class of society. The northside caught no sunlight, making it the cold side in combination with the Biblical view that the door on the northside of churches was reserved for heathens, sinners and plagues. These views made the northside an undesirable location and therefore affordable for the lower working classes of societies (Baetsen *et al.* 2018, 38; van Oosten 2019, 155, 163). It is highly likely that the interred in ‘Oude Kerkhof’ were members of the working classes.

3.2.3.2 Excavation history

At the end of the 20th century, the south of the inner city was in decline, therefore a project was started in 2011 to give this area a boost. Besides constructing new buildings, an effort was made to bring back some elements of the historical old city. This included bringing back the Sint-Jansbeek that was taken underground. This project of building and rebuilding went hand in hand with archaeological research. During the excavation that took place between February and September 2017, city walls and buildings, the old watercourse of the Sint-Jansbeek, and foundations of the former Minderbroedersklooster were uncovered. Most importantly for this research, on the North side of the Eusebius church, trench 10 was opened which uncovered a cemetery where the skeletal collection used for this study comes from (Baetsen *et al.* 2018, 36).

A combination of contractors GMB-Hoornstra, municipality Arnhem and RAAP, widened the trench and scaled up the excavation due to the expectations of many burials and the limited amount of time. In total they were able to recover around 700 burials, this only includes the primary burials. This means that this was the original place the deceased were put to rest and that they were not relocated. However, of those 700 burials, only about half of them were complete individuals. This was probably because the burials were not indicated, therefore, it is possible that they buried individuals in places other individuals were already buried. (Baetsen *et al.* 2018, 36).

Figure 3.5: Two uncovered burials (Baetsen et al. 2018, 40).

3.2.4 Data selection

For this research, a selection of the excavated individuals was used. Even though the Middenbeemster collection uncovered well over 400 burials, only 211 individuals were selected for the purpose of this research. The non-adults have been removed from the database for this research, since osteoarthritis is not a common disease in non-adults. The burials date from the period between 1615 and 1866, which is the period this study examines. Therefore, no individuals have to be filtered out of the dataset based on date. Lastly, this is a study where synovial joints are key. Only individuals with one or more synovial joints present are included in this database. Of the remaining 211 individuals, 108 individuals were estimated to be male, 98 were female, and for five individuals it was not possible to give a sex estimation deeming them of indeterminate sex.

In total the Arnhem collection has over 800 individuals. This research does not require all of these individuals, therefore it was filtered. First of all, this research only looks at adults over the age of 18. Next, this cemetery dates back further then post-medieval, therefore older individuals were filtered out. The individuals dating from 1650 to 1829 were used for this study. Similar to the Middenbeemster collection, synovial joints are needed, therefore, only individuals with one or more synovial joints present are included. After these requirements, the collection used for this research totals to 230 individuals, of which 90 individuals are male, 89 are female, and the remaining 51 were deemed to be of indeterminate sex.

3.3 Methods

The methods will encompass all the methods that are used by the osteoarchaeologists investigating the skeletal assemblages of the sites. Many of these methods were the same for both sites, making it unnecessary to discuss the sites separately. This chapter will also provide an insight into how the data was selected and analysed for this particular research.

3.3.1 Estimation of sex

When estimating sex there are multiple methods and bones that can be used. This is useful when a skeleton is not entirely complete, which is usually the case. The researchers of the Middenbeemster collection used a combination of multiple morphological methods as well as a few osteo-metric techniques. The guidelines from the Workshop for European Anthropologists (WEA) was used. This method scores the cranium, mandible and pelvis of the individual. The cranium, mandible and pelvis have certain traits that can be deemed more feminine or more male. These traits are scored within the interval of -2, which is hyperfeminine, and of +2, which is hypermale. These trait scores are then multiplied by the scored weight of the specific trait. These scores are added and finally divided by the sum of the weights of the individual traits (Lemmers *et al.* 2013, 36; WEA 1980, 517-521). The same traits were scored using a different method designed by Buikstra and Ubelaker (1994) (Lemmers *et al.* 2013, 36), they use a scale of five points. The lower end of the scale contains the more gracile and feminine features, while the higher end of the scale has the more robust, male features (White and Folkens 2015, 387). The pelvis of men and women has a very different function, which is why it is useful when estimating sex. For the Middenbeemster collection the osteoarchaeologists used a method specifically designed for the pelvis, the Phenice method. This method looks at the morphology of three specific traits in the os pubis; the presence of the ventral arc (which is only present in females), the subpubic concavity (in males it is not concave), and the medial aspect of the ischiopubic ramus (in females it has a sharp edge) (White and Folkens 2015, 397; Lemmers *et al.* 2013, 36). Lastly, they looked at the morphology of the sacrum. The sacrum in females is smaller than in males, and in addition to this, the pelvic inlets of the females pelvis is wider than in males (White and Folkens 2015, 394; Lemmers *et al.* 2013, 36).

As mentioned before, the Middenbeemster collection also used osteo-metric techniques. These techniques cannot be used for sex estimation on their own, but are merely used to support the morphological sex estimation. They measured widths and lengths of multiple bones and compared those values to standard values of men and women (Lemmers *et al.* 2013, 36).

In order to estimate the sex, the osteoarchaeologists of the Arnhem collection have used mainly the same methods as described above for the Middenbeemster collection. On the pelvis and skull they used the methods designed by the Workshop of European Anthropologists (WEA). Besides the WEA methods, the researches have also applied the Phenice traits to the skeleton as well as osteo-metric techniques (Baetsen in press).

3.3.2 Non-adult vs adult

In this research the non-adults are not included. Osteoarthritis is a disease that is highly unlikely to occur in children and adolescents. Besides this, non-adults cannot be sexed properly which is necessary for this study.

The age at death is again an estimation and is done within age groups. It is not possible to determine a specific age for skeletal elements. Both skeletal collections use the age categories; Early Young Adult (18-25 years), Late Young Adult (26-35 years), Middle Adult (36-49 years), Old Adult (50+ years). In both cases the age of the adults was estimated by looking at the wear and ossification of various elements of the skeleton. Researchers looked at the closure of the cranial sutures, the pubic symphysis, the auricular surface of the ilium, the sternal rib ends, and the fusion of multiple epiphysis (Hakvoort 2013, 37; Baetsen in press).

Although the estimation of age is available in age groups and it can produce different data, this research will not differentiate between the groups. Instead, it will regard all groups from Early Young Adult up to Old Adult as adults, due to the relative smaller scale of this research.

