Vertebral pathology and social status: A comparison between a post-medieval population from Arnhem and three contemporary populations from London

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A comparison between a post-medieval population from Arnhem and three contemporary populations from London.

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CHAPTER 1 Introduction

Previous studies have shown that there is a relationship between health and social status in past populations. The lower classes of populations often had to deal with inadequate nutrition, poorer living conditions like polluted living sites and water sources, greater exposure and susceptibility to disease and/or poor or no medical care. Furthermore, they often had physically demanding and risky jobs where they had to work for long hours and years of their life (Robb et al., 2001, p. 213). The health consequences that these stresses cause can leave visible changes in the skeletons (Vyroubal et al., 2020, p. 87). In many modern societies, the results of these factors are well known. Studies have confirmed that poorer people often have poorer health, shorter stature and shorter lifespans than people that are well-off (Robb et al., 2001, p. 213). A number of studies have argued that there is a relationship between health and social status in past (archaeological) populations as well. These studies have suggested that people in high social classes were taller, had better nutrition and had a better overall health than the people of lower social classes (Robb et al., 2001, p. 213; Roberts & Manchester, 2010, p. 118).

It has previously been suggested that vertebral pathological conditions can, indirectly, be related to social status (Richardson, 2018, p. 14; Robb et al., 2001). The development of vertebral pathology is namely, to some extent, influenced by activity and can thus possibly be an indicator of heavy manual labour (Jiménez-Brobeil et al., 2012, p. 526; Stirland & Waldron, 1997, p. 329). To elaborate, joints are put under a lot of stress when people are involved in heavy labour regularly. The joints that are under stress, as a result of this labour, might eventually react to this by showing signs of degeneration. For example, repetitive use of a joint can cause cartilage to degenerate which can lead to changes in the bone like the development of bone spurs on the joint margins or the polishing of the joint surface as a result of bone-on-bone contact (Roberts & Manchester, 2010, p. 331; Stanco, 2017, p. 8; Zhang et al., 2017, p. 13). Since activity may have varied between high-status and low-status population it might be possible to infer differences in labour between the populations.

This thesis research will focus on testing if the prevalence of vertebral pathological conditions reflect hard labour/tough life in the Arnhem Eusebiuskerk population and three populations from London. This will be done by comparing the prevalence of multiple vertebral pathological conditions between the low-status Arnhem Eusebiuskerk population and a low-status, middle-status and high-status London population.

The social status of these populations has previously been inferred from their archaeological context. This will be discussed in more detail in chapter 2, but in short, it has been inferred that the Arnhem population was likely of a low social status since the individuals were buried on the northern side of the church. This location may be associated with a lower social status (Zielman & Baetsen, 2020, p. 420). Besides that, an event that took place at the level of the excavated northern part of the cemetery can be used to support this inference. This event is known as the Kerkhofoproer (literally translated as "cemetery riot"). During this event, graves were cleared in a 'very rough and unmannered way' so that the cemetery could be refurbished into a garden for a wealthy merchant (Cappers, 2012, p. 145-184; Zielman & Baetsen, 2020, p. 707).

As for the London populations, it has been inferred that the Chelsea Old Church population is of high social status based on the location of the burials and the presence of coffin plates that enabled (partial) identification of some of the individuals (Bekvalac & Kausmally, 2009). Based on Parish records, it has been inferred that the St. Benet Sherehog population is likely of middle social status and the St. Bride's Lower Churchyard population of low social status (Bekvalac & Cowal, 2008; Kausmally, 2008).

The relationship between health, including vertebral pathology, and social status is considered to be very complex as of yet (Vyroubal et al., 2020, p. 88). Besides that, not much osteological studies has been found in which vertebral pathological conditions, that can be related to activity, are compared between different status groups. To gain more insight into the relationship between these kind of pathological conditions and social status, it is important that more research is done on this. This thesis will do so by testing if the prevalence of the vertebral pathological conditions reflect hard labour/tough life in populations of a different status. The following research question has been formulated and will be answered to accomplish this:

- To what extent is there a relationship between social status and vertebral pathology in the low status Arnhem population and the low-high status London populations?

To answer this research question, two sub-questions have been formulated:

- To what extent is there a correlation between sex and the prevalence of vertebral pathology?
- To what extent is there a correlation between age and the prevalence of vertebral pathology?

1.1 Research approach

As stated before, this thesis research will focus on testing if the prevalence of vertebral pathological conditions reflect hard labour/tough life in the Arnhem Eusebiuskerk population and three populations from London. The vertebral pathological conditions that will be analysed for the Arnhem population are vertebral osteoarthritis, osteophytes, intervertebral disc disease, Schmorl's nodes and fusion. These specific pathological conditions have been chosen for two reasons. First, all of these pathological conditions can, at least to some extent, be related to activity; activity may have varied between a high-status and low-status group meaning that it might be possible to infer embodied practice and labour in these populations. The guiding principle of this is that the frequency, type and development of spinal lesions are influenced by occupational activities (Richardson, 2018, p. 21). The hypothesis that will be tested, based on this principle, is then that individuals with lower social status had harder working conditions than individuals of higher social status and that therefore lower status individuals are more prone to the development of degenerative changes in the vertebral column (Hofmann et al., 2008, p. 14).

The second reason is the availability of a large dataset, made by the Museum of London, in which these specific pathological conditions are very well documented. Conclusions regarding the social status of a population can namely only be made when the prevalence of the vertebral pathological conditions are compared with that of other relatively contemporary populations.

So first, vertebral osteoarthritis, osteophytes, intervertebral disc disease, Schmorl's nodes and fusion will be recorded for the Arnhem population. After that, the prevalence of these pathological conditions will be compared to that of a low-status, middle-status and high-status population from London to gain insight into the relationship between social status and activity. Furthermore, it may also give insight into how labour was different or similar between the Arnhem population and the London populations. The high-status Chelsea Old Church, middle-status St. Benet Sherehog and low-status St. Bride's Lower Churchyard populations have been chosen, because, first of all, they are relatively contemporary with the Arnhem population, which is necessary to make comparisons. The second reason is that their social status is well known which makes them very suitable for this kind of research.

After comparing the overall prevalence of the vertebral pathological conditions between the Arnhem population and the three London populations, comparisons, with regard to the prevalence of the vertebral pathological conditions by sex and age, will be made to determine if males and females might have had different occupational roles, if the presence or absence of different occupational roles for males and females can be linked to a specific social status, whether or not males and females had harder working conditions in the Arnhem population than in the others and to find possible bias in the population(s).

1.2 Structure

The thesis will start with discussing the background of this thesis research. Specifically, the five vertebral pathological conditions, the link between vertebral pathology and social status and the previous research on the social status of the Arnhem population will be discussed. In the chapter after that, the cemetery and the demographics of the Arnhem population and the three London populations will be discussed. The sample size and strategy of the Arnhem population and the research methods will be discussed in this chapter as well. In chapter 4, the results of the statistical analysis will be presented. These results will be discussed and interpreted in chapter 5. Lastly, in chapter 6 the research questions will be answered and suggestions will be made for further research.

CHAPTER 2 Background/context

This chapter will discuss the background information that is needed to understand the thesis project, research questions and methods. First, relevant anatomy and features will be discussed. This will be followed by information on the vertebral pathological conditions and a discussion on the link between vertebral pathology and social status. Lastly, the previous research on the social status of the Arnhem population will be summarised.

2.1 The vertebral pathological conditions

Joint diseases are quite common in both past and modern populations. In fact, joint disease is, together with dental disease and trauma, the most commonly found disease in skeletal remains of past populations (Jurmain & Kilgore, 1995, p. 443; Roberts & Manchester, 2020, p. 214). Joint diseases manifest themselves in several ways; in principle they can cause bone loss, bone formation or they can promote both of these. All the joints in the human body can be affected by joint disease, but this thesis specifically focusses on vertebral joint disease (Weston, 2007, p. 159). The vertebral pathological conditions this thesis research focusses on are vertebral osteoarthritis, osteophytes, intervertebral disc disease, Schmorl's nodes and fusion.

2.1.1 Relevant anatomy and features vertebral column

First, the for the methodology relevant, anatomy and features of the vertebrae will be discussed. The vertebral column generally consists of 33 elements (see figure 2.1) (DeWitt, 2014). Typically five of these segments are fused together and form the sacrum. Three to five, but most often four, of these form the coccyx (White & Folkens, 2005, p. 241-245). The remaining elements are the 24 separate vertebrae that can be divided into three different types, namely cervical, thoracic and lumbar vertebrae. In total, there are seven cervical, twelve thoracic and five lumbar vertebrae. The cervical vertebrae are located in the neck, the thoracic vertebrae in the upper and middle back and lumbar vertebrae in the lower back (White & Folkens, 2005, p. 156-180).

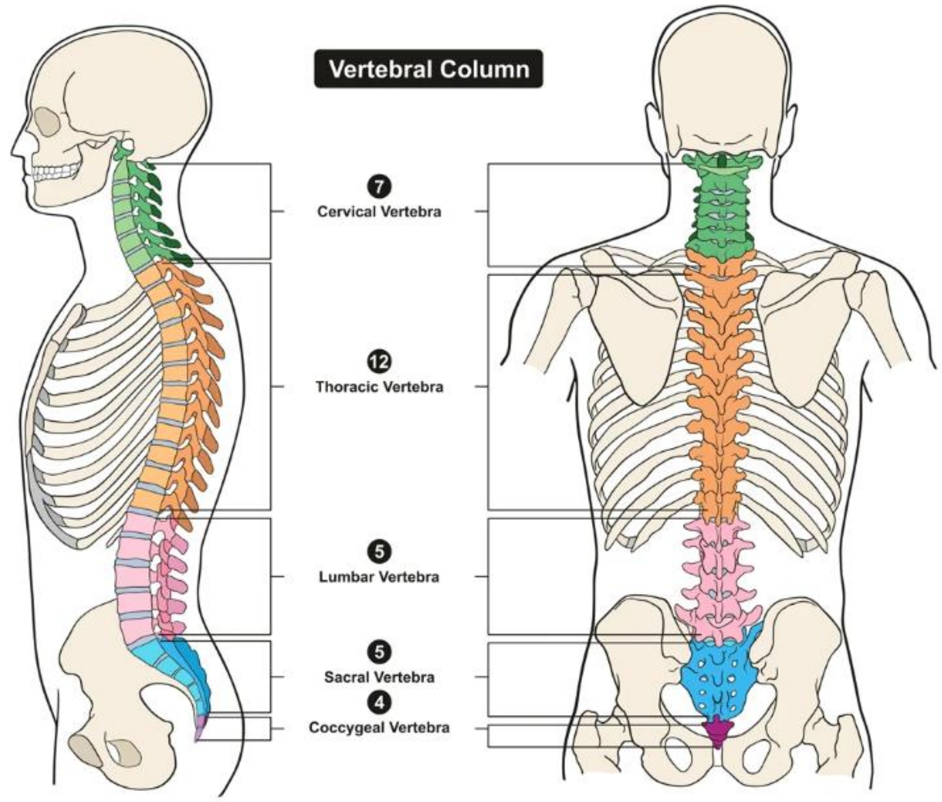

Figure 2.1: The anatomy of the vertebral column including the cervical, thoracic, lumbar, sacral and coccygeal vertebrae (Udaix, n.d.).

As stated before, there are a few features of the vertebrae that are relevant for the methodology. These features are the vertebral body, intervertebral disc and zygapophyseal joints. The vertebral body is the large cylindrical part on the anterior side (at the front) of a vertebrae (see figure 2.2). Their role is to give strength to and to bear the weight of the spine. Each successive vertebral body is larger in size than their preceding vertebral body, because the lower vertebral bodies have more weight bearing-responsibilities than the upper (Rad, 2022).

The intervertebral disc is situated between all adjacent vertebral bodies (see figure 2.3) (Rad, 2022). Each disc consists of a fibrous capsule (the annulus fibrosus) that holds a gelatinous internal substance (the nucleus pulposus) (see figure 2.2) (Roberts & Manchester, 2010, p. 341). Their role is to absorb shock, prevent friction and allow some flexibility between the vertebrae (Rad, 2022).

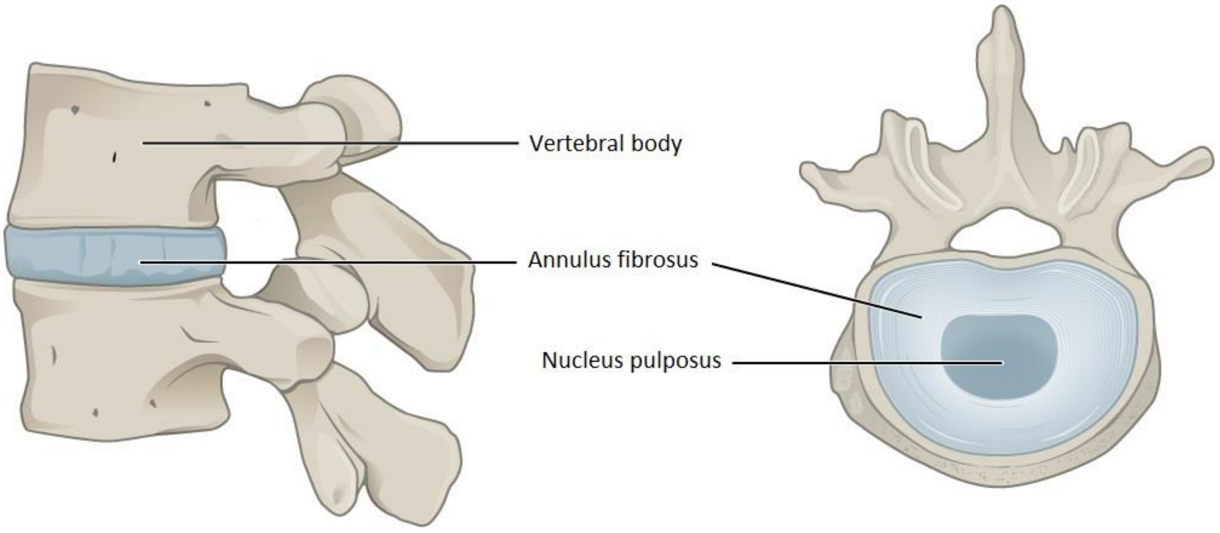

Figure 2.2: A lateral view of two adjacent vertebral bodies and the anulus fibrosus of the intervertebral disc (left) and a superior view of the annulus fibrosus and nucleus pulposus of the intervertebral disc (right) (Betts et al., 2013, p. 281)

Lastly, the zygapophyseal joint, also known as the apophyseal or facet joint, connects adjacent vertebrae with each other (see figure 2.3) (Jaumard et al., 2011, p. 2). Their role is to facilitate flexion and extension in the cervical and thoracic spine and to permit rotational movements in the thoracic spine (Rad, 2022).