3.3.3 Osteoarthritis

Osteoarthritis can leave certain marks on the synovial joints that can be seen by the investigating osteoarchaeologist. These marks can be eburnation, osteophytes, new bone formation on the joint surface, pitting on the joint surface, as well as alteration of the joint contour (Waldron 2009, 33). Waldron (2009) caries the standard procedure of determining osteoarthritis in an individual. This standard determination was used for both collections (Hakvoort 2013, 40; Baetsen in press). In order for an individual to be diagnosed with osteoarthritis, the individual must either have eburnation on the joint, or at least two of the smaller criteria; marginal osteophytes, new bone formation on the joint surface, pitting on the joint surface, or alteration of the contour of the joint. With only one of the smaller criteria present the disease cannot be diagnosed, because, for example, a marginal osteophyte can also be just an age-related phenomenon instead of osteoarthritis (Waldron 2009, 33-34).

3.3.4 Data analysis

3.3.4.1 Estimation of sex

Both collections handle the five categories for sex estimation. Possible male, male, indeterminate, possible female, and female. For the purpose of this research, the possible males and possible females were grouped with the males and females to increase the sample size.

3.3.4.2 Joints

For this study the synovial joints are investigated separately as well as into two groups. The synovial joints that are used are; the temporo-mandibular joint (TMJ), this is the joint where the mandible connects with the skull's temporal bone; the acromio-clavicular joint (ACJ), this joint is located at the top of the shoulder between the acromion and the clavicle; the sterno-clavicular joint (SCJ), this joint is located between the other end (medial end) of the clavicle and the manubrium of the sternum; the shoulder, this is the gleno-humeral joint; the elbow, the synovial joint where the humerus connects with the ulna and radius; the wrist connects the distal radius and ulna with the carpals; the hand, these are the joints between the metacarpals and phalanges; the spine, the synovial joints in the spine are the facet joints; the hip, this is the joint of the femoral head in the acetabulum of the pelvis; the knee, this had three connection points, between the patella and the femur, and the medial and lateral sides of the tibiofemoral joint; the ankle, the distal end of the tibia and fibula connects with the tarsal talus; lastly, the foot, these are the joints between the metatarsals and foot phalanges. The two groups will be the upper limb: shoulder, elbow, wrist, and hand, and the lower limb: hip, knee, ankle, foot (Schats 2016, 74). These groups are made to study particular movements and activities and to increase the sample size for groups comparison (Schats 2016, 101).

3.3.4.3 Statistical analysis

In order to retrieve results from the obtained data statistical analysis is done. The goal of performing statistical tests is to determine if the observed data set is significantly different from the values that you would expect to be under the null hypothesis in order to reject the null hypothesis. The null hypothesis shows the observations that are the same as the theoretical expectation, which is usually not that exciting. In order to reject this null hypothesis, the probability value or p-value has to be calculated. This p-value shows the chance that the observed difference happened randomly. When this p-value is very small, it usually means that the observed difference was not by chance, therefore, the null hypothesis can be rejected. On the other hand, when the p-value is high, it is possible that the results were random and can therefore not be deemed statistically significant (McDonald 2009, 16-18; Schats 2016, 82).

For this research chi-squared tests were performed in order to get the p-value. In order for the difference to be significant the significance level has to be 5% or lower, meaning that the p-value is below 0.05 ($p<0.05$). This significance level is the most common in archaeological and osteological research, and therefore it is used for this research as well (Schats 2016, 82). This means that when $p<0.05$, the difference between values is statistically significant and when the p-value is higher than 0.05 the difference is not statistically significant. To study if there is a difference between the number of males and females, chi-squared tests for goodness-of-fit were run, using the theoretical expectation of a 1:1 sex ratio (McDonald 2009, 39). For the rest of the analysis, chi-squared tests of independence were used. The null hypothesis for these tests is that the values of one variable are independent from the second variable (McDonald 2009, 58).

4. Results

4.1 Introduction

In this chapter the results of the skeletal analysis will be presented per site and furthermore, it will make a comparison between the two sites in order to establish if there are any similarities or differences between the two sites. This chapter will first display results of the estimation of sex, this will be discussed per site and then a comparison between the sites will be made to highlight potential variances in sex distribution. Consequently, this chapter will continue with the results of osteoarthritis. Again, it will be divided per site and then finish with a comparison between the two sites.

4.2 Estimation of sex

4.2.1 Middenbeemster

In this study, 211 individuals were included; sex could be estimated for 206 individuals. Of these, 108 individuals were male, and 98 were female. The remaining five were of indeterminate sex, which is either due to incompleteness of the skeleton or ambiguity when estimating sex. For this research, estimations of possible males and possible females have been counted as males and females. In order to determine if there is an imbalance of the male-female ratio of the site, a chi-square goodness-of-fit test was run. The expected male-female ratio is 1:1. While there are more males than females included in this research, the difference in number of males and females is not statistically significant ($\chi^2 = 0.485$, df = 1, $p = 0.486$, $n = 206$).

4.2.2 Arnhem

Of the total of 230 adult individuals included in this research, sex estimation was possible for 179 individuals. This means that it was not possible for 51 individuals to estimate the sex. Of the 179 individuals, 90 were male and 89 were female. In this assemblage, the difference in the number of males and females is very small and not statistically significant ($\chi^2 = 0.006$, df = 1, $p = 0.940$, $n = 179$).

4.2.3 Site comparison

Figure 4.1 shows a combination of the sex distribution for both Middenbeemster and Arnhem. A combination between the male-female ratios of the two site is made to establish if there is a large difference between the two. A chi-squared test is executed here in order to see if there is a statistical difference; $\chi^2 = 0.177$, df = 1, $p = 0.674$, $n = 385$. There is are no statistical significances between the male-female ratio of Middenbeemster and Arnhem ensuring that the following osteoarthritis results are not influenced by differences in sex-ratio between the sites.