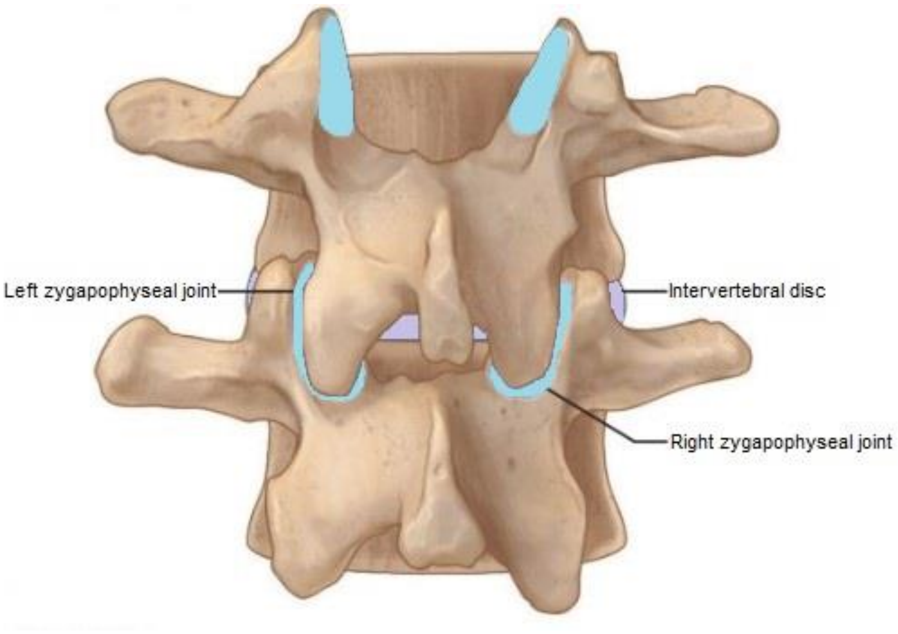

Figure 2.3: A posterior view of two adjacent vertebrae with the zygapophyseal joints highlighted in blue and the intervertebral disc highlighted in purple (Muscolino, 2021).

2.1.2 Vertebral osteoarthritis, osteophytes and intervertebral disc disease

Vertebral osteoarthritis, osteophytes and intervertebral disc disease will be discussed in this section. It is important to note that these three pathological conditions are largely the same thing. To elaborate, osteophytes and changes associated with intervertebral disc disease are both features of vertebral osteoarthritis and these conditions thus all follow the same pathological process (Fine et al., 2023, p. 136; Lindsey & Dydyk, 2023; van der Kraan & van den Berg, 2007, p. 237). As will be discussed in chapter 3, these three conditions have been analysed and scored separately.

An important factor that has made humans more susceptible to the development of vertebral osteoarthritis is their adoption of an upright posture. This upright posture puts the spine under a lot of mechanical stress and strain. This mechanical stress and strain is not constant in each segment of the spine, because the spine is curved and not a straight line. It is suggested that some vertebrae are, because of these curves, under more stress than other vertebrae and that therefore some vertebrae are more prone to developing osteoarthritis. The fifth cervical, eight thoracic and fourth lumbar vertebrae should then be most affected since there is a backward curve in the thoracic region and a forward curve in the cervical and lumbar regions (DeWitt, 2014; Roberts & Manchester, 2010, p. 340-341).

Many different methods have been proposed to diagnose vertebral osteoarthritis in human skeletal remains. These all look at different (combinations of) features and different segments of the vertebrae. Vertebral osteoarthritis can namely affect multiple segments of the vertebra, like the vertebral bodies and apophyseal joints (Brothwell, 1981, p. 335). In case of this thesis research, it will be recorded at the level of the zygapophyseal joints so only degenerative changes on this joint will be discussed for vertebral osteoarthritis.

Osteoarthritis in the apophyseal joints is characterized by the formation of osteophytes (bone spurs) on the margins of the joint and pitting on the articular surface of the joint as a result of degenerating cartilage (Stanco, 2017, p. 8). However, as will be discussed in the next chapter, the most important degenerative change for diagnosing osteoarthritis is eburnation (Waldron, 2009, p. 28). Eburnation occurs once the cartilage in a joint is completely destroyed. If an individual continues to use the joint, of which the cartilage is destroyed, the bone can become hard and polished as a result of bone on bone friction. Eburnation is thus the hardening and polishing of bone in a joint (Molnar et al., 2011, p. 284; Roberts & Manchester, 2010, p. 331). The degenerative changes associated with vertebral osteoarthritis can be seen in figure 2.4 and 2.5 with eburnation being especially well visible in the latter figure.

Figure 2.4: Eburnation (arrows), osteophytes and porosity (vertebral osteoarthritis) on the left inferior cervical apophyseal facet. The scale bar is 1 cm (Zhang et al., 2017, p. 7)

Figure 2.5: Eburnation osteophytes and porosity (vertebral osteoarthritis) on the left superior lumbar apophyseal facet (Woo & Pak, 2012, p. 678).

Vertebral osteoarthritis is a direct consequence of spinal stress and is highly correlated with heavy physical activity. Vertebral osteoarthritis is likely the result of repetitive actions like the lifting and carrying of heavy objects, pushing and pulling (Zhang et al., 2017, p. 13). However, physical activity is not the only factor that influences its development. Another important factor that strongly influences its development is age (Zhang et al., 2017). A study that reviewed relatively modern spines shows that a large portion of the studied individuals, who were in their 30s, had vertebral osteoarthritis and that the individuals, who were in their 50s, all had vertebral osteoarthritis (Roberts & Manchester, 2010, p. 341-343). Some other factors that influence the development of osteoarthritis are sex, race, genetic predisposition, genetics, diet and obesity and trauma (Cox & Mays, 2000, p. 393; Lindsey & Dydyk, 2023; Waldron, 2009, p. 28).

Now, osteophytes will be discussed. Osteophyte formation (or osteophytosis) is recorded at the level of the vertebral body margins, see figure 2.6. Osteophyte formation also happens to be a feature of vertebral osteoarthritis. However, osteoarthritis cannot be diagnosed by this feature on its own, but only in combination with other features like pitting and eburnation (Roberts & Manchester, 2010, p. 335; Waldron, 2009, p. 4). Since only osteophyte formation will be recorded for the vertebral body margins, and not pitting and eburnation, this is not considered to be osteoarthritis in this case.

Osteophyte formation on the vertebral body margins is caused by the degeneration of the intervertebral discs. The discs are subject to constant stress caused by everyday activities like lifting and bending. This stress eventually causes a degenerative change to occur in these two tissues of the intervertebral disc. This degenerative change involves the nucleus pulposus invading the annulus fibrosus. As a compensatory reaction to the rupture of the annulus fibrosus, new bone is formed from the margins of the vertebral body. These newly formed bone spurs are called osteophytes (or osteophytosis) (Adjei, 2022, p. 46; Roberts & Manchester, 2010, p. 341). So in short, osteophyte formation is a result of erosion of cartilage in the intervertebral disc (Quick, 2008, p. 1).

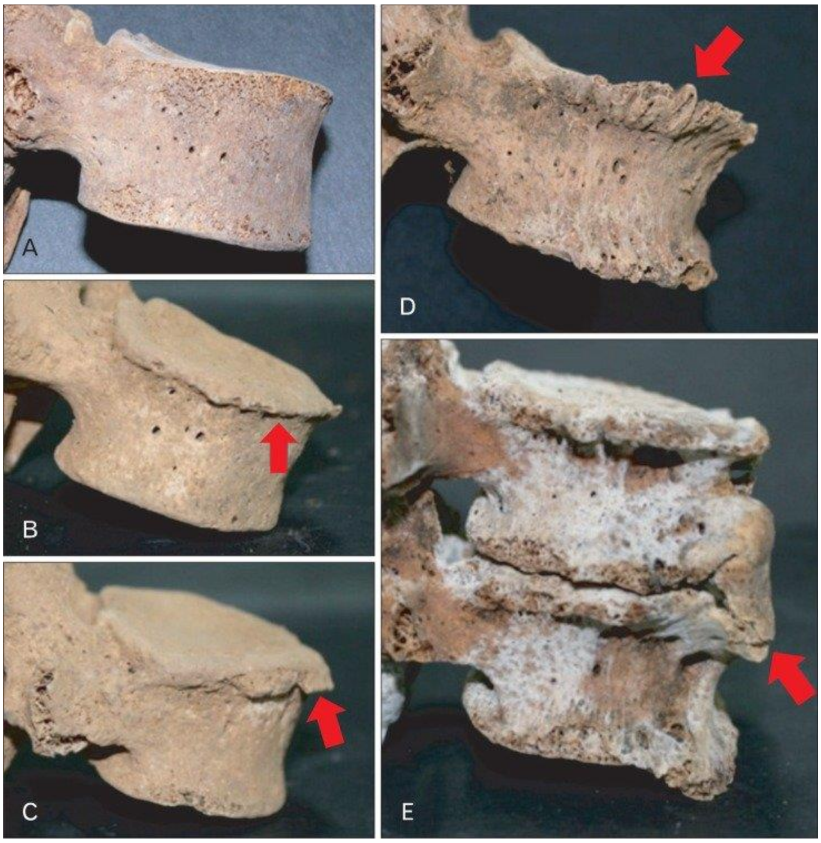

Figure 2.6: Multiple stages of osteophyte formation (indicated with arrows). A=no osteophytes, B=slight osteophytes, C=moderate osteophytes, D=severe osteophytes and E=osteophytes of two adjacent vertebrae fused together (Kim et al., 2012, p. 275).

Physical activity and age strongly influence the development of osteophytes. However, other factors have been proven to influence osteophyte formation like injury to a bone or tendon, genetics, diet and obesity (WebMD Editorial Contributors, 2022; Wong et al., p. 403).

The formation of osteophytes is not the only degenerative change that can occur on the vertebral bodies. The articular surface of the vertebral body degenerates as well. The degenerative change of the vertebral body surface is referred to as intervertebral disc disease and is also known under the name intervertebral disc degeneration (Roberts & Manchester, 2010, p. 343). This condition is characterized by pitting on and around the centrum of the vertebrae, see figure 2.7. This pitting is caused by dehydration of the nucleus pulposus in the intervertebral disc. The dehydration causes premature hardening, rupturing and herniation of the disc which manifests into pitting (Powers, 2012, p. 47). Intervertebral disc disease most frequently appears on the mid-lower cervical, upper thoracic and lower lumbar vertebrae (Roberts & Manchester, 2010, p. 343).

Pitting on the joint surface is also a feature of vertebral osteoarthritis. However, osteoarthritis cannot be diagnosed by this feature on its own, but only in combination with the other features discussed above (osteophytes and eburnation) (Roberts & Manchester, 2010, p. 335). Since only osteophyte formation will be recorded for the vertebral body margins, and not osteophytes and eburnation, this is not considered to be osteoarthritis in this case.

Figure 2.7: Intervertebral disc disease on the inferior articular surface of a cervical vertebra of individual 1862 from Arnhem (photo by author).

Heavy physical activity is one of the factors that can influence the development of intervertebral disc disease. However, several studies have proven that other factors like age, injury, obesity, failure of the nutrient supply to the disc cells, infection, familial predisposition and genetic factors can also influence its development (Kalichman, 2010, p. 396; Koyama et al., 2015, p. 65; Urban & Roberts, 2003).

2.1.3 Schmorl's nodes

Another degenerative lesion, that occurs at the vertebral body surface and is also associated with the degeneration of the vertebral disc, are Schmorl's nodes. Schmorl's nodes are caused by the herniation of the nucleus pulposus (Plomp et al., 2015). The herniation is a result of very high pressure on the nucleus pulposus that is often caused by heavy physical activity. When exposed to high pressure, the inner nucleus pulposus can break through the outer annulus fibrosus and protrude into the adjacent vertebra (Jiménez-Brobeil et al., 2010, p. 37). This protrusion is called a Schmorl's node and manifests itself as a circular or linear lesions in the articular surfaces of the vertebral bodies, see figure 2.8 (Connell & Rauxloh, 2003, p. 15) Schmorl's nodes appear most frequently in the lower thoracic and the lumbar vertebrae since these bear most of the weight and are thus under the most stress (Roberts & Manchester, 2010, p. 343).

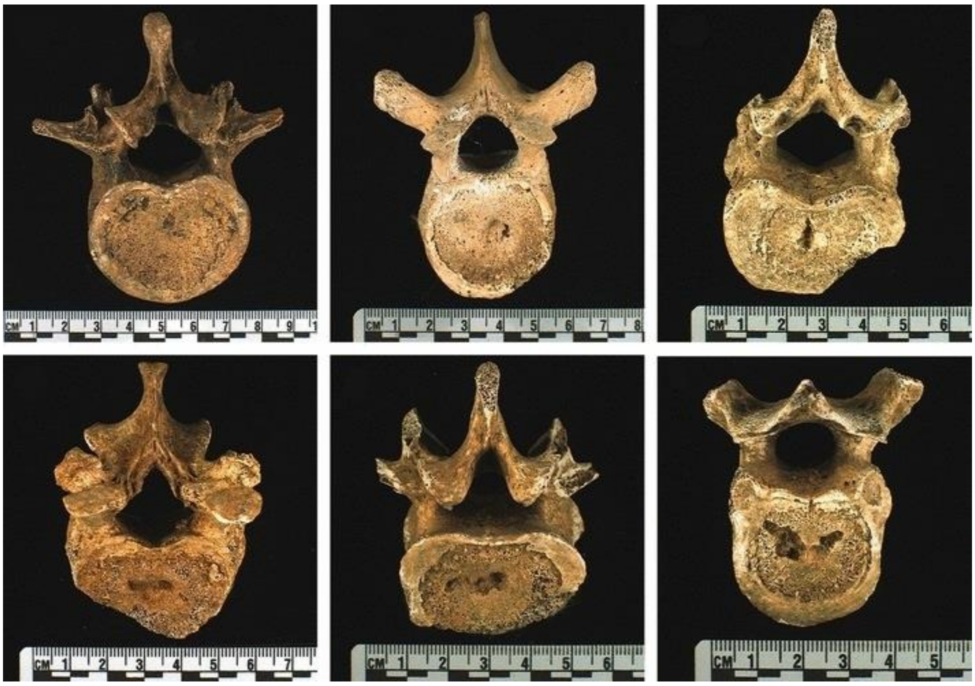

Figure 2.8: Multiple shapes of Schmorl's nodes on the anterior and posterior vertebral body surface (Burke, 2011, p. 573).

The specific aetiology of Schmorl's nodes is unknow in most cases. A traditional view about the aetiology of Schmorl's nodes is that they are related to heavy physical activity. Clinical studies on military populations have suggested that Schmorl's nodes might be caused by repetitive movement and flexion of the spine (e.g. Burke, 2012). Another clinical study that studied back injuries in young athletes has suggested that they are caused by flexion and heavy loading (d'Hemecourt et al., 2000, p. 669). However, it has been argued that underlying conditions, that weaken the bone structure, can also play a part in the development of the Schmorl's nodes. Some other factors are trauma, congenital disorders and degenerative processes. Lastly, there is a strong correlation between age and Schmorl's nodes, because Schmorl's nodes are proven to be rare in individuals younger than 30 and common in individuals older than 45 years (Dar et al., 2009, p. 314; Jiménez-Brobeil et al., 2010, p. 37).

2.1.4 Fusion

Osteophytes will continue to grow in size with increasing stress and the resulting annulus fibrosus rupture (Roberts & Manchester, 2010, p. 341). When the osteophytes continue to grow, they can eventually, in extreme cases, cause adjacent vertebrae to grow together and unite, see figure 2.9 and image E of figure 2.6. The spinal segments would then be fixed and it would not allow movement. The growing together of adjacent vertebrae is known as fusion (or ankylosis spondylitis) (Quick, 2008, p. 1).

Figure 2.9: Anterior fusion of the cervical vertebrae in an individual from the St. Bride's Lower Churchyard population (Museum of London, n.d.).

The aetiology of degenerative fusion can thus be increasing stress on vertebrae that are affected by osteophytes. This stress can cause the osteophytes to develop until they extend up into the other articulating vertebra causing the vertebrae to unite (Roberts & Manchester, 2010, p. 340-341). However, this is not the only factor that influences its development. Clinical research has shown that fusion is largely influenced by genetics, sex and age. Besides that, it has been argued that there are environmental factors that can make people more susceptible to the development of fusion in the spine. These environmental factors include a lower socioeconomic status and a lot of physical occupational activity (Doran et al., 2003, p. 316).

2.2 Vertebral pathology, activity and social status

Vertebral pathology can indirectly be related to the social status of a population. This can be done by looking at, amongst other things, the frequency, type and development of spinal lesions. The guiding principle of this kind of research is that the frequency, type and development of spinal lesions are influenced by occupational activities (Richardson, 2018, p. 21). The starting point is that individuals with lower social status may have had harder working conditions than individuals of higher social status and that therefore lower status individuals are more prone to the development of degenerative changes in the vertebral column (Hofmann et al., 2008, p. 14) In other words, people who are engaged in heavy manual work, often people of a lower status, are thus more likely to develop joint diseases than people who do not have such an active lifestyle, which are often people of a higher status (Roberts & Manchester, 2010, p. 342-245). This is an assumption that will be discussed further in the discussion in chapter 5 since this is not necessarily the case.

Furthermore, previous research, that looked at the relationship between physical activity and skeletal findings, concluded that there can also be differences in the prevalence of vertebral pathology between males and females. An example of such a study is one that examined a Croatian population from the 14th-18th century. This study showed that there was a significantly higher prevalence of vertebral osteoarthritis and Schmorl's nodes in males than in females. These differences could not be related to the age distribution of the population and therefore they may be indicative of differences in activity between males and females within the population (Slaus, 2000, p. 205). The same conclusion was made in a study that examined a population of which the occupational activities for males and females were well known (Jiménez et al., 2012, p. 521-525).

This latter study also focussed on examining differences in occupational activity by comparing the sexes between sites. They analysed two skeletal populations, of which the activity patterns were already well known, namely Villanueva de Soportilla and La Torrecilla (both located in Spain). Historical records had shown that males of Villanueva were peasant-soldiers while the males in the other population were only peasants. Besides that, the records had shown that females in Villanueva performed agricultural activities while the females of the other population worked at home. This means that it was expected that both the males and females of Villanueva reflected harder life conditions, due to occupation, than the males and females in the other population. As expected, almost all the pathological conditions were statistically significantly more prevalent in the males and females of Villanueva than in those of La Torrecilla. In other words, this study has proven that differences in the prevalence of (vertebral) pathological conditions can indicate different occupational roles for males and females between populations (Jiménez et al., 2012, p. 521-525).

Lastly, when doing research like discussed in this section, it is important to note that activity is not the only factor that plays a role in the development of these vertebral pathological conditions. Each vertebral pathology has multiple possible aetiologies, of which some have been mentioned in section 2.1. The multiple possible aetiologies thus complicate research that focusses on the relationship between vertebral pathology and social status/activity (Jiménez-Brobeil et al., 2010, p. 36). Factors that highly influence the development of vertebral pathology and that most, or even all, of the five pathological conditions share are sex and age (Jiménez-Brobeil et al., 2010, p. 36).

2.3 Previous research on the social status of Arnhem

As stated before, previous research has been done on the social status of the Arnhem population. An event that can reliably be used to support the claim that the population consists of low-status individuals is the so-called kerkhofoproer, which is literally translated as "cemetery riot", in the year 1782. This event, that took place at the level of the excavated northern part of the cemetery, is described in historical sources. In short, the northern part of the cemetery was sold to a Jewish merchant who wanted to use the land to expand his garden, which resulted in the demolition of a cemetery gate, the cemetery wall and a charnel house. Besides that, bones and even recently buried corpses were cleared and reburied in a pit outside the cemetery in a 'very rough and unmannered way'. The people of Arnhem disagreed strongly with this and started a riot which brought an end to the refurbishments and lead to the restoration of the cemetery (Cappers, 2012, p. 145-184). The refurbishment of this part of the cemetery and the disrespectful way in which the graves were cleared and reburied is likely an indicator that the individuals buried here had a lower social status (Zielman & Baetsen, 2020, p. 707).

Furthermore, the skeletons were buried on the northern side of the church. This may also be associated with a lower social status (Zielman & Baetsen, 2020, p. 420). To elaborate, this side of the church is considered to be the least valued location for burial while the most valued location for burial within a cemetery is on the southern side of the church. Therefore, the northern side is usually where the lower status individuals were buried (Baetsen et al., 2018, p. 37; Veselka & Klomp, 2019, p. 139).

There is osteoarchaeological evidence that also supports that this population was physiologically stressed in life. The average stature of the individuals of Arnhem was relatively shorter than that of the individuals of the other populations, which may indicate a lower social status in the Arnhem population. The age and sex distribution were not significantly different than those of contemporary populations (Zielman & Baetsen, 2020, p. 706).

Another possible indication of low social status is the high prevalence of enamel hypoplasia in the Arnhem population, which is an indication for nutrient deficiencies or pathology during childhood. Furthermore, there is a large number of individuals with fractures, which could indicate a lot of physical activity and exposure to danger during heavy labour. Other signs of heavy labour, and thus a possible lower social status, is the high prevalence of osteoarthritis of the peripheral joints, which are the joints of the arms and legs, and the vertebral column (Zielman & Baetsen, 2020, p. 706).

There are very few lesions that can be associated with common infection diseases like tuberculosis and syphilis and deficiency diseases like rickets (vitamin D deficiency) or scurvy (vitamin C deficiency). This may be an indicator of lower social status as well. To elaborate, a poor overall health status in a population, which is often associated with a lower social status, could often lead to rapid death from diseases like infections. The rapid course of these diseases does not give the skeleton enough time to react to it, meaning that they do not leave marks on the skeleton. It is however important to keep in mind that the low prevalence of these diseases is not necessarily a result of poor overall health, but it could also mean that they are just not that common in the Arnhem population (Zielman & Baetsen, 2020, p. 706). Additionally, these diseases, even if they don't kill quickly, induce bone changes in only a small percentage of people (Roberts, 2000, p. 145). An example of this is tuberculosis which leaves marks in the skeleton in only 3-5% of the cases (Roberts, 2000, p. 145; Roberts & Manchester, 2010, p. 405).

Now all the needed background information of this thesis research has been discussed. In the next chapter, the four archaeological populations and the methods of this thesis research will be discussed.

CHAPTER 3 Materials and methods

In this chapter, the materials and methods that have been used for this thesis research will be discussed. Data, concerning the vertebral pathological conditions, has been collected for the Arnhem population during this thesis research through skeletal analysis. The three London populations, to which the data of the Arnhem population has been compared, will be discussed as well. The London populations in question are the high-status Chelsea Old Church population, the middle-status St. Benet Sherehog population and the low-status St. Bride's Lower churchyard population. Data for the London collections was, unlike that of Arnhem, available prior to the thesis research on the website of the Museum of London (museumoflondon.org.uk).

3.1 Materials

In this section, the skeletal populations of this thesis research will be discussed. The cemetery, the excavation and the demographics will be discussed for each population. The sample size and strategy will also be discussed, but only for the Arnhem population since this is the only population for which data has been collected during this thesis research.

3.1.1 Arnhem

Cemetery

The excavation of the cemetery has been carried out in the southern part of the historic city centre of Arnhem by the archaeological company RAAP (RAAP Archaeological Consultancy) in 2017. The excavation took place, because a new watercourse and sewer lines were to be constructed in this part of Arnhem (Zielman & Baetsen, 2020, p. 3). Remains of a stream called the Sint-Jansbeek, city walls, buildings (including the former church the Broerenkerk), cesspits and wells were found during this excavation. However, the majority of the finds concerned the human skeletal remains that were found near the church the Eusebiuskerk (Zielman & Baetsen, 2020, p. 3).

The cemetery contains graves dated between 1350 and 1829 AD. Two phases of burial were recognised, namely 1350-1650 AD and 1650-1829 AD (Zielman & Baetsen, 2020, p. 386). A total of 659 skeletons were found on the cemetery of the Eusebiuskerk and its predecessor the Maartenskerk. This part of the cemetery is referred to as "het Oude Kerkhof", which literally translates to "the Old Cemetery". Furthermore, twenty skeletons were found in and surrounding the former Broerenkerk. Lastly, skeletal remains were found in secondary context outside of these cemeteries. By secondary context is meant that most of the bones were not in anatomical position when they were found meaning that the bones were not in their original position anymore and that they most likely have moved secondarily (Zielman & Baetsen, 2020, p. 361-365). Only primary burials, the skeletons that were found in anatomical position, near the Eusebiuskerk have been researched for this thesis (Zielman & Baetsen, 2020, p. 10).

Sample size and strategy

As stated before, a total of 659 primary burials have been excavated on the cemetery of the Eusebiuskerk. Most of these skeletons are now on loan to the Laboratory for Human Osteoarchaeology within the Faculty of Archaeology of Leiden University (Zielman & Baetsen, 2020, p. 10). The exact number of skeletons that were given on loan is 511 (Zielman & Baetsen, 2020, p. 362).

Not all of these skeletons have been analysed for this thesis research due to time constraints. Only the skeletons, of which the sex and age have previously been determined, have been studied for this thesis research. Specifically, 76 skeletons have been analysed for this thesis research. Furthermore, it is important to note that only the adult individuals (>18 years old) have been studied. The non-adults have not been studied, because the vertebral pathology databases of the London populations, to which the Arnhem population has been compared in chapter 5, also focus on adult individuals. Besides that, vertebral pathology is correlated with age which means that it is far more common in adults than in non-adults (Roberts & Manchester, 2010, p. 342-343). The non-adults are thus also not included to prevent biased results.

Demographics

The sample population consists of the 76 skeletons that have been studied for this thesis. An overview of the sex and age distribution of the population can be seen in table 3.1. The population consists of sixteen females and 25 males. Furthermore, fifteen individuals are scored as probable female and nineteen as probable male. There are thus more males than females in the sample. One of the sub-questions of this thesis focusses on determining if there are differences in the prevalence of vertebral pathology between males and females. Therefore, the amount of males and females in the sample population should ideally be approximately the same to prevent biased results. There are, as stated, more males than females, but this is not a big difference.

The sample population consists of young adults, middle adults and old adults. Specifically, there are eight early young adults, nineteen late young adults, 35 middle adults and thirteen old adults. Besides that, there is one unclassified adult. In short, there is a fairly even amount of young adults (n=27) and middle adults and a lesser amount of old adults.

	Category	n	%
Sex	Undeterminable	0	0
	Female	16	21,1
	Probable female	15	19,7
	Intermediate	1	1,3
	Probable male	19	25
	Male	25	32,9
Age	Adult	1	1,3
	Early young adult	8	10,5
	Late young adult	19	25
	Middle adult	35	46,1
	Old adult	13	17,1

Table 3.1: Sex and age distribution of the Arnhem Population(N=76) in numbers and percentages.

3.1.2 Chelsea Old Church

Cemetery

The church of the Chelsea Old Church population was completely destroyed by bombings during the Second World War, but was rebuilt in the 1950s. Further building works took place in the 1960s, which resulted in the partial excavation of the cemetery. However, the skeletons of this excavation are not recorded in the database that will be used for this thesis (Bekvalac & Kausmally, 2009).

The database of the Chelsea Old Church population, that will be used for thesis, contains the data of skeletons that were excavated in the year 2000 by the Museum of London Archaeological Services (MoLAS) when further building developments were being made. A total of 290 skeletons were found during the excavation and 165 adult individuals were analysed. Unique is the presence of some coffin plates that were attached to the burials. These coffin plates provided (partial) identification of 25 individuals and allowed the retrieval of biographical data. Based on this biographical data and the location of the burials, it could be determined that the cemetery consists of mainly high-status individuals. Furthermore, the coffin plates were used to date the cemetery between the 18th-19th century, specifically between 1712 and 1842 (Bekvalac & Kausmally, 2009).