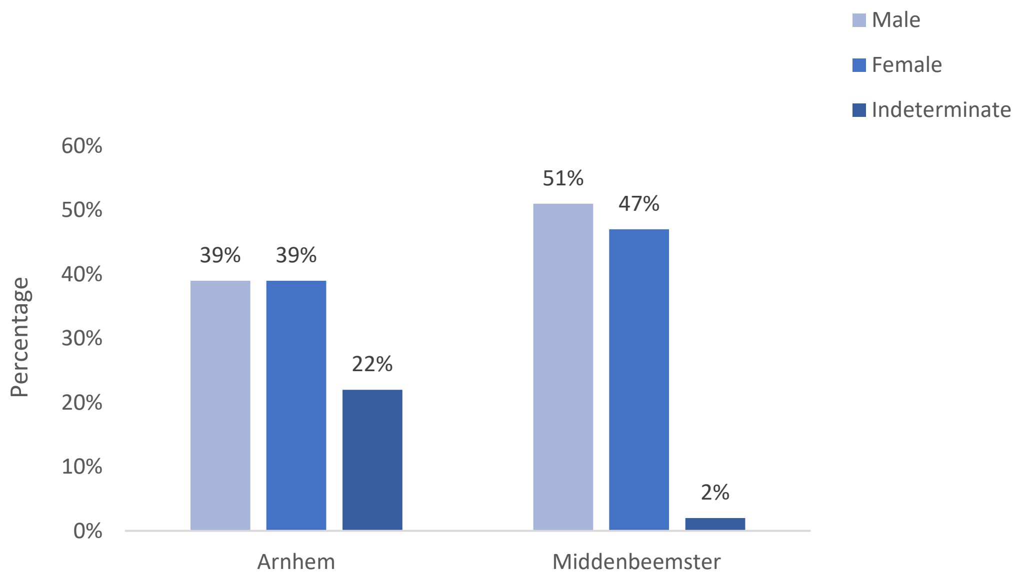

Figure 4.1: Sex distribution (%) of the collections Arnhem (n=230) and Middenbeemster (n=211).

4.3 Osteoarthritis

4.3.1 Middenbeemster

A total of 91 of the 211 individuals were affected by osteoarthritis (43.1%). Of these, 47 (43.5 %) were male and 44 (44.9%) were female, none of the indeterminate sex individuals were affected by the disease. There is no statistically significant difference in the number of males and females affected by osteoarthritis; $\chi^2 = 0.040$, df = 1, $p = 0.842$, $n = 206$. Table 4.2 shows an overview of the affected joints specifically, separated by male and female. If one joint is more frequently affected than another, it can be an indication that that particular joint was used more often and may hint at certain activity types. A total of 202 joints have been diagnosed with osteoarthritis (11.2%). The joints of the males appear to be more affected, with a total of 105 joints affected (11.2%), than the joints of the females, of which 97 joints were affected (11.1%). This difference, however, is not statistically significant; $\chi^2 = 0.009$, df = 1, p = 0.992, n = 1810. Table 4.1 shows that in both males and females, the spine is affected most. The differences between the men and women are small, apart from, at first glance, the acromio-clavicular joint and the wrist. The former is more commonly affected in the males relative to the females, and the latter is more affected in females. Interestingly, osteoarthritis of the wrist occurs more frequent in females and this difference is also statistically significant; $\chi^2 = 6.255$, df = 1, p = 0.012, n = 120.

Table 4.1: Number of joints affected by osteoarthritis per joint type in the Middenbeemster collection.

	Male		Female		Total	
Joints	**n**	**%**	**n**	**%**	**n**	**%**
ACJ	14	18.7	7	11.3	21	15.1
SJC	4	6.9	2	3.4	6	5.0
TMJ	6	7.1	7	9.5	13	8.1
Shoulder	4	4.8	5	7.0	9	5.8
Elbow	5	6.0	2	2.3	7	4.1
Wrist	1	1.5	7	13.0	8	6.6
Hand	8	12.3	6	8.7	14	10.2
Spine	38	52.8	35	51.5	73	51.8
Hip	11	12.2	12	14.3	23	13.1
Knee	3	3.4	6	7.0	9	5.0
Ankle	3	3.4	0	0.0	3	1.7
Foot	8	10.1	8	10.7	16	10.3

n = number of affected joints, ACJ = acromio-clavicular joint, SJC = sterno-clavicular joint, TMJ = temporo-mandibular joint. Total includes individuals of indeterminate sex.

Joints can also be placed into two groups, upper and lower limbs, in order to study particular movements and activities. The shoulder, elbow, wrist and hand have been placed into the upper limb group, and the hip, knee, ankle and foot are a part of the lower limbs (Schats 2016, 101). Table 4.2 shows the differences between males and females per joint group. Overall, females are affected more by the disease than males, which becomes apparent now that certain joints are excluded. For both joint groups, however, the observed differences between males and females are not statistically significant (upper: $\chi^2 = 0.286$, df = 1, p = 0.593, n = 578; lower: $\chi^2 = 0.118$, df = 1, p = 0.731, n = 676).). A chi-squared test was also run with the males and females combined in order to see if there was a significant difference between the two joint groups in general which was not the case; (χ^2 = 0.467, df = 1, p = 0.494, n = 1254). The males and females were also tested separately, to compare the upper and lower limbs. However, the differences between the upper limb and lower limb for both males and females were not statistically significant; male: χ^2 = 0.349, df = 1, p = 0.555, n = 645; female: χ^2 = 0.125, df = 1, p = 0.724, n = 609).

Table 4.2: Number of joints affected by osteoarthritis per joint group in the Middenbeemster collection.

	Male		Female		Total	
Joint groups	**n**	**%**	**n**	**%**	**n**	**%**
Upper limb	18	6.0	20	7.1	38	6.5
Lower limb	25	7.2	26	10.0	51	7.4

n = number of affected joints, total includes individuals of indeterminate sex.

4.3.2 Arnhem

Osteoarthritis was diagnosed in 151 of the 230 individuals (65.7%), of which 68 (75.6%) males and 58 (65.2%) females were affected. The remaining 25, are of indeterminate sex (49.0%). Males appear to be more affected by osteoarthritis, but this difference is not statistically significant (χ^2 = 2.316, df = 1, p = 0.128, n = 179). Here again, every joint is looked at separately. Table 4.3 shows that overall 214 joints of the men were affected (27.3%) and 149 joints of the females (22.8%). Combining these male and female joints with the joints of indeterminate sex, a total of 431 joints are affected (25.9%). Even though more men are affected than women, this difference is just shy of being statistically significant; χ^2 = 3.309, df = 1, p = 0.069, n = 1446. The acromio-clavicular joint is highly affected in males, while in the females the spine is affected most. In most of the synovial joints the males are more affected by osteoarthritis, apart from the hand and spine which are equal, and the knee, where females are more affected. The differences that stand out most are the acromio-clavicular joint and the elbow. However, only the differences in osteoarthritis between males and females in the elbow joint is statistically significant (χ^2 = 6. 417, df = 1, p = 0.011, n = 148).