Demographics

An overview of the sex and age distribution of the population can be seen in table 3.2. The population consists of 59 females and 64 males. Besides that, fifteen individuals were scored as probable female and fourteen as probable male. The amount of males and females in the population is thus approximately the same.

The population of Chelsea Old Church consists of fourteen early young adults, seventeen late young adults, 46 middle adults and 72 old adults. Furthermore, sixteen individuals have been classified as an adult. This latter category is for skeletons that can be classified as an adult, but for which no more specific age could be determined. In short, there is a relatively small amount of young adults (n=31) in the population. There are slightly more middle adults than young adults, but the largest part of the population consists of old adults.

	Category	**n**	**%**
Sex	Undeterminable	8	4,8
	Female	59	35,8
	Probable female	15	9,1
	Intermediate	5	3
	Probable male	14	8,5
	Male	64	38,8
Age	Adult	16	9,7
	Early young adult	14	8,5
	Late young adult	17	10,3
	Middle adult	46	27,9
	Old adult	72	43,6

Table 3.2: Sex and age distribution of the Chelsea Old Church population (N=165) in numbers and percentages.

3.1.3 St. Benet Sherehog

Cemetery

The excavation of the church and cemetery of the St. Benet Sherehog population took place between 1994 and 1996 and was carried out by the MOLAS. The church itself most likely dates to the late 11th century. It was part of a small Parish in London until the church was destroyed during the great fire of London in the year 1666. After the fire, the church was not rebuilt and the land was used as a cemetery for the St. Benet and St. Stephen Walbrook Parishes instead. The site remained a cemetery until its closure in 1853 (Bekvalac & Cowal, 2008).

A total of 274 skeletons were found during the excavation and 167 adult individuals were analysed. The burials primarily date from the 16th and 17th centuries. Based on the Parish records, it has been determined that the cemetery contains both wealthy and poor individuals. Furthermore, there is known to be a large amount of middle-status individuals (Bekvalac & Cowal, 2008).

Demographics

An overview of the sex and age distribution of the population can be seen in table 3.3. The population consists of 34 females and 65 males. Besides that, twelve individuals were scored as probable female and sixteen as probable male. There are thus a lot more males in the population than females.

The St. Benet Sherehog population consists of nine early young adults, 33 late young adults, 50 middle adults and 32 old adults. Besides that, there are 43 unclassified adults. There is thus a fairly even amount of young adults (n=42) and middle adults. There are slightly less old adults, but the difference with the other age categories is not big.

	Category	**n**	**%**
Sex	Undeterminable	37	22,2
	Female	34	20,4
	Probable female	12	7,2
	Intermediate	3	1,8
	Probable male	16	9,6
	Male	65	38,9
Age	Adult	43	25,7
	Early young adult	9	5,4
	Late young adult	33	19,8
	Middle adult	50	29,9
	Old adult	32	19,2

Table 3.3: Sex and age distribution of the St. Benet Sherehog population (N=167) in numbers and percentages.

3.1.4 St. Bride's Lower Churchyard

Cemetery

The cemetery of the St. Brides Lower Churchyard population was part of the Parish of St. Bride's and contains the skeletal remains of people who lived there during the 17th-19th centuries. However, most of the skeletons that were found here mainly date from the late 18th-19th century. The cemetery was established when the original churchyard, that was linked to St. Bride's church, became overcrowded (Kausmally, 2008).

The excavation of the cemetery took place in 1990. A total of 606 skeletons were found during the excavation and 369 adult individuals were analysed. A total of 47 skeletons were found in a fault and the 497 in an open yard (Kausmally, 2008). Interesting is that the archaeological population of St. Bride's Lower Churchyard likely includes individuals from the Bridewell workhouse since this was located nearby the cemetery (Kausmally, 2008). Workhouses were institutions where the poorest people of London were housed and set to work. The Bridewell also functioned as a prison, hospital and an industrial school for children (London Lives, n.d.). Based on the Parish records, it has been determined that the majority of the individuals buried in the cemetery were of low status (Kausmally, 2008).

Demographics

An overview of the sex and age distribution of the population can be seen in table 3.4. The St. Bride's Lower Churchyard population consists of 99 females and 161 males. Besides that, 26 individuals were scored as probable female and 33 as probable male. There are thus a lot more males in the population than females.

The population consists of ten early young adults, 44 late young adults, 88 middle adults and 162 old adults. Besides that, there are 65 unclassified adults. In short, there are a lot more old adults than middle adults and young adults. There are also more middle adults than young adults (n=54).

	Category	**n**	**%**
Sex	Undeterminable	36	9,8
	Female	99	26,8
	Probable female	26	7
	Intermediate	14	3,8
	Probable male	33	8,9
	Male	161	43,6
Age	Adult	65	17,6
	Early young adult	10	2,7
	Late young adult	44	11,9
	Middle adult	88	23,8
	Old adult	162	43,9

Table 3.4: Sex and age distribution of the St. Bride's Lower Churchyard population (N=369) in numbers and percentages.

3.2 Methods skeletal analysis

In this section, the methodology that was used for the skeletal analysis of the Arnhem population will be discussed. Furthermore, the age-at-death and sex estimation methods that have been used for the Arnhem population and the London populations will be discussed. As stated before, data was not collected for the London populations since this was already available on the website of the Museum of London (museumoflondon.org.uk). The vertebral pathology in Arnhem has been recorded using the same methods as the London collections to make the data comparable.

First, the vertebrae of the skeletons were laid out in anatomical position. A minimum of ten vertebrae had to be present for data to be collected on an individual. Individuals with less vertebrae were not analysed to prevent biased results. Each vertebra was examined for degenerative changes associated with the vertebral pathological conditions. It is important to note that all of the vertebral pathological conditions were recorded per opposing pair of vertebrae (e.g. first to second cervical vertebrae and second to third cervical vertebrae). Vertebral pathology was recorded if degenerative changes were present on at least one of the facets. Each set of vertebrae, on which pathology was present, received a score to indicate the severity of the degenerative changes (Powers, 2012, p. 47). The scoring system will be discussed in detail for each pathology in subsection 3.2.4 to 3.2.7. Based on the given scores, a separate column was created for each pathology indicating whether the pathology is absent or present.

3.2.1 Ethics

First it is important to consider that the ethical treatment of human remains is a common and delicate issue in (osteo)archaeology (Waters-Rist et al., 2018, p. 9). In the Netherlands, the principles defined by the Behavioural Code for Professional Archaeologists (NVvA) should be considered. This code states that human remains should be treated with dignity and respect during the excavation and during analysis (Nederlandse Vereniging van Archeologen, 2001)

The ethical aspect of analysing human remains has carefully been considered and the remains were handled with dignity and respect. Only the skeletons that were necessary for the analysis were handled. Furthermore, the methods by which the data was collected, were al non-invasive and thus left no marks on the bones.

3.2.2 Age-at-death estimation

Master's students of Leiden University, with as specialization Human Osteoarchaeology, have conducted the age-at-death estimations of the individuals from Arnhem. The age-of-death of the individuals from Arnhem has been determined by using the methods of dental attrition of the molars (Maat, 2001), auricular surface morphology (Buckberry & Chamberlain, 2002), cranial suture closure (Meindl & Lovejoy, 1985), pubic symphyseal face morphology (Brooks & Suchey, 1990), sternal rib end morphology (Iscan et al., 1984; Iscan et al., 1985) and late epiphyseal fusion for young adults. The individuals have been divided into the following age categories:

- Adult: 18+ years old
- Early young adult: 18-25 years old
- Late young adult: 26-35 years old
- Middle adult: 36-49 years old
- Old adult: 50+ years old

The age-of death estimations of the London populations have been conducted by the MoLAS and the Centre for Human Bioarchaeology (CHB) and have been described by Natasha Powers (Powers, 2012, p. 12). The age-of-death of the London individuals has been determined by using the methods of dental attrition of the molars (Brothwell, 1981), auricular surface degeneration (Lovejoy et al., 1965), pubic symphyseal face morphology (Brooks & Suchey, 1990) and sternal rib end morphology (Iscan et al., 1984; Iscan et al., 1985). The London populations had slightly different ages assigned to the age categories than the Arnhem population, namely the following:

- Adult: 18+ years old
- Early young adult: 18-25 years old
- Late young adult: 26-35 years old
- Middle adult: 36-45 years old
- Adult: 46+ years old

The age categories of the London collections have been reworked to the standards of the Laboratory of Human Osteoarchaeology to allow data comparison with the Arnhem population.

In the analysis in chapter 4, the individuals that were scored as adult have been left out, because this age category is not specific enough for answering the sub-question about the relationship between age and vertebral pathology. The individuals that were scored as early young adult and late young adult have been combined into one age category, namely young adult to enlarge the sample size and to better answer the research question.

3.2.3 Sex estimation

Master's students of Leiden University, with as specialization Human Osteoarchaeology, have conducted the sex estimations of the individuals from Arnhem. The sex of the individuals from Arnhem has been determined by scoring multiple cranial traits, mandible traits, pelvic traits and post-cranial bone measurements based on the standard of Buikstra and Ubelaker (1994) and that of Workshop for European Anthropologists (1980) (Buikstra & Ubelaker, 1994; WEA, 1980).

The sex estimations of the London populations have been conducted by the MoLAS and the CHB and have been described by Jelena Bekvalac (Bekvalac, 2012, p. 15). The sex of the individuals from London has been determined by scoring multiple cranial traits (Bass, 1987; Brothwell, 1981; Ferembach et al., 1980), a mandible trait (Brothwell, 1981) and pelvic traits (Bass, 1987; Phenice, 1969).

The populations have been divided into five groups, namely female, probable female, intermediate, probable male and male. Furthermore, individuals were scored as indeterminable if the sex could not be determined. In the analysis in chapter 4, the individuals that were scored as intermediate or undeterminable have been left out, because these categories are not relevant for answering the sub-question about the relationship between sex and vertebral pathology. Furthermore, the individuals that were scored as probable female or probable male have been grouped together with the individuals that were scored as female and male to better answer the research question. This means that there are only two groups, namely female and male.

3.2.4 Vertebral osteoarthritis

Vertebral osteoarthritis can affect multiple segments of the vertebra, like the vertebral bodies and apophyseal joints. However, most important in choosing what method to use is that the lesions are recorded in a standardized format so comparisons can be made (Brothwell, 1981, p. 335). Therefore, the vertebral pathology in Arnhem has been recorded using the same methods as the London collections. This means that osteoarthritis will only be recorded for the zygapophyseal joints and not the vertebral bodies.

The method of Brothwell 1981 (after Sager 1969) has been used to record vertebral osteoarthritis at the level of the zygapophyseal joints (Brothwell, 1981, p. 150). This method uses several macroscopic changes as an indicator for vertebral osteoarthritis, namely osteophytes, porotic changes and eburnation (Brothwell, 1981, p. 150). This method is a bit old, but it has still been chosen, because of two reasons. The first reason is that this method has been used to record vertebral osteoarthritis in the London collections. Using the same method for the Arnhem collection makes sure these collections are comparable. The second reason is that it can be used to study vertebral osteoarthritis with eburnation as the defining feature. This can be done, because of its grading system which will be discussed later in this subsection. Vertebral osteoarthritis has been studied with eburnation as its defining feature, because it has been argued that the other features of osteoarthritis are not necessarily indicative of this pathology. Pitting is closely related to growth and ageing and is often indicative of other pathological conditions as well. Furthermore, when osteophytes are present on their own, and thus not in combination with eburnation, there can be other causes like new bone growth on the joint surface and joint deformation (Larner, 2022, p. 144-145). In contrast, it has been suggested that eburnation is a pathognomonic trait of osteoarthritis and that therefore only this trait should be used to identify osteoarthritis (Molnar et al., 2011, p. 283; Weiss & Jurmain, 2007, p. 445).

A scoring system, consisting of three grades, has been used to determine the severity of the vertebral pathology (see table 3.5 and figure 3.1 to 3.3) (Connell & Rauxloh, 2003., p. 14). This pathology was scored as present when a vertebra was scored as grade 3 since this indicates that eburnation was present and that it was thus "true osteoarthritis". In other words, individuals were only considered to have vertebral osteoarthritis if grade 3 degenerative changes were present. (Powers, 2012, p. 47). The data regarding vertebral osteoarthritis has thus been handled in a presence/absence format and not on an ordinal scale. As discussed above, the reason for this is that it has been argued that eburnation is the only pathognomonic trait of osteoarthritis while pitting and osteophytes can also be influenced by other processes or pathological conditions.

Grade 1	Intermittent osteophytes
Grade 2	Osteophytes continuous, some porotic changes
Grade 3	Osteophytic lipping, extensive porosis and eburnation (or eburnation on its own)

Table 3.5: The different grades of vertebral osteoarthritis based on Brothwell 1981 (Brothwell, 1981, p. 150; Connell & Rauxloh, 2003., p. 14)

Figure 3.1: Grade 1 vertebral osteoarthritis on the left superior zygapophyseal joint of a cervical vertebra of individual 1862 from Arnhem (photo by author).

Figure 3.2: Grade 2 vertebral osteoarthritis on the left and right superior zygapophyseal joints of a lumbar vertebra of individual 2120 from Arnhem (photo by author).

Figure 3.3: Grade 3 vertebral osteoarthritis (including eburnation) on the left superior zygapophyseal joint of a cervical vertebra of individual 1754 from Arnhem (photo by author).