Table 4.3: Number of joints affected by osteoarthritis per joint type in the Arnhem collection.

Joints	Male		Female		Total	
	n	%	n	%	n	%
ACJ	49	69.0	23	52.3	85	63.0
SJC	19	30.2	8	16.3	37	25.5
TMJ	25	36.8	23	53.3	56	39.7
Shoulder	4	7.1	7	15.9	15	12.8
Elbow	7	8.9	0	0.0	9	5.3
Wrist	7	10.1	3	5.2	12	8.2
Hand	10	16.1	10	23.8	23	20.2
Spine	41	53.9	41	57.7	98	57.0
Hip	19	23.8	12	15.6	33	18.3
Knee	2	3.2	4	6.7	9	6.1
Ankle	2	3.8	0	0.0	20	1.7
Foot	29	64.4	18	52.9	52	56.5

n = number of affected joints, ACJ = acromio-clavicular joint, SJC = sterno-clavicular joint, TMJ = temporo-mandibular joint. Total includes individuals of indeterminate sex.

Table 4.4 shows the prevalence of osteoarthritis in the joint groups of the upper and lower limb, for both men and women. For both joint groups the males are affected by the disease more than the females. Yet, when they are compared statistically, these differences are not statistically significant (upper: $\chi^2 = 0.169$, df = 1, p = 0.681, n = 479; lower: $\chi^2 = 2.679$, df = 1, p = 0.102, n = 455). Here, again, a chi-squared test was run with a combination of the males and females in order to see if there was a significant difference between the upper and lower limbs. This is indeed statistically significant, indicating that generally the lower limbs are more affected; $\chi^2 = 14.974$, df = 1, $p < 0.001$, n = 934. Males and females were also tested separately, both show a big difference between the upper limb and lower limb. The difference between the upper and lower limbs is for both sexes statistically significant; male: $\chi^2 = 11.910$, df = 1, p = 0.001, n = 505; female; $\chi^2 = 3.932$, df = 1, p = 0.047, n = 429.

Table 4.4: Number of joints affected by osteoarthritis per joint group in the Arnhem collection.

Joint groups	Male		Female		Total	
	n	%	n	%	n	%
Upper limb	28	10.5	20	9.4	59	10.7
Lower limb	52	21.8	34	15.7	96	17.9

n = number of affected joints, total includes individuals of indeterminate sex.

4.3.3 Site comparisons

Table 4.5 shows an overview of the individuals affected by osteoarthritis per site both in numbers and in percentages. Overall, it seems that osteoarthritis was more common in the city of Arnhem than in the village of Middenbeemster. A large difference can be seen between the two in the total column, which contains individuals of indeterminate sex. A total of 65.7 % of the Arnhem individuals is affected by the disease whereas only 43.1% of individuals in Middenbeemster is affected. Table 4.6 displays statistical comparisons of the affected individuals of the sites. These test were done with the males, females, and indeterminates combined, as well as males and females separately. All three of them show that there is a statistical significance between the two sites.

Table 4. 5: Number of individuals affected by osteoarthritis in the two collections.

Sites	Male		Female		Total	
	n	%	n	%	n	%
Middenbeemster	47	43.5	44	44.9	91	43.1
Arnhem	68	75.6	58	65.2	151	65.7

n = number of affected individuals, total includes individuals of indeterminate sex.

Table 4.6: Statistical comparison of the number of individuals affected by osteoarthritis in the two collections.

Site comparison	Sex	χ^2	df	p	n
Arnhem - Middenbeemster	C	22.547	1	**<0.001**	441
	M	20.695	1	**<0.001**	198
	F	7.730	1	**0.005**	187

C = all the individuals combined, M = males, F = females, n = number of individuals in the test.

Table 4.7 contains the number of joints that are affected by osteoarthritis. Arnhem still has a higher prevalence of osteoarthritis compared to Middenbeemster. Table 4.8 shows a statistical comparison between Arnhem and Middenbeemster using the number of joints that are affected. Male, female, and a combination of the sexes and indeterminates show that there is a statistical significance between them.

Table 4.7: Number of joints affected by osteoarthritis in the two collections.

Sites	Male		Female		Total	
	n	%	n	%	n	%
Middenbeemster	105	11.2	97	11.1	202	11.0
Arnhem	214	27.3	149	22.8	449	27.0

n = number of affected joints, total includes individuals of indeterminate sex.

Table 4.8: Statistical comparison of the number of joints affected by osteoarthritis in the two collections.

Site comparison	Sex	χ^2	df	p	n
Arnhem - Middenbeemster	C	141.070	1	**<0.001**	3525
	M	70.592	1	**<0.001**	1727
	F	37.741	1	**<0.001**	1525

C = all affected joints combined, M = male, F = female, n = number of joints included in the test.

Table 4.9 shows the individuals of Middenbeemster and the individuals of Arnhem affected by osteoarthritis per joint type. Overall the numbers of Arnhem are higher than those of Middenbeemster, with the few exceptions of the female elbow, wrist, knee as well as the male knee and ankle. At first glance, large differences are seen in the acromio-clavicular joint, the sterno-clavicular joint, the temporo-mandibular joint, and foot. However, chi-squared tests showed a significant difference in the shoulder and hand joints as well. The chi-squared test that were run used a combination of the males, females, and indeterminates. For clarity, all tests are put into table 4.10 , this shows that the differences between the sites in osteoarthritis prevalence in ACJ, SJC, TMJ, shoulder, hand, and foot joints are statistically significant.

Table 4.9: Number of joints affected by osteoarthritis per joint type in the two collections.

Joint	Sex	Middenbeemster		Arnhem	
		n	%	n	%
ACJ	C	21	15.1	85	63.0
	M	14	18.7	49	69.0
	F	7	11.3	23	52.3
SCJ	C	6	5.0	37	25.5
	M	4	6.9	19	30.2
	F	2	3.4	8	16.3
TMJ	C	13	8.1	56	39.7
	M	6	7.1	25	36.8
	F	7	9.5	23	53.3
Shoulder	C	9	5.8	15	12.8
	M	4	4.8	4	7.1
	F	5	7.0	7	15.9
Elbow	C	7	4.1	9	5.3
	M	5	6.0	7	8.9
	F	2	2.3	0	0.0
Wrist	C	8	6.6	12	8.2
	M	1	1.5	7	10.1
	F	7	13.0	3	5.2
Hand	C	14	10.2	23	20.2
	M	8	12.3	10	16.1
	F	6	8.7	10	23.8
Spine	C	73	51.8	98	57.0
	M	38	52.8	41	53.9
	F	35	51.5	41	57.7
Hip	C	23	13.1	33	18.3
	M	11	12.2	19	23.8
	F	12	14.3	12	15.6
Knee	C	9	5.0	9	6.1
	M	3	3.4	2	3.2
	F	6	7.0	4	6.7
Ankle	C	3	1.7	20	1.7
	M	3	3.4	2	3.8
	F	0	0.0	0	0.0
Foot	C	16	10.3	52	56.5
	M	8	10.1	29	64.4
	F	8	10.7	18	52.9

n = number of affected joints, ACJ = acromio-clavicular joint, SJC = sterno-clavicular joint, TMJ = temporo-mandibular joint. C = all the individuals combined, M = male, F = female.