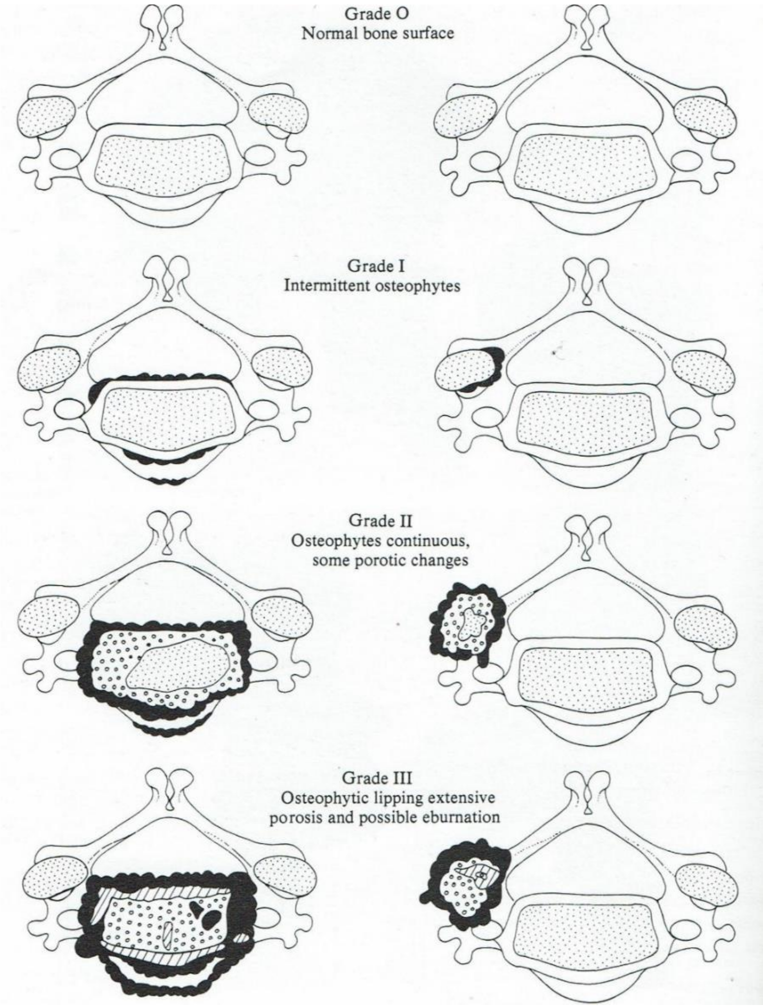

Figure 3.4: A schematic drawing of the grades that have been used to score vertebral osteoarthritis and osteophytes (Brothwell, 1981, p. 150).

These grades require a bit more explanation than that of most of the other pathological conditions. The reason for this is that the grades of vertebral osteoarthritis, and also osteophytes, are more prone to observers bias than the grades of the other pathological conditions. To elaborate, the grades of intervertebral disc disease, Schmorl's nodes and fusion are based on the location or measurement of the degenerative change(s). These are fairly objective criteria and therefore they suffer less from observers bias. However, in vertebral osteoarthritis, and osteophytosis as well, there may be different views on when an osteophyte should be scored as intermittent or continuous (i.e. whether it should be scored as grade 1 or 2) or when it should be scored as absent or grade 1.

For this thesis, vertebral osteoarthritis was scored based on, in addition to table 3.5, the figure in the publication of Brothwell 1981 (see figure 3.4). The degenerative changes were scored as grade 1 when the osteophytes were discontinuous or present only on a small portion (less than half) of the facet. The earliest subtle stages of osteophyte formation were also scored as grade 1. The changes were scored as grade 2 when porotic changes were present and/or when the osteophytes were continuous and present on the entire facet (Brothwell, 1981, p. 150). Lastly, the changes were scored as grade 3 only when eburnation was present (Connell & Rauxloh, 2003., p. 14).

3.2.5 Osteophytes

Osteophytes have separately been recorded for the margins of the vertebral bodies (Powers, 2012, p. 47). These changes have also been recorded following the method of Brothwell 1981 (Brothwell, 1981, p. 150). A scoring system, consisting of three grades, has been used to indicate the severity of the osteophytes (see table 3.6 and figure 3.5 to 3.7) (Powers, 2012, p. 47). This pathology was scored as present when a vertebra was scored as grade 1 or higher, because of two reasons. The first reason is that it has also been done this way for the London collections. Using the same scoring system for the Arnhem collection makes the collections comparable. The second reason is that when osteophytes are present, even if only slightly, it means that the individual might have been regularly exposed to hard labour. To elaborate, osteophytes develop over time and only start to form after being exposed to stress and strain regularly and for a prolonged period of time (Stirland & Waldron, 1996, p. 335). In other words, all degrees of osteophyte formation might be indictive of physical activity and hard labour. This is not linked to a certain severity of osteophytes.

Grade 1	Intermittent
Grade 2	Continuous
Grade 3	Extensive lipping

Table 3.6: The different grades of osteophytes based on Brothwell 1981 (Brothwell, 1981, p. 150; Connell & Rauxloh, 2003, p. 14).

Figure 3.5: Grade 1 osteophytes on the superior vertebral body margin of a lumbar vertebra of individual 1862 from Arnhem (photo by author).

Figure 3.6: Grade 2 osteophytes on the inferior vertebral body margin of a thoracic vertebra of individual 1837 from Arnhem (photo by author).

Figure 3.7: Grade 3 osteophytes on the inferior vertebral body margin of a lumbar vertebra of individual 2120 from Arnhem (photo by author).

As stated before, like vertebral osteoarthritis, these grades require a bit more explanation than the other pathological conditions, because of observers bias. Like in vertebral osteoarthritis, osteophytes can range from being very subtle to being very extensive (see figure 3.5 to 3.7). Osteophytes were, in addition to table 3.6, scored based on the figure in the publication of Brothwell 1981 (see figure 3.4). The changes were scored as grade 1 when the osteophytes were discontinuous or present only on a small portion (less than half) of the vertebral body margin. The earliest stages of osteophyte formation were also scored as grade 1. The changes were scored as grade 2 when the osteophytes were continuous and present on the entire facet. Lastly, the changes were scored as grade 3 when osteophytes were continuous and extensive (Brothwell, 1981, p. 150).

3.2.6 Intervertebral disc disease

The method of Rogers and Waldron 1995 has been used to record intervertebral disc disease (Rogers & Waldron, 1995, p. 26-27). Intervertebral disc disease has been recorded by the location of pitting on the centrum of the vertebrae. The scoring system that has been used to record intervertebral disc disease consists of three grades (see table 3.7 and figure 3.8 to 3.10) (Powers, 2012, p. 47). This pathology was scored as present when a vertebra was scored as grade 1 or higher.

Grade 1	Coarse pitting on the centrum, under the footprint of the annulus fibrosus (outer rim of the surface)
Grade 2	Coarse pitting on the centrum, on the central part of the articular surface
Grade 3	Coarse pitting on both of the above

Table 3.7: The different grades of intervertebral disc disease based on Rogers & Waldron 1995 (Connell & Rauxloh, 2003, p. 14; Rogers & Waldron, 1995, p. 26-27).

Figure 3.8: Grade 1 intervertebral disc disease on the superior articular surface of a cervical vertebra of individual 1862 from Arnhem (photo by author).

Figure 3.9: Grade 2 intervertebral disc disease on the superior articular surface of a cervical vertebra of individual 490 from Arnhem (photo by author).

Figure 3.10: Grade 3 intervertebral disc disease on the inferior articular surface of a cervical vertebra of individual 1862 from Arnhem (photo by author).

3.2.7 Schmorl's nodes

Schmorl's nodes have been recorded based on the maximum dimension of the lesion. The maximum dimension of the lesion was measured with a digital sliding caliper. The scoring system that has been used consists of three grades (see table 3.8 and figure 3.11 to 3.13) (Powers, 2012, p. 47). This pathology was scored as present when a vertebra was scored as grade 1 or higher, because of two reasons. The first reason is that it has also been done this way for the London collections. The second reason is that, like with osteophytes, all degrees of Schmorl's nodes might be indictive of physical activity and hard labour since all degrees are a sign that there might have been stress and strain on the spine. This is not linked to a certain severity of Schmorl's nodes.

Grade 1	Small <15mm wide and/or in depth
Grade 2	Medium >15mm wide and/or in depth
Grade 3	Large >25mm wide and/or in depth

Table 3.8: The different grades on Schmorl's nodes (Connell & Rauxloh, 2003, p. 15).

Figure 3.11: Grade 1 Schmorl's nodes on the inferior articular surface of a thoracic vertebra of individual 1375 from Arnhem (photo by author).

Figure 3.12: Grade 2 Schmorl's node on the inferior articular surface of a lumbar vertebra of individual 1375 from Arnhem (photo by author).

Figure 3.13: Grade 3 Schmorl's node on the inferior articular surface of a thoracic vertebra of individual 1375 from Arnhem (photo by author).

3.2.8 Fusion

Lastly, fusion has been recorded by location when two or more vertebrae were affected. It is important to note that a distinction was made between pathological fusion and congenital segmentation failures. Only the pathological fusion has been recorded (Powers, 2012, p. 47). A scoring system, consisting of six grades, has been used to score pathological fusion (see table 3.9 and figure 3.14 to 3.19) (Connell & Rauxloh, 2003, p. 15). This pathology was scored as present when a vertebra was scored as grade 1 or higher.

Grade 1	Fusion across centrum only: Right side
Grade 2	Fusion across centrum only: Left side
Grade 3	Fusion across centrum only: Median
Grade 4	Fusion across zygapophyseal joints only
Grade 5	Fusion across centrum and zygapophyseal joints
Grade 6	Fusion across centrum only: Median, right and left sides

Table 3.9: The different grades of fusion (Connell & Rauxloh, 2003, p. 15).

Figure 3.14: Grade 1 fusion of five thoracic vertebrae of individual 2120 from Arnhem (photo by author).

Figure 3.15: Grade 2 fusion of five thoracic vertebrae of individual 1862 from Arnhem. The lower two vertebrae are fused on the right side as well (grade 1) (photo by author).

Figure 3.16: Grade 3 fusion of two thoracic vertebrae of individual 1350 from Arnhem (photo by author).

Figure 3.17: Grade 4 fusion of six thoracic vertebrae of individual 1346 from Arnhem (photo by author).

Figure 3.18: Grade 5 fusion of two thoracic vertebrae of individual 2120 from Arnhem (photo by author).

Figure 3.19: Grade 6 fusion of seven cervical vertebrae of an individual from St. Bride's Lower Churchyard (Museum of London, n.d.).

3.3 Methods data analysis

In this section, changes that had to be made to the London databases will be discussed. These changes were needed to make the databases more comparable with the statistical software that has been used for this thesis and with the osteoarchaeological guidelines of Leiden University. Furthermore, the statistics that have been used for the statistical analysis in chapter 4 will be discussed.

3.3.1 Reworking of the databases

The databases of the three London collections were transformed to another layout to make it more compatible with SPSS, which is the programming application that was used for this thesis for statistical analysis.

A significant part of this thesis research is the comparison between the Arnhem population and three London populations. It has been decided to not use the original database layout of the London populations in order to increase the compatibility with SPSS. The original databases of the London populations had multiple rows per skeleton. More specifically, there were separate rows for each pathological condition and for each opposing set of vertebrae per skeleton. The databases were reworked to make them more compatible with SPSS by making unique columns for each pathological condition and for each opposing set of vertebrae per skeleton. These changes have ensured that there is only one row per skeleton in the databases.

Another thing that has been reworked for the databases of London are the age categories. There were slight differences in the ages that were assigned to the age categories between the London collections and the collections of the Laboratory for Human Osteoarchaeology in Leiden. The London collections divided the skeletons into the following age categories:

- Unclassified adult >18
- Adult 18-25
- Adult 26-35
- Adult 36-45
- Adult >46

These age categories have been reworked to the standards of the Laboratory of Human Osteoarchaeology to allow data comparison. These age categories have already been described in subsection 3.2.2.

Furthermore, only the individuals with vertebral pathology were recorded in the databases of London, so they did not include individuals without vertebral pathology while these individuals have been analysed for this. Therefore, the sex estimation databases have been used for all the London populations to determine the total number of individuals in the population. This dataset was then fused with the reworked databases of London, by adding the missing individuals into it, in order to be able to do the statistical tests.

3.3.2 Statistics

Three different types of statistical tests have been used for the statistical analysis. Statistical analysis has been performed to be able to make inter- and intra-population comparisons of the prevalence of the vertebral pathological conditions. The observed differences were considered to be statistically significant if the p-value was <0.05.

The inter- and intra-population differences in the overall prevalence of the vertebral pathological conditions and in the prevalence of the vertebral pathological conditions between the sexes have been analysed by using chi-squared tests (χ^2), because this statistical test can be used to determine if there is a relationship between two qualitative values by comparing the observed frequencies with the expected frequencies (Barceló, 2018, p. 1; van Pool & Leonard, 2010, p. 240).

A different test was used when not all the expected frequencies were over five individuals, namely a Fisher's Exact Test. The reason for using another test is that it has been argued that if the expected frequencies are not over five individuals, the results of the chi-squared tests might become less reliable since it might then not accurately reflect the parent archaeological population. A Fisher's Exact Test has been used, because this is the most commonly used alternative for the chi-squared test and it is considered to be especially useful when dealing with small sample sizes or expected frequencies higher than zero (van Pool & Leonard, 2010, p. 249-250).

The intra-population differences that relate to the age categories, specifically to the differences in the prevalence of the vertebral pathological conditions between the age categories, have been analysed by using a Kruskal-Wallis test. This test was used, because three rather than two variables will be compared (young adult vs middle adult vs old adult rather than male vs female or Arnhem vs Chelsea Old Church etc.). A chi-squared test could have been used for this since they can also indicate if there is a relationship between more than two categorical variables. However, chi-squared tests can only indicate whether or not there is a relationship between two or more categorical variables, but it does not give insight into the nature of this relationship when more than two variables are compared. In other words, it indicates if there is a significant difference between the variables, but it does not indicate what variables are statistically significantly different. It can be argued that the largest differences are most likely responsible for the test outcomes that indicate a relationship between variables (van Pool & Leonard, 2010, p. 245). However, to be sure, it is better to use a Kruskal-Wallis test since this test can give insight into where these statistically significant differences lie if you choose to do a pairwise comparison in addition to this. The test that is used for the pairwise comparison in the Dunn-Bonferroni test. The results of the pairwise comparison are not included in the results chapter, but can be found in the appendices.

Now the skeletal collections and their context have been discussed. Furthermore, the methodology that was used in the skeletal and data analysis have been discussed in detail. In the next chapter, the results of these analyses will be discussed.

CHAPTER 4 Results

In this chapter, the results of the data analysis/statistical tests will be discussed. First the results of the skeletal analysis of the Arnhem population will be discussed briefly. After that, the prevalence of the vertebral pathological conditions will be compared between the Arnhem population and the three London populations. Then the prevalence of the vertebral pathological conditions will be compared between the males and females within each population. The prevalence of the vertebral pathological conditions across the age categories will be compared after that. This will also be done for each population. Lastly, the males and female sample of the populations will be compared separately between the Arnhem population and the three London populations. It is important to note that the comparisons will focus on the percentages rather than the numbers due to the different sizes of the sample populations.