Table 4.10: Statistical comparison of the number of joints affected by osteoarthritis per joint type in the two collections.

Site comparison	Joint	χ^2	df	p	n
Arnhem-Middenbeemster	ACJ	66.121	1	**<0.001**	274
	SJC	21.249	1	**<0.001**	259
	TMJ	42.335	1	**<0.001**	301
	Shoulder	4.146	1	**0.042**	273
	Elbow	0.275	1	0.600	343
	Wrist	0.250	1	0.617	269
	Hand	4.908	1	**0.027**	251
	Spine	0.847	1	0.358	313
	Hip	1.861	1	0.173	356
	Knee	0.185	1	0.667	326
	Ankle	0.000	1	0.992	294
	Foot	62.243	1	**<0.001**	248

n = number of affected joints, ACJ = acromio-clavicular joint, SJC = sterno-clavicular joint, TMJ = temporo-mandibular joint.

For both skeletal assemblages, certain joints were grouped into two categories: the upper and lower limbs. Table 4.11 shows those numbers and percentages in one table. The affected female upper limbs are similar in both collections, but this does not apply to the other groups. The other values suggest that Arnhem has a higher osteoarthritis count. To see if there is any statistical significance to the differences, table 4.12 shows the outcome of the chi-squared tests that were run. Apart from the male and female upper limb, they are all statistical significant.

Table 4.11: Number of joints affected by osteoarthritis per joint group in the two collections.

Sites	Joint group	Males		Females		Total	
		n	%	n	%	n	%
Middenbeemster	Upper	18	6.0	20	7.1	38	6.5
	Lower	25	7.2	26	10.0	51	7.4
Arnhem	Upper	28	10.5	20	9.4	59	10.7
	Lower	52	21.8	34	15.7	96	17.9

n = number of affected joints, total includes individuals of indeterminate sex.

Table 4.12: Statistical comparison of the number of joints affected by osteoarthritis per joint group in the two collections.

Site comparison		Sex	χ^2	df	p	n
Arnhem - Middenbeemster	Upper limb	C	6.633	1	**0.010**	1136
		M	3.776	1	0.052	564
		F	0.819	1	0.365	493
	Lower limb	C	31.419	1	**<0.001**	1224
		M	26.261	1	**<0.001**	586
		F	8.176	1	**0.004**	545

C = all affected joints combined, M = male, F = female, n = number of joints included in the test.

4.4 Summary

4.4.1 Summary sex distribution

Both sites showed a higher prevalence of osteoarthritis in males than in females, however, this was not statistically significant for either of the sites. A comparison between the two sites also showed there was no statistically significance. This means that the results of the osteoarthritis data was not influenced by the differences in the sex-ratio.

4.4.2 Summary osteoarthritis

The results showed that osteoarthritis is more common in the city of Arnhem (65.7%) than in the village of Middenbeemster (43.1%). This difference in numbers is statistically significant, this shows when the sexes are combined, as well as when males and females are compared separately. In both Arnhem and Middenbeemster osteoarthritis is more common in males than in females, however, within both sites this difference is not statistically significant. When the joints are studied separately as well, this again shows a higher prevalence in Arnhem, with statistical significance in inter-site comparison. Certain joints show a statistical significant difference between the sites. Lastly, the upper and lower limbs have been tested. The differences between upper and lower limbs for both sexes are not statistically significant for Middenbeemster, it is, however, statistically significant for Arnhem. A comparison between the two sites showed that especially the differences in lower limbs of both sexes are statistically significant.

5. Discussion

5.1 Introduction

This research has investigated the differences in activity patterns between a rural and an urban environment in the post-medieval period in the Netherlands using an analysis of osteoarthritis. Chapter one discussed the written and historical data on this subject, showing the different occupations of city and countryside in the Netherlands. However, this historical literature does not mention the impact of labor on the body. The analysis done on the skeletal remains of the two different collections can provide a new perspective on the activity patterns of rural and urban populations in a post-medieval Netherlands.

This chapter will discuss the results of the analysis done on the skeletal collections while combining it with the historical context provided in the previous chapters. The two skeletal assemblages will be discussed separately, with a discussion of the male and female differences and the upper and lower limbs differences as well. It will then continue with discussing the comparison between the rural and urban collections, again discussing the males versus females and upper versus lower limbs differences. Lastly, it will also discuss the limitations of this research.

5.2 Activity and osteoarthritis

5.2.1 Rural assemblage of Middenbeemster

The Middenbeemster skeletal assemblage shows that a total of 43.1% individuals habe been affected by osteoarthritis. This high percentage of affected individuals coincides with the believe that Middenbeemster was a dairy farming community only implementing machines and mechanical instruments quite late into the Industrial Revolution and, thus, physical manual labour was still very important for a long period of time (Palmer 2019, 18).

In both males and females there is a high prevalence of spinal and hip osteoarthritis. The difference in percentages between men (in spine 52.8%; in hip 12.2%) and women (in spine 51.5%; in hip 14.3%) are not large, meaning that, albeit they likely performed different tasks, these tasks were likely equally heavy and strenuous on the hips and the spine. In the spine, the affected facet joints play a big role in supporting mechanical load as well as in the rotation of the spine. They support up to 40 to 65% of rotational and shear forces and up to 25% of axial compressive forces (Bezci *et al.* 2018, 2266). Movements that cause these forces and often associated with spinal osteoarthritis are, heavy lifting from the ground up, altering positions of the body (i.e. lying to sitting, sitting to standing), and upper body flexion, like bending (Rohlmann *et al.* 2014, 8). Hip osteoarthritis is associated with similar movements like the ones that affect the spine. The most strenuous movement is heavy lifting. Bending and twisting, as well as doing heavy work whilst standing, are some other commonly associated movements (Gignac *et al.* 2019, 391; Allen *et al.* 2010, 847). These movements can be explained by typical agricultural tasks, for example, carrying hay, pushing ploughs, fertilising the soil, milking cows, and for the women also pouring the milk from one vessel to another during the process of producing butter and cheese (Boekel 1929, 38-41).