4.1 Arnhem

In this section, the results of the skeletal analysis of the Arnhem individuals will briefly be discussed. The prevalence of the vertebral pathological conditions (vertebral osteoarthritis, osteophytes, intervertebral disc disease, Schmorl's nodes and fusion) in the Arnhem population is presented in table 4.1. The pathology that is the least prevalent in the population is fusion. A total of eleven individuals (14,5% of all individuals) have two or more vertebrae that are fused together. The most prevalent pathological conditions are osteophytes and Schmorl's nodes with osteophytes being present in the spine of 55 individuals (72,4%) and Schmorl's nodes in that of 53 individuals (69,7%). Vertebral osteoarthritis and intervertebral disc disease are equally prevalent in the Arnhem population. Both are present in 27 individuals (35,5%). The intrapopulation statistics of the Arnhem population, including sex and age, will be presented in section 4.3 and 4.4.

	N	**n**	**%**
Vertebral osteoarthritis	76	27	35,5
Osteophytes	76	55	72,4
Intervertebral disc disease	76	27	35,5
Schmorl's nodes	76	53	69,7
Fusion	76	11	14,5

Table 4.1: The prevalence of the vertebral pathological conditions in the Arnhem population

4.2 Inter-population comparison of the prevalence of the vertebral pathological conditions

4.2.1 Arnhem (low status) vs Chelsea Old Church (high status)

First, the prevalence of the vertebral pathological conditions in the Arnhem and high-status Chelsea Old Church population will be compared with each other. An overview of the prevalence of the vertebral pathological conditions in the two populations can be seen in table 4.2. All the pathological conditions examined for this thesis are more prevalent in the Arnhem population than in the Chelsea Old Church population.

35,5% of the Arnhem individuals and 24,8% of the Chelsea Old Church individuals have vertebral osteoarthritis. Vertebral osteoarthritis is thus, relatively speaking, more prevalent in the Arnhem population. Since the p-value is <0.05 this difference is not considered to be statistically significant ($\chi^2(1)=2.929$, p=0.087). However, it can be argued that this difference is near to significance. There are several articles that argue that we should move away from a p-value of <0.05 as a steadfast rule for significance (e.g. Amrhein et al., 2019; McShane et al., 2019; Wasserstein et al., 2019). It has been emphasised that an association should not necessarily be considered absent just because, for example, the p-value exceeds the threshold of <0.05 (Wasserstein et al., 2019, p. 1). Since the chi-square statistic value is relatively high and the p-value is low and close to the 0.05 threshold, it can be argued that this difference is near to significance and that the Arnhem population had meaningfully higher rates of vertebral osteoarthritis than the Chelsea Old Church population. To elaborate, the chi-square statistic value is high if there are large differences between the observed and expected values and small if there are small differences between these values. In other words, the higher the chi-square statistic value is, the greater the probability that the difference is statistically significant (Schumacker & Tomek, 2013, p. 171).

The most prevalent pathology in both populations is osteophytes with it being present in the spine of 72,4% of the Arnhem individuals and in that of 58,8% of the Chelsea Old Church individuals. However, osteophytes are statistically significantly more prevalent in the Arnhem population than in the Chelsea Old Church population ($\chi^2(1)=4.120$, p=0.042)

A pathology of which the difference in prevalence between the Arnhem and Chelsea Old Church population is not statistically significant, is intervertebral disc disease ($\chi^2(1)=0.507$, p=0.477). Even though the difference is not statistically significant, the prevalence is higher in the Arnhem population than in the Chelsea Old Church population. Namely, 35,5% of the Arnhem individuals and 30,9% of the Chelsea Old Church individuals have intervertebral disc disease.

A statistically significant difference can be seen in the prevalence of Schmorl's nodes between the two populations ($\chi^2(1)=23.271$, p=<0.001). Schmorl's nodes are namely present in the spine of 69,7% of the Arnhem individuals and in that of 36,4% of the Chelsea Old Church individuals. Percentage-wise, there are almost twice as many individuals with Schmorl's nodes in the Chelsea Old Church population than in the Arnhem population.

Lastly, fusion is the least prevalent pathology in both populations. It is present in 14,5% of the Arnhem individuals and 5,5% of the Chelsea Old Church individuals. There is a statistically significant difference in the prevalence of fusion between the Arnhem and Chelsea Old Church population with it being more prevalent in the Arnhem population (χ^2(1)=5.562, p=0.018). Interestingly, even though the Chelsea Old Church population consists of more individuals, the number of individuals with fusion is higher in the Arnhem population.

Group	**Pathology**	**Number of individuals**	**Individuals with pathology**		**Statistical analysis**		
			n	*%*	*χ^2-value*	*df*	*p*
Arnhem	Vertebral osteoarthritis	76	27	35,5	2.929	1	0.087
Chelsea		165	41	24,8			
Arnhem	Osteophytes	76	55	72,4	4.120	1	**0.042**
Chelsea		165	97	58,8			
Arnhem	Intervertebral disc disease	76	27	35,5	0.507	1	0.477
Chelsea		165	51	30,9			
Arnhem	Schmorl's nodes	76	53	69,7	23.271	1	**<0.001**
Chelsea		165	60	36,4			
Arnhem	Fusion	76	11	14,5	5.562	1	**0.018**
Chelsea		165	9	5,5			

Table 4.2: Comparison of the prevalence of the vertebral pathological conditions between the Arnhem population and the Chelsea Old Church population.

4.2.2 Arnhem (low status) vs St. Benet Sherehog (middle status)

The prevalence of the vertebral pathological conditions in the Arnhem population and in the middle-status St. Benet Sherehog population will be compared with each other. An overview of the prevalence of the vertebral pathological conditions in the two populations can be seen in table 4.3. All the pathological conditions examined for this thesis are more prevalent in the Arnhem population than in the St. Benet Sherehog population.

A total of 35,5% of the Arnhem individuals and 12,6% of the St. Benet Sherehog individuals have vertebral osteoarthritis. Vertebral osteoarthritis is statistically significantly more prevalent in the Arnhem population than in the St. Benet Sherehog population (χ^2(1)=17.357, p=<0.001).

The most prevalent pathology in the Arnhem population is osteophytes. This pathology is the second most prevalent pathology in the St. Benet Sherehog population with Schmorl's nodes being the most prevalent one. Osteophytes are present in the spine of 72,4% of the Arnhem individuals and in that of 40,7% of the St. Benet Sherehog individuals. Osteophytes are statistically significantly more prevalent in the Arnhem population than in the St. Benet Sherehog population (χ^2(1)=20.931, p=<0.001).

The only pathology, that does not have a statistically significant difference in prevalence between the Arnhem and St. Benet Sherehog population, is intervertebral disc disease (χ^2(1)=1.344, p=0.246). Even though the difference is not statistically significant, it is more prevalent in the Arnhem population since 35,5% of the Arnhem individuals and 28,1% of the St. Benet Sherehog individuals have it.

As stated before, the most prevalent pathology in the St. Benet Sherehog population is Schmorl's nodes. However, Schmorl's nodes are statistically significantly more prevalent in the Arnhem population than in the St. Benet Sherehog population (χ^2(1)=15.488, p=<0.001). Namely, 69,7% of the Arnhem individuals and 42,5% of the St. Benet Sherehog individuals have Schmorl's nodes.

Lastly, fusion is the least prevalent pathology in both populations. It is present in 14,5% of the Arnhem individuals and 4,8% of the St. Benet Sherehog individuals. The difference in the prevalence of fusion between the two populations is statistically significant (1)=6.795, p=0.009). Fusion is more prevalent in the Arnhem population. The number of individuals with fusion is, again, higher in the Arnhem population than in the St. Benet Sherehog population even though the latter consists of more individuals.

Group	**Pathology**	**Number of individuals**	**Individuals with pathology**		**Statistical analysis**		
			n	*%*	*χ^2-value*	*df*	*p*
Arnhem	Vertebral osteoarthritis	76	27	35,5	17.357	1	**<0.001**
St. Benet		167	21	12,6			
Arnhem	Osteophytes	76	55	72,4	20.931	1	**<0.001**
St. Benet		167	68	40,7			
Arnhem	Intervertebral disc disease	76	27	35,5	1.344	1	0.246
St. Benet		167	47	28,1			
Arnhem	Schmorl's nodes	76	53	69,7	15.488	1	**<0.001**
St. Benet		167	71	42,5			
Arnhem	Fusion	76	11	14,5	6.795	1	**0.009**
St. Benet		167	8	4,8			

Table 4.3: Comparison of the prevalence of the vertebral pathological conditions between the Arnhem population and the St. Benet Sherehog population.

4.2.3 Arnhem (low status) vs St. Bride's Lower Churchyard (low status)

The prevalence of the vertebral pathological conditions in the Arnhem population and in the low-status St. Bride's Lower Churchyard population will be compared with each other. An overview of the prevalence of the vertebral pathological conditions in the two populations can be seen in table 4.4. Nearly all the pathological conditions examined for this thesis are more prevalent in the Arnhem population than in the St. Bride's Lower Churchyard population. The only pathological condition that is not more prevalent in the Arnhem population is intervertebral disc disease.

35,5% of the Arnhem individuals and 31,4% of the St. Bride's Lower Churchyard individuals have vertebral osteoarthritis. This is a difference of only 4,1%. Percentage-wise, this pathology is thus approximately equally prevalent in both populations. The difference in the prevalence of vertebral osteoarthritis is therefore not statistically significant between the Arnhem and St. Bride's Lower Churchyard population ($\chi^2(1)=0.483$, p=0.487).

Osteophytes is the most prevalent pathology in both populations. It is present in 72,4% of the Arnhem individuals and 63,4% of the St. Bride's Lower Churchyard individuals. It is more prevalent in the Arnhem population than in the St. Bride's Lower Churchyard population, but this difference is prevalence is not statistically significant ($\chi^2(1)=2.219$, p=0.136).

35,5% of the Arnhem individuals and 36,9% of the St. Bride's Lower Churchyard population have intervertebral disc disease. The difference in the prevalence of intervertebral disc disease is thus even smaller between the two populations than that of vertebral osteoarthritis, namely 1,4%. This pathology is thus, percentage-wise, approximately equally prevalent in the two populations. This difference in the prevalence of intervertebral disc disease is therefore not statistically significant between the Arnhem population and the St. Bride's Lower Churchyard population ($\chi^2(1)=0.048$, p=0.827).

The only statistically significant difference in prevalence between the Arnhem and St. Bride's Lower Churchyard population can be found in Schmorl's nodes with it being more prevalent in the Arnhem population ($\chi^2(1)=15.446$, p=<0.001). Schmorl's nodes are namely present in 69,7% of the Arnhem individuals and in 45% of the St. Bride's Lower Churchyard individuals.

Lastly, fusion is the least prevalent pathology in both populations. It is present in 14,5% of the Arnhem individuals and 8,9% of the St. Bride's Lower Churchyard individuals. Fusion is thus more prevalent in the Arnhem population, but the difference in the prevalence of fusion between the two populations is not statistically significant ($\chi^2(1)=2.163$, p=0.141).

Group	Pathology	Number of individuals	Individuals with pathology		Statistical analysis		
			n	*%*	χ^2*-value*	*df*	*p*
Arnhem	Vertebral osteoarthritis	76	27	35,5	0.483	1	0.487
St. Bride's		369	116	31,4			
Arnhem	Osteophytes	76	55	72,4	2.219	1	0.136
St. Bride's		369	234	63,4			
Arnhem	Intervertebral disc disease	76	27	35,5	0.048	1	0.827
St. Bride's		369	136	36,9			
Arnhem	Schmorl's nodes	76	53	69,7	15.446	1	**<0.001**
St. Bride's		369	166	45			
Arnhem	Fusion	76	11	14,5	2.163	1	0.141
St. Bride's		369	33	8,9			

Table 4.4: Comparison of the prevalence of the vertebral pathological conditions between the Arnhem population and the St. Bride's Lower Churchyard population.

4.3 Intra-population comparison of the prevalence between males and females

In this section, the prevalence of the vertebral pathological conditions will be compared between males and females to determine if one sex is more affected than the other. This will be done separately for each population.

4.3.1 Arnhem

There are a total of 31 females and 44 males in the Arnhem population. In other words, approximately 41% of the population consists of females and 58% of males. The remaining 1% consists of one individual that was scored as intermediate. The prevalence of the vertebral pathological conditions by sex in the Arnhem population is presented in table 4.5.

The only statistically significant difference in the prevalence of the vertebral pathological conditions between males and females in the Arnhem population can be found in Schmorl's nodes (χ^2(1)=10.904, p=<0.001). This vertebral pathology is present in the spine of 84,1% of the males. About half of the females, specifically 48,4%, have Schmorl's nodes. This pathology is thus statistically significantly more prevalent in males than in females.

The difference in prevalence between males and females is not statistically significant for vertebral osteoarthritis (χ^2(1)=0.741, p=0.389), osteophytes (χ^2(1)=3.006, p=0.083), intervertebral disc disease (χ^2(1)=0.741, p=0.389) and fusion (p=0.110). However, all these pathological conditions are, even though the difference is not statistically significant, more prevalent in males than in females. Furthermore, it is important to note that the chi-square statistic value is relatively high and the p-value is low and close to the 0.05 threshold for one of these pathological conditions, namely osteophytes. Therefore, it can be argued that this difference is near to significance and that the males had meaningfully higher rates of osteophytes than the females in the Arnhem population.

Group	Pathology	Number of individuals	Individuals with pathology		Statistical analysis		
			n	*%*	*χ^2-value*	*df*	*p*
Female	Vertebral osteoarthritis	31	9	29	0.741	1	0.389
Male		44	17	38,6			
Female	Osteophytes	31	19	61,3	3.006	1	0.083
Male		44	35	79,5			
Female	Intervertebral disc disease	31	9	29	0.741	1	0.389
Male		44	17	38,6			
Female	Fusion	31	2	6,5	-	-	0.110*
Male		44	9	20,5			
Female	Schmorl's nodes	31	15	48,4	10.904	1	**<0.001**
Male		44	37	84,1			

**Fisher's Exact test*

Table 4.5: Comparison of the prevalence of the vertebral pathological conditions between males and females in the Arnhem population.

4.3.2 Chelsea Old Church

There are a total of 74 females and 78 males in the Chelsea Old Church population. In percentages, approximately 45% of the population consists of females and 47% of males. The remaining 8% consists of individuals that were scored as intermediate or undeterminable. The prevalence of the vertebral pathological conditions by sex in the Chelsea Old Church population is presented in table 4.6.

The only vertebral pathology that is significantly different in prevalence between males and females in the Chelsea Old Church population is Schmorl's nodes (χ^2(1)=10.681, p=0.001). 24,3% of the females and 50% of the males have Schmorl's nodes. Schmorl's nodes are thus statistically significantly more prevalent in males than in females.

The difference in prevalence between males and females is not statistically significant for vertebral osteoarthritis (χ^2(1)=1.298, p=0.255), osteophytes (χ^2(1)=1.190, p=0.275), intervertebral disc disease (χ^2(1)=0.088, p=0.767) and fusion (p=1.000). However, vertebral osteoarthritis and osteophytes are, even though the difference is not statistically significant, more prevalent in males than in females. Fusion and intervertebral disc disease are, percentage-wise, approximately equally prevalent in males and females since the difference in prevalence is only 1% for fusion and 2,2% for intervertebral disc disease. Though they are approximately equally prevalent, the percentage of individuals with fusion and intervertebral disc disease is still slightly higher in males.

Group	Pathology	Number of individuals	Individuals with pathology		Statistical analysis		
			n	*%*	*χ^2-value*	*df*	*p*
Female	Vertebral osteoarthritis	74	15	20,3	1.298	1	0.255
Male		78	22	28,2			
Female	Osteophytes	74	42	56,8	1.190	1	0.275
Male		78	51	65,4			
Female	Intervertebral disc disease	74	23	31,1	0.088	1	0.767
Male		78	26	33,3			
Female	Schmorl's nodes	74	18	24,3	10.681	1	**0.001**
Male		78	39	50			
Female	Fusion	74	4	5,4	-	-	1.000*
Male		78	5	6,4			

**Fisher's Exact test*

Table 4.6: Comparison of the prevalence of the vertebral pathological conditions between males and females in the Chelsea Old Church population.

4.3.3 St. Benet Sherehog

There are a total of 46 females and 81 males in the St. Benet Sherehog population. This means that approximately 28% of the population consists of females and 49% of males. The remaining 24% consists of individuals that were scored as intermediate or undeterminable. The prevalence of the vertebral pathological conditions by sex in the St. Benet Sherehog population is presented in table 4.7.

There are two vertebral pathological conditions that are statistically significantly different in prevalence between males and females in the St. Benet Sherehog population. The first pathology that is statistically significantly different in prevalence between males and females is Schmorl's nodes (χ^2(1)=6.023, p=0.014). These are present in the spine of 39,1% of the females and in that of 61,7% of the males, so they are statistically significantly more prevalent in males than in females.

The second pathology that is statistically significantly different in prevalence between males and females is fusion (p=0.026). 13% of the females and 2,5% of the males have fused vertebrae. This means that fusion is statistically significantly more prevalent in females than in males.

The difference in prevalence between males and females is not statistically significant for vertebral osteoarthritis (χ^2(1)=1.415, p=0.234), osteophytes (χ^2(1)=0.496, p=0.481) and intervertebral disc disease (χ^2(1)=0.261, p=0.607). Vertebral osteoarthritis and intervertebral disc disease are, even though the difference is not statistically significant, more prevalent in females than in males. Osteophytes are more prevalent in males than in females.

Group	Pathology	Number of individuals	Individuals with pathology		Statistical analysis		
			n	*%*	χ^2*-value*	*df*	*p*
Female	Vertebral osteoarthritis	46	10	21,7	1.415	1	0.234
Male		81	11	13,6			
Female	Osteophytes	46	22	47,8	0.496	1	0.481
Male		81	44	54,3			
Female	Intervertebral disc disease	46	18	39,1	0.264	1	0.607
Male		81	28	34,6			
Female	Schmorl's nodes	46	18	39,1	6.023	1	**0.014**
Male		81	50	61,7			
Female	Fusion	46	6	13	-	-	**0.026***
Male		81	2	2,5			

**Fisher's Exact test*

Table 4.7: Comparison of the prevalence of the vertebral pathological conditions between males and females in the St. Benet Sherehog population.

4.3.4 St. Bride's Lower Churchyard

There are a total of 126 females and 193 males in the St. Bride's Lower Churchyard population. This means that approximately 34% of the population consists of females and 52% of males. The remaining 14% consists of individuals that were scored as intermediate or undeterminable. The prevalence of the vertebral pathological conditions by sex in the St. Bride's Lower Churchyard population is presented in table 4.8.

The only vertebral pathology that is significantly different in prevalence between males and females in the St. Bride's Lower Churchyard population is Schmorl's nodes (χ^2(1)=35.043, p= <0.001). Schmorl's nodes are present in the spine of 27,8% of the females and in that of 61,7% of the males, so they are statistically significantly more prevalent in males than in females.

The difference in prevalence between males and females is not statistically significant for vertebral osteoarthritis χ^2(1)=0.206, p=0.650), osteophytes (χ^2(1)=0.007, p=0.934), intervertebral disc disease (χ^2(1)=0.490, p=0.484) and fusion (χ^2(1)=0.019, p=0.891. All these pathological conditions are, percentage-wise, approximately equally prevalent in males and females since the difference in prevalence is only 2,5% for vertebral osteoarthritis, 0,4% for osteophytes, 3,9% for intervertebral disc disease and 0,5% for fusion. Though they are approximately equally prevalent, the percentage of individuals with vertebral osteoarthritis, intervertebral disc disease and osteophytes is still slightly higher in males. The percentage of individuals with fusion is slightly higher in females.

Group	Pathology	Number of individuals	Individuals with pathology		Statistical analysis		
			n	*%*	χ^2-*value*	*df*	*p*
Female	Vertebral osteoarthritis	126	40	31,7	0.206	1	0.650
Male		193	66	34,2			
Female	Osteophytes	126	83	65,9	0.007	1	0.934
Male		193	128	66,3			
Female	Intervertebral disc disease	126	46	36,5	0.490	1	0.484
Male		193	78	40,4			
Female	Schmorl's nodes	126	35	27,8	35.043	1	**<0.001**
Male		193	119	61,7			
Female	Fusion	126	13	10,3	0.019	1	0.891
Male		193	19	9,8			

Table 4.8: Comparison of the prevalence of the vertebral pathological conditions between males and females in the St. Bride's Lower Churchyard population.

4.4 Intra-population comparison of the prevalence between the age categories

In this section, the prevalence of the vertebral pathological conditions will be compared between the age categories to determine if there is a correlation between age and the prevalence of vertebral pathology and if there are thus any possible age biases in the populations. This will be done separately for each population.

Kruskall-Wallis tests have been used to compare the prevalence of the vertebral pathological conditions between the age categories. This test indicates that the prevalence of the vertebral pathological conditions is different across the age categories if there is a statistically significant difference between at least two of them. A post-hoc Dunn-Bonferroni test has been done after this to find out where the statistically significant differences lie (between which age categories). The results of this test can be found in the appendices.

4.4.1 Arnhem

There are a total of 27 young adults, 35 middle adults and thirteen old adults in the Arnhem population. In percentages, approximately 36% of the population consists of young adults, 46% of middle adults and 17% of old adults. The remaining 1% consists of individuals that were scored as adult. The prevalence of the vertebral pathological conditions by age category in the Arnhem population is presented in table 4.9.

Four out of the five vertebral pathological conditions are statistically significantly different in prevalence across the age categories, namely vertebral osteoarthritis ($H(2)=16.726$, $p=<0.001$), osteophytes ($H(2)=18.740$, $p=<0.001$), intervertebral disc disease ($H(2)=27.123$, $p=<0.001$) and fusion ($H(2)=7.097$, $p=0.029$). There is a trend, namely a trend of percentual increase in the prevalence of pathology with age. The only pathology that does not show this trend is fusion. The percentage of individuals with fusion is in this case approximately equal for young adults and middle adults, but, relative to these two categories, it still increases in the old adults.

There is no statistically significant difference in the prevalence of Schmorl's nodes across the age categories ($H(2)=0.024$, $p=0.988$). The percentages are fairly equal in all the age categories meaning that this pathology does not follow the trend of percentual increase in the prevalence of pathology with age.

Group	Pathology	Number of individuals	Individuals with pathology		Statistical analysis		
			n	*%*	*H-value*	*df*	*p*
Young adult	Vertebral osteoarthritis	27	3	11,1	16.726	2	**<0.001**
Middle adult		35	14	40			
Old Adult		13	10	76,9			
Young adult	Osteophytes	27	12	44,4	18.740	2	**<0.001**
Middle adult		35	30	85,7			
Old Adult		13	13	100			
Young adult	Intervertebral disc disease	27	2	7,4	*27.123*	2	**<0.001**
Middle adult		35	13	37,1			
Old Adult		13	12	92,3			
Young adult	Schmorl's nodes	27	19	70,4	0.024	2	0.988
Middle adult		35	25	71,4			
Old Adult		13	9	69,2			
Young adult	Fusion	27	3	11,1	7.097	2	**0.029**
Middle adult		35	3	8,6			
Old Adult		13	5	38,5			

Table 4.9: Comparison of the prevalence of the vertebral pathological conditions between young adults, middle adults and old adults in the Arnhem population.

4.4.2 Chelsea Old Church

There are a total of 31 young adults, 46 middle adults and 72 old adults in the Chelsea Old Church population. In percentages, approximately 19% of the population consists of young adults, 28% of middle adults and 44% of old adults. The remaining 9% consists of individuals that were scored as adult. The prevalence of the vertebral pathological conditions by age category in the Chelsea Old Church population is presented in table 4.10.

Three out of the five vertebral pathological conditions are statistically significantly different in prevalence across the age categories, namely vertebral osteoarthritis (H(2)=27.780, p=<0.001), osteophytes (H(2)=30.011, p=<0.001) and intervertebral disc disease (H(2)=26.187, p=<0.001). All these pathological conditions show a trend of percentual increase in the prevalence of pathology with age.

There is no statistically significant difference in the prevalence of Schmorl's nodes (H(2)=1.529, p=0.466) and fusion (H(2)=2.216, p=0.330) across the age categories. These pathological conditions thus do not seem to follow the trend of percentual increase in the prevalence of pathology with age. Instead, the percentages are fairly equal in all the age categories.

Group	Pathology	Number of individuals	Individuals with pathology		Statistical analysis		
			n	*%*	*H-value*	*df*	*p*
Young adult	Vertebral osteoarthritis	31	0	0	27.780	2	**<0.001**
Middle adult		46	6	13			
Old adult		72	32	44,4			
Young adult	Osteophytes	31	9	29	30.011	2	**<0.001**
Middle adult		46	24	52,2			
Old adult		72	60	83,3			
Young adult	Intervertebral disc disease	31	1	3,3	26.187	2	**<0.001**
Middle adult		46	10	21,7			
Old adult		72	37	51,4			
Young adult	Schmorl's nodes	31	10	32,3	1.529	2	0.466
Middle adult		46	17	37			
Old adult		72	32	44,4			
Young adult	Fusion	31	0	0	2.216	2	0.330
Middle adult		46	3	6,5			
Old adult		72	5	6,9			

Table 4.10: Comparison of the prevalence of the vertebral pathological conditions between young adults, middle adults and old adults in the Chelsea Old Church population.

4.4.3 St. Benet Sherehog

There are a total of 42 young adults, fifty middle adults and 32 old adults in the St. Benet Sherehog population. In percentages, approximately 25% of the population consists of young adults, 30% of middle adults and 19% of old adults. The remaining 26% consists of individuals that were scored as adult. The prevalence of the vertebral pathological conditions by age category in the St. Benet Sherehog population is presented in table 4.11.

Three out of the five vertebral pathological conditions are statistically significantly different in prevalence across the age categories, namely vertebral osteoarthritis (H(2)=20.526, p=<0.001), osteophytes (H(2)=15.628, p=<0.001) and intervertebral disc disease (H(2)=16.247, p=<0.001). All these pathological conditions show a trend of percentual increase in the prevalence of pathology with age.

There is no statistically significant difference in the prevalence of Schmorl's nodes (H(2)=0.978, p=0.613) and fusion (H(2)=5.405, p=0.067) across the age categories. These pathological conditions do not, unlike the other pathological conditions, seem to follow the trend of percentual increase in the prevalence of pathology with age. Instead, the percentages are fairly equal in all the age categories.

Group	Pathology	Number of individuals	Individuals with pathology		Statistical analysis		
			n	*%*	*H-value*	*df*	*p*
Young adult	Vertebral osteoarthritis	42	1	2,4	20.526	2	**<0.001**
Middle adult		50	6	12			
Old adult		32	13	40,6			
Young adult	Osteophytes	42	15	35,7	15.628	2	**<0.001**
Middle adult		50	24	48			
Old adult		32	26	81,3			
Young adult	Intervertebral disc disease	42	7	16,7	16.247	2	**<0.001**
Middle adult		50	19	38			
Old adult		32	20	62,5			
Young adult	Schmorl's nodes	42	23	54,8	0.978	2	0.613
Middle adult		50	29	58			
Old adult		32	15	46,9			
Young adult	Fusion	42	0	0	5.405	2	0.067
Middle adult		50	6	12			
Old adult		32	2	6,3			

Table 4.11: Comparison of the prevalence of the vertebral pathological conditions between young adults, middle adults and old adults in the St. Benet Sherehog population.

4.4.4 St. Bride's Lower Churchyard

There are a total of 54 young adults, 88 middle adults and 162 old adults in the St. Bride's Lower Churchyard population. In percentages, approximately 15% of the population consists of young adults, 24% of middle adults and 44% of old adults. The remaining 17% consists of individuals that were scored as adult. The prevalence of the vertebral pathological conditions by age category in the St. Bride's Lower Churchyard population is presented in table 4.12.