Additionally, the acromio-clavicular joints of these individuals are highly affected. The occurrence of osteoarthritis in this joint is associated with heavy lifting and over the head activities (Menge *et al.* 2014, 325). In this farming community this can be caused by carrying hay and other food, or perhaps from carrying the butter and cheese up on their shoulder to and from the market (Boekel 1929, 50).

Male-female differences

The most interesting difference between men and women is seen in the prevalence of osteoarthritis in the wrist. The women have a high percentage of 13.0% wrist osteoarthritis in contrast to a low 1.5% in men. This suggests that in post-medieval rural life there was a certain task or even multiple tasks assigned to the duties of women which was demanding on their wrists. Part of women’s job description was the preparation of the dairy (de Vries and van der Woude 1995, 690). Making butter was one of those preparations, which was not a light task and consisted of multiple steps. Right after milking the cows, the collected milk was strained through a sieve and put into shallow barrels in order to cool off and to separate the cream from the milk. The cream was then scooped off with a special spatula and put into a different barrel, until the cream became acidic as well as thicker. After this process, the cream was again poured into a different vessel and the churning of the butter could commence. The women churned the butter using a stick with a plate with holes attached to the bottom. They beat the butter using up and down motions. The last step was to squeeze out as much of the water and leftover milk liquids from the butter using their hands. Making cheese was also done by the farmers wives. The process of cheese making also consisted of a lot of physical work with the hands, it involved stirring, kneading and pushing (Boekel 1929, 41-44). All these steps are demanding for the wrist, which can explain why women are more affected than men in the wrist, since the men did not engage in these tasks.

Upper vs. lower limbs

Middenbeemster does not show an interesting difference between the upper and lower limbs. The lower limbs are affected more than the upper limbs in both males and females, but this is hardly significant. This can mean that activity was equally strenuous on both the upper and lower limbs. What these limb groups do show us is that when removing the spine, the acromio-clavicular joint, the sterno-clavicular joint, and the temporo-mandibular joint, women have a higher osteoarthritis prevalence than men in both limb groups.

5.2.2 The urban assemblage of Arnhem

The urban sector of Arnhem shows an even higher percentage of affected individuals than the rural sector of Middenbeemster. A total of 65.7% of the researched individuals have been diagnosed with osteoarthritis. It is believed that the interred individuals of this assemblage belonged to the lower working class due to the placement of the cemetery on the northside of the church (Baetsen *et al,* 2018, 38). This high percentage of individuals affected by osteoarthritis is a good indication that these individuals took part in much hard and strenuous work likely reserved for the lower working class of this cities society.

Just like in the rural assemblage, the spine is the joint that is affected most by osteoarthritis, with a total of 57.0% of joints affected. In the industrial sector the activities likely consisted of lifting and bending (Rohlmann *et al.* 2014, 8). The hips are also affected, albeit in a lower, but still noticeable percentage (18.3%). Again, this is associated with heavy lifting and carrying heavy load while standing (Gignac *et al.* 2019, 391; Allen *et al.* 2010 ,847). In the process of brewing beer there are many stages and every ingredient as well as appliances had their own place inside the factory. For example the grain was initially stored in an attic. Once ready to use, it had to be brought down, cleansed, sieved, sprout, brought up to a different attic in order to dry (van de Venne 2008, 40). All these tasks meant that the grain and other ingredients had to be moved from place to place in order to be processed, which was probably strenuous on the spine and hips. Individuals working in a brewery also had to bend over the kettles in order to stir the mixtures, making it strenuous on the spine (Unger 2001, 108).

Besides the spine and hips, the feet in both men and women are heavily affected (56.5%). During activities that are weight-bearing, like walking, standing, and stair climbing, the mid-foot bones distribute these loads (Arnold *et al.* 2019, 660). There is no evidence suggesting that the lower class of society had to go up and down stairs much. In fact, their houses were usually only one story high, except for the occasional attic used for storage (Klep 2009, 153; Wijsenbeek-Olthuis 1987, 223). Inside of the brewery most of the work was done on the ground floor. The stairs that were present were to access the attics where the grain and hop were stored (van de Venne 2008, 39-40). Therefore, it is likely that the presence of foot osteoarthritis in the men and women was mostly due to walking and standing, and going up and down the stairs was not a daily activity. A lot of the houses in the poorer parts of the city did not have drinking water readily available, rather, women had to walk far in order to get water (Klep 2009, 152). In the brewing industry there were a few jobs that were typically executed by women. There were the 'wringsters', these women stood up on their feet for most of the day while stirring the malt with hot water (Unger 2001, 160). Women also performed the job of 'Joncwijf', these were women active in helping out in every aspect of the brewing process, meaning that they probably walked around a lot (van Dekken 2010, 110). Women were also active outside of the brewery in the form of serving beer. Women are often associated with working in inns, because those jobs resembled household activities. There were also women that sold beer on the streets (van Dekken 2010, 150). This meant that they were again up on their feet most of the time. Men were, most likely, up on their feet during their tasks as well, both inside and outside of the breweries. Men moved the ingredients from place to place in order to be processed, fires had to be started and maintained for the boiling processes and mixtures had to be stirred (Unger 2001, 110). Besides these jobs inside the factory, there were also different occupations associated with the beer industry. For example there were carpenters, beer carriers, blacksmiths, and men who fetched the needed water (van de Venne 2008, 34). All these tasks involved standing for long periods of time and walking a lot.

Male-female differences

Almost every type of joint is more affected in males than in females. However, the elbow is one joint where osteoarthritis is significantly more present in males than in females. In women the elbow is 0.0% affected, while in males it is 8.9%. This is not a high percentage in contrast to the other joint. However, it is interesting that the disease does not occur at all in the elbows of female individuals, even though it might be expected when looking at the women's job of 'wringsters'. This job involved stirring the malt with hot water using paddles, this mixture had the consistency of thick dough, and should have been strenuous on the elbow (Unger 2001, 160). The percentage in males is also lower than one might expect. Inside the breweries, males performed tasks involving repetitive movement of the elbow. They shovelled coal in order to heat the kettles, and they also used shovels to move the grain. Besides this, they were also involved in stirring different mixtures (Unger 2001, 109). This all involves strenuous movement of the elbow, therefore, this low percentage is not easy to explain when looking at the brewery industry, neither is the difference between males and females. It is therefore possible that there were other activities not mentioned by historical literature.

Another joint that showed difference between males and females, albeit just shy of significant, is the acromio-clavicular joint. Unlike the elbow, besides the difference between male (69.0%) and female (52.3%), this joint is overall highly affected. Activities that can cause acromio-clavicular joint osteoarthritis are once again heavy lifting and activities that take place over the head, like for example, throwing. However, it must be mentioned that osteoarthritis in this particular joint is also heavily associated with old age (Menge *et al.* 2014, 325). When looking at activities the higher prevalence in men might be due to the men lifting up the bags or baskets of grain, hop, and other ingredients up on their shoulder. Perhaps, the movement of using a pickaxe to loosen up the coal, was also strenuous on the acromio-clavicular joint (van de Venne 2008, 40).

Upper vs. lower limbs

The data shows that both men and women put significantly more strain on their lower limbs than on their upper limbs. The joints in this limb group are all weight-bearing joints. This means that these individuals most likely carried heavy weights on a regular basis (Neogi and Zhang 2013, 6-7). These can again be the bags of grain and other type of ingredients they carried in the factory.

5.2.3 Comparison between Middenbeemster and Arnhem

The prevalence of osteoarthritis is, both in individuals as in joints, as well as between males and females, in Arnhem significantly higher than in Middenbeemster. This suggests that both the male and female individuals in the urban sector were involved with more physically demanding tasks then the individuals in the rural sector. Specific joint comparison showed some interesting differences between Arnhem and Middenbeemster. First off, a joint that has not been discussed yet, the temporo-mandibular joint. In both collections, the prevalence of osteoarthritis in this joint is noteworthy, however, this joint does not necessarily reflect activity but is rather an indication of dietary patterns. It is related to the opening and closing of the jaw, therefore, chewing is an activity that can cause osteoarthritis in the temporo-mandibular joint (Broussard 2005, 328). The individuals of Arnhem likely had a diet that required more and harder chewing than the diet of the individuals of Middenbeemster.

The sterno-clavicular joint, again a joint that has not been discussed in the individual assessments, but in comparison shows significant differences between the rural and urban sector. Arnhems prevalence (male: 30.2%) in this joint is quite a lot higher than the prevalence in Middenbeemster (male: 6.9%), especially in the males. Another joint, at least in the upper half of the body, that shows large differences between Arnhem (63.0%) and Middenbeemster (15.1%), is the acromio-clavicular joint. Both these joints are active in shoulder movements and are associated with over the head activities and lifting heavy load (Dobsen and Waldron 2019, 48; Menge *et al.* 2014, 325). In both environments, individuals likely carried heavy loads on their shoulders during their work. Individuals in Arnhem perhaps did it more frequently and it was perhaps somewhat heavier.

In the lower half of the body, the difference in prevalence that sticks out most is in the feet. In the urban environment of Arnhem 56.5% is affected, where as in the rural environment of Middenbeemster it is only 10.3%. This large difference suggests that the individuals of Arnhem had to walk and stand much more than the individuals of Middenbeemster. Perhaps this is due to the city individuals not having a mode of transportation besides walking and the farmers in general had a carriage in order to go to the market with their products (Boekel 1929, 56). This low percentage suggests that it is likely that these individuals used this carriage for other non-market related distances.

Male-female differences

Comparing the males and the females of both environments, generally, both males and females have a higher osteoarthritis prevalence in Arnhem than in Middenbeemster. The exception to this are the elbow, wrist, and knee in women, here the women of Middenbeemster have a slightly higher prevalence. The hip is also an exception, the hip has the same prevalence in both environments for the women. However, these exceptions where the Middenbeemster prevalence is higher are quite small and therefore not that noteworthy. Overall the data suggests that women in Arnhem performed harder and more strenuous work working in the factory than women did working in the farming community. For men it is more of the same, Arnhem's osteoarthritis prevalence is higher in every joint of the men, except for the knee and ankle in which Middenbeemster is more affected, and the shoulder in which the prevalence is the same. These differences in prevalence in the exceptions consists of only one male more affected. Again, this suggests that factory life was more strenuous and hard on the male body than farming life was.

Upper vs. lower limbs

In both environments the lower limbs are more affected than the upper limbs. When comparing the lower limbs of both collections, we see that the lower limbs in the individuals of Arnhem are significantly more affected than the lower limbs of Middenbeemsters individuals. This can be once again connected to the same factors causing the foot osteoarthritis or with heavier lifting causing hip, knee, and ankle osteoarthritis.

5.2.4 Limitations

The biggest limitation for this thesis is the Arnhem. Although this research accepts its data as true, there is a possibility that the osteoarthritis prevalence in the data is higher than it is in reality. The data has been collected using the criteria as discussed in chapter 3, which was also employed for the Middenbeemster data, however, the skeletons have been researched by many different people with different levels of skill and experience. Therefore, the investigation into osteoarthritis in Arnhem might have been done much better in comparison to the data of Middenbeemster. This in turn could be a cause of the large difference in osteoarthritis prevalence between the two environments.

6. Conclusion

6.1 Introduction

This research investigated the differences in activity patterns between a rural and an urban environment in the Netherlands during the post-medieval period. This was done by osteoarchaeological research into the individuals of the collections of rural Middenbeemster and urban Arnhem. By using the prevalence of the disease of osteoarthritis it was possible to investigate past activity patterns while linking it to historical literature. This chapter is structured by first answering the two sub-questions before providing a concluding answer to the main research question. Lastly, possibilities for future research will be discussed.

6.2 Sub-question 1: differences in men and women

- What are the differences between men and women in osteoarthritis prevalence, both within and between environments?

The skeletal analysis on the Middenbeemster collection revealed that the osteoarthritis prevalence in men and women is almost equal, even in the separate joints. This means that both males and females engaged in similar strenuous activity in their daily lives. The high prevalence in women’s wrist leaves the suggestion that although the strain on the other joints of the body was the same, they most likely performed different activities than the men. Women were in charge of churning butter and making cheese, while the men were working on the land.

The skeletal analysis on the collection of Arnhem, on the other hand, shows a larger division of labour, because the males have a higher prevalence of osteoarthritis in almost every joint. This shows that men engaged in more strenuous and harder work than the women in Arnhem. The higher prevalence of osteoarthritis in acromio-clavicular joints of the men shows that men had to lift heavy objects up on their shoulder, which was not an activity women often engaged in.

The men and women of the village of Middenbeemster show a big difference in osteoarthritis prevalence in comparison to the men and women of urban Arnhem. Apart from a few joints, the women of Arnhem have a higher prevalence in every joint than the women of Middenbeemster. This means that activity was more strenuous on the body of the urban women than the activity of the rural women was. The same can be concluded for the men. Again, the prevalence of osteoarthritis in urban men is higher in almost every joint in comparison to the rural men. Factory work was harder on the body than farming life was.

6.3 Sub-question 2: number and type of affected joints

- What differences are observed in the number and type of affected joints, both within and between environments, and what does this say about specific activities?

The numbers of the affected joints of the individuals in Middenbeemster are overall not that different from each other and quite low in number, apart from a few outliers. These outliers, the spine, hips, and the acromio-clavicular joints can be linked to certain activities. The spine and hips play a big role in supporting mechanical loading, which the acromio-clavicular joint does not. However, the latter is also, just like the spine and hips, associated with heavy lifting, albeit lifting from different positions. Heavy lifting can be assigned to many agricultural tasks. This can be, for example, carrying the hay, butter, and cheese. The high spinal and hip osteoarthritis prevalence also suggests that it is likely that these individuals often stood in a bending position. This can be from milking cows or fertilising soil. Although there are these outliers, the lack of high prevalence in joints that can suggest specific movements, make it hard to assign specific repetitive activities to these individual. This is not considering the wrist in the females, which is very specific.

Arnhem's osteoarthritis prevalence, in contrast to that of Middenbeemster, shows big differences in the number of affected joints. A few joints are barely affected, while others have a high prevalence, and a couple are big outliers. This suggests that mechanical strain was not equally distributed in the individuals of Arnhem. Spinal and hip osteoarthritis were in these individuals also very common, in the beer industry this most likely can be attributed to carrying the ingredients from one place to another, or to bending over the kettles in order to stir the beer mixtures. These individuals also walked or stood for long periods of time, which can be seen in the high foot osteoarthritis prevalence.

Analysis showed that much of the highly affected joints are the same joints in both environments, although, they do differ in prevalence. Especially the acromio-clavicular joint, the sterno-clavicular joint and the feet show a big difference in their numbers. This means that whatever the individuals of Arnhem carried up on their shoulder was heavier, and done more often, than the individuals of Middenbeemster carried. Individuals of Arnhem did not have a different mode of transportation other than walking in contrast to the individuals of Middenbeemster, who most likely had a carriage in order to move from market to home. This is supported by the high prevalence of osteoarthritis in the foot of the individuals living and working in the city.

6.4 Main research question

- What can be concluded about differences in activity patterns between a rural environment and an urban environment through the study of osteoarthritis?

Through different markers on the bone, like eburnation, osteophytes, and contour alteration, among others, the disease of osteoarthritis was detected and analysed on an urban and a rural skeletal collection. This produced data that was able to connect with historical literature about the post-medieval period in the Netherlands. Historical literature described the types of activity, however, the disease of osteoarthritis showed the severity of strain these activities had on the individuals of both environments. The skeletal analysis made it possible to make a comparison as well as provide a more detailed image between the two environments in terms of these activity patterns.

In terms of the overall picture, it is evident that both males and females of the city performed much more strenuous activity than males and females of the village. This remains a given throughout every aspect of the skeletal analysis. These two environments have in common that they utilised many of the same joints for their activities. These joints are heavily associated with load-bearing activities. The difference in number can therefore be attributed to the individuals of Arnhem carrying heavier weight around than the individuals of Middenbeemster.

The clavicular joints showed that the individuals of the city carried out activities over their head much more than the individuals of the rural environment. In addition to this, they also had to walk and stand for longer periods of time than the individuals of the farming community.

Another difference in activity patterns that was observed is that in the city there was a bigger division of labour than there was in the countryside. The skeletal data shows that women in the farming community had to help out on the land as much as the males, albeit in different forms of activity. The women of the city did have to engage in more strenuous work than the women of the rural community, however, these city women took part in less strenuous activity than their male counterparts.

Osteoarthritis analysis on two skeletal collections from different environments has been able to provide a clearer, more well-rounded picture into the activity patterns of these two environments. Life in the city for the working class was harder and more strenuous on the body than rural, farming live was in the post-medieval period of the Netherlands.

6.5 Future research

This research has used osteoarthritis in order to investigate activity patterns. This approach showed interesting results, however, other activity markers could be investigated as well in order to get a better activity profile. This can, for example, be done by, adding entheseal changes, which Palmer (2019) has done in her research, or perhaps inclusion of bone morphology, like Schats (2016) included in her research into medieval activity patterns. Entheseal changes are a good marker for activity, because these changes are a result of the amount of muscle pull the bone had to endure (Palmer 2019, 15). On the bone these changes can be seen in the form of ridges, bony spurs, and pitting on the bony cortex of muscle attachment sites of the bone (Weiss 2017, 43). Bone morphology is another good marker for activity. It is believed that strenuous activity can alter the shape of certain bones. In order to withstand strenuous mechanical loading, the body can deposit extra bone. On the other hand, when strain is decreased, bone can be removed from the surface (Schats 2016, 44). Together with osteoarthritis, these two markers could potentially give a fuller, more rounded, activity pattern profile of the individuals of Middenbeemster and Arnhem.

Abstract

This research uses the disease of osteoarthritis in order to investigate the activity patterns of a rural and an urban environment in the Netherlands during the post-medieval period. It produced two datasets with matching criteria obtained from the skeletal assemblages of the heavily researched rural site of Middenbeemster and the relatively new urban site of Arnhem. Historical literature is combined with osteoarthritis prevalence give a more clear and detailed image of past activity patterns. This literature has provided this research with the knowledge that Middenbeemster was a dairy farming community, while Arnhem was a city with a focus on the beer brewing industry. Different markers on the bones associated with osteoarthritis resulted in differences in osteoarthritis prevalence. This differences were not only investigated within the environments but also between the environments. In the urban environment a sexual division of labour was seen, while in the rural environment men and women performed similar strenuous activities. Besides this, it is evident that industrial city life was more strenuous on the bodies of individuals than farming life was during the post-medieval period in the Netherlands.

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Figures

Tables