Four out of the five vertebral pathological conditions are statistically significantly different in prevalence across the age categories, namely vertebral osteoarthritis (H(2)=49.865, p=<0.001), osteophytes (H(2)=49.386, <0.001), intervertebral disc disease (H(2)=35.138, p=<0.001) and fusion (H(2)=8.208, p=0.017). All these pathological conditions show a trend of percentual increase in the prevalence of pathology with age.

There is no statistically significant difference in the prevalence of Schmorl's nodes across the age categories (H(2)=1.910, p=0.385). The percentages are fairly equal in all the age categories meaning that this pathology does not follow the trend of percentual increase in the prevalence of pathology with age.

Group	Pathology	Number of individuals	Individuals with pathology		Statistical analysis		
			n	*%*	*H-value*	*df*	*p*
Young adult	Vertebral osteoarthritis	54	4	7,4	49.865	2	**<0.001**
Middle adult		88	15	17			
Old adult		162	83	51,2			
Young adult	Osteophytes	54	17	31,5	49.386	2	**<0.001**
Middle adult		88	52	59,1			
Old adult		162	133	82,1			
Young adult	Intervertebral disc disease	54	7	13	35.138	2	**<0.001**
Middle adult		88	24	27,3			
Old adult		162	87	53,7			
Young adult	Schmorl's nodes	54	22	40,7	1.910	2	0.385
Middle adult		88	46	52,3			
Old adult		162	81	50			
Young adult	Fusion	54	1	1,9	8.208	2	**0.017**
Middle adult		88	6	6,8			
Old adult		162	23	14,2			

Table 4.12: Comparison of the prevalence of the vertebral pathological conditions between young adults, middle adults and old adults in the St. Bride's Lower Churchyard population.

4.5 Inter-population comparison of the prevalence in males

The prevalence of the vertebral pathological conditions between the Arnhem population and the three London populations will also separately be compared for the male and female sample of the populations. The goal of this analysis is to determine if there are differences in the prevalence of vertebral pathological conditions in males between the populations and in females between the populations, so it can be determined if, for example, the males in the Arnhem population were more affected than males in the other populations. Another goal is to determine if these differences will remain the same as in section 4.2, in which the prevalence of the vertebral pathological conditions was compared between the Arnhem population and the London populations. In this chapter, the prevalence of the vertebral pathological conditions in males will be compared between the Arnhem population and the three London populations. The next section will focus on the prevalence of the vertebral pathological conditions in females.

4.5.1 Arnhem (low status) vs Chelsea Old Church (high status)

In the comparison of section 4.2, it was concluded that fusion, osteophytes and Schmorl's nodes are statistically significantly more prevalent in the Arnhem population than in the Chelsea Old Church population. The difference is the prevalence of Schmorl's nodes remains statistically significant when it is compared between the males of the Arnhem and Chelsea Old Church population ($\chi^2(1)$=13.919, p=<0.001). Schmorl's nodes are present in the spine of 84,1% of the males of the Arnhem population and in that of 50% of the males of the Chelsea Old Church population, so it is statistically significantly more prevalent in the males of the Arnhem population.

The difference in the prevalence of fusion also remains statistically significant ($\chi^2(1)$=5.462, p=0.019). 20,5% of the males of the Arnhem population and 6,4% of the males of the Chelsea Old Church population have fused vertebrae. Fusion is thus statistically significantly more prevalent in the males of the Arnhem population.

However, the difference is the prevalence of osteophytes does not remain statistically significant ($\chi^2(1)$=2.712, p=0.100). Furthermore, there is, like in the comparison in section 4.2, no statistically significant difference in prevalence of vertebral osteoarthritis ($\chi^2(1)$=1.407, p=0.235) and intervertebral disc disease ($\chi^2(1)$=0.347, p=0.556) when it is compared between the males of the Arnhem and Chelsea Old Church population. Even though the difference in prevalence of these three vertebral pathological conditions is not statistically significant, they are all more prevalent in the males of the Arnhem population. These vertebral pathological conditions were more prevalent in the Arnhem population in the comparison in section 4.2 as well, so this remains the same.

Group	Pathology	Number of individuals	Individuals with pathology		Statistical analysis		
			n	*%*	χ^2*-value*	*df*	*p*
Male Arnhem	Vertebral osteoarthritis	44	17	38,6	1.407	1	0.235
Male Chelsea		78	22	28,2			
Male Ar	Osteophytes	44	35	79,5	2.712	1	0.100
Male COC		78	51	65,4			
Male Ar	Intervertebral disc disease	44	17	38,6	0.347	1	0.556
Male COC		78	26	33,3			
Male Ar	Schmorl's nodes	44	37	84,1	13.919	1	**<0.001**
Male COC		78	39	50			
Male Ar	Fusion	44	9	20,5	5.462	1	**0.019**
Male COC		78	5	6,4			

**Fisher's Exact test*

Table 4.13: Comparison of the prevalence of the vertebral pathological conditions in males between the Arnhem population (Ar) and the Chelsea Old Church population (COC).

4.5.2 Arnhem (low status) vs St. Benet Sherehog (middle status)

In the comparison of section 4.2, it was concluded that fusion, vertebral osteoarthritis, osteophytes and Schmorl's nodes are statistically significantly more prevalent in the Arnhem population than in the St. Benet Sherehog population.

The difference in the prevalence vertebral osteoarthritis (χ^2(1)=10.298, p=0.001), osteophytes (χ^2(1)=7.800, p=0.005), Schmorl's nodes (χ^2(1)=6.739, p=0.009) and fusion (p=0.001) remains statistically significant when it is compared between the males of the Arnhem and St. Benet Sherehog population. Vertebral osteoarthritis is statistically significantly more prevalent in the males of the Arnhem population since 38,6% of the males of the Arnhem population and 13,6% of the males of the St. Benet Sherehog population have this pathology.

Osteophytes are present in the spine of 79,5% of the males of the Arnhem population and in that of 54,3% of the males of the St. Benet Sherehog population. Osteophytes are thus statistically significantly more prevalent in the males of the Arnhem population as well.

84,4% of the males in the Arnhem population and 61,7% of the males in the St. Benet Sherehog population have Schmorl's nodes. These are thus also statistically significantly more prevalent in the males of the Arnhem population.

20,5% of the males of the Arnhem population and 2,5% of the males in the St. Benet Sherehog population have fused vertebrae, meaning that fusion is statistically significantly more prevalent in the males of the Arnhem population.

Lastly, there is, like in the comparison of the overall prevalence between the two populations, no statistically significant difference in the prevalence of intervertebral disc disease when it is compared between the males of the Arnhem and St. Benet Sherehog population (χ^2(1)=0.205, p=0.651). Even though this difference is not statistically significant, this pathology is more prevalent in the males of the Arnhem population. This vertebral pathology was more prevalent in the Arnhem population in the comparison in section 4.2 as well, so this remains the same.

Group	**Pathology**	**Number of individuals**	**Individuals with pathology**		**Statistical analysis**		
			n	*%*	χ^2*-value*	*df*	*p*
Male Arnhem	Vertebral osteoarthritis	44	17	38,6	10.298	1	**0.001**
Male SBS		81	11	13,6			
Male Ar	Osteophytes	44	35	79,5	7.800	1	**0.005**
Male SBS		81	44	54,3			
Male Ar	Intervertebral disc disease	44	17	38,6	0.205	1	0.651
Male SBS		81	28	34,6			
Male Ar	Schmorl's nodes	44	37	84,1	6.739	1	**0.009**
Male SBS		81	50	61,7			
Male Ar	Fusion	44	9	20,5	-	-	**0.001***
Male SBS		81	2	2,5			

**Fisher's Exact test*

Table 4.14: Comparison of the prevalence of the vertebral pathological conditions in males between the Arnhem population (Ar) and the St. Benet Sherehog population (SBS).

4.5.3 Arnhem (low status) vs St. Bride's Lower Churchyard (low status)

In the overall comparison of the prevalence of the vertebral pathological conditions between the Arnhem and St. Benet Sherehog population it was concluded that there was only one statistically significant difference in the prevalence of the vertebral pathological conditions, namely in Schmorl's nodes. These were statistically significantly more prevalent in the Arnhem population.

The difference in the prevalence Schmorl's nodes (χ^2(1)=8.015, p=0.005) remains statistically significant when it is compared between the males of the Arnhem and St. Bride's Lower Churchyard population. 84,1% of the males of the Arnhem population and 61,7% of the males of the St. Bride's Lower Churchyard population have Schmorl's nodes, so these are more prevalent in the males of the Arnhem population.

Unlike in the comparison of the overall prevalence between the two populations, there is a statistically significant difference in the prevalence of fusion when it is compared between the males of the Arnhem and St. Bride's Lower Churchyard population with it being more prevalent in the males of the Arnhem population (χ^2(1)=3.872, p=0.049). Namely, 20,5% of the males of the Arnhem population and 9,8% of the males of the St. Bride's Lower Churchyard population have fused vertebrae. It is important to note that the p-value of this comparison is 0.049 while the difference is considered to be statistically significant when this value is under 0.05. Since the p-value is so close to 0.05 this analysis could considered to be less reliable.

There is, like in the previous comparison in section 4.2, no statistically significant difference in the prevalence of vertebral osteoarthritis (χ2(1)=0.310, p=0.577), osteophytes (χ^2(1)=2.918, p=0.088) and intervertebral disc disease (χ^2(1)=0.047, p=0.828) when it is compared between the males of the Arnhem and St. Bride's Lower Churchyard population. Vertebral osteoarthritis and intervertebral disc disease are approximately equally prevalent in the males of the Arnhem and St. Bride's Lower Churchyard population. Though they are approximately equally prevalent, the percentage of individuals with vertebral osteoarthritis is still slightly higher in the males of the Arnhem population and the percentage of males with intervertebral disc disease is slightly higher in the St. Bride's Lower Churchyard population. Osteophytes are, although not statistically significantly, more prevalent in the males of the Arnhem population.

Osteophytes were more prevalent in the Arnhem population and vertebral osteoarthritis and intervertebral disc disease were approximately equally prevalent in both populations in the comparison in section 4.2 as well, so this remains the same. What also remains the same is that, although the latter two pathological conditions are approximately equally prevalent, the percentage of individuals with vertebral osteoarthritis is still slightly higher in the males of the Arnhem population and the percentage of individuals with intervertebral disc disease is slightly higher in the males of the St. Bride's Lower Churchyard population.

Group	Pathology	Number of individuals	Individuals with pathology		Statistical analysis		
			n	*%*	χ^2-*value*	*df*	*p*
Male Ar	Vertebral osteoarthritis	44	17	38,6	0.310	1	0.577
Male SBLC		193	66	34,2			
Male Ar	Osteophytes	44	35	79,5	2.918	1	0.088
Male SBLC		193	128	66,3			
Male Ar	Intervertebral disc disease	44	17	38,6	0.047	1	0.828
Male SBLC		193	78	40,4			
Male Ar	Schmorl's nodes	44	37	84,1	8.015	1	**0.005**
Male SBLC		193	119	61,7			
Male Ar	Fusion	44	9	20,5	3.872	1	**0.049**
Male SBLC		193	19	9,8			

**Fisher's Exact test*

Table 4.15: Comparison of the prevalence of the vertebral pathological conditions in males between the Arnhem population (Ar) and the St. Bride's Lower Churchyard population (SBLC).

4.6 Inter-population comparison of the prevalence in females

In the previous chapter, the prevalence of the vertebral pathological conditions in males were compared between the Arnhem population and the three London populations. In this section, the prevalence of the vertebral pathological conditions in females will be compared between the Arnhem population and the three London populations. The goal of this analysis is to determine if there are differences in the prevalence and if differences in prevalence will remain the same as in section 4.2, in which the prevalence of the vertebral pathological conditions was compared between the Arnhem population and the London populations.

4.6.1 Arnhem (low status) vs Chelsea Old Church (high status)

In the overall comparison of the prevalence of the vertebral pathological conditions between the Arnhem and Chelsea Old Church population in section 4.2 it was concluded that fusion, osteophytes and Schmorl's nodes are statistically significantly more prevalent in the Arnhem population than in the Chelsea Old Church population. The difference in the prevalence of Schmorl's nodes remains statistically significant when it is compared between the females of the Arnhem and Chelsea Old Church population (χ^2(1)=5.870, p=0.015). 84,1% of the females of the Arnhem population and 61,7% of the females of the Chelsea Old Church population have Schmorl's nodes, so these are thus statistically significantly more prevalent in the females of the Arnhem population.

However, the difference is the prevalence of osteophytes (χ^2(1)=0.184, p=0.669) and fusion (p=1.000) does not remain statistically significant. Percentage-wise, these pathological conditions are approximately equally prevalent in the females of the Arnhem and Chelsea Old Church population. This is unlike the comparison of the overall prevalence in section 4.2 in which both pathological conditions were more prevalent in the Arnhem population. However, it is important to note that, even though the prevalence of these pathological conditions is approximately equal, the percentage of individuals with these pathological conditions is still somewhat higher in the Arnhem population.

There is, like in the comparison in section 4.2, no statistically significant difference in prevalence of vertebral osteoarthritis ($= \chi^2$(1)=0.951, p=0.329) and intervertebral disc disease (χ^2(1)=0.043, p=0.835) when it is compared between the females of the Arnhem and Chelsea Old Church population. Even though the difference in prevalence of vertebral osteoarthritis is not statistically significant, it is more prevalent in the females of the Arnhem population.

Vertebral osteoarthritis was more prevalent in the Arnhem population in the comparison in section 4.2 as well, so this remains the same. Unlike the comparison in section 4.2, in which intervertebral disc disease was more prevalent in the Arnhem population, intervertebral disc disease is slightly more, but approximately equally, prevalent in the females of the Chelsea Old Church population.

Group	Pathology	Number of individuals	Individuals with pathology		Statistical analysis		
			n	*%*	χ^2*-value*	*df*	*p*
Female Ar	Vertebral osteoarthritis	31	9	29	0.951	1	0.329
Female COC		74	15	24,8			
Female Ar	Osteophytes	31	19	61,3	0.184	1	0.668
Female COC		74	42	58,5			
Female Ar	Intervertebral disc disease	31	9	29	0.043	1	0.835
Female COC		74	23	30,9			
Female Ar	Schmorl's nodes	31	15	48,4	5.870	1	**0.015**
Female COC		74	18	36,4			
Female Ar	Fusion	31	2	6,5	-	-	1.000*
Female COC		74	4	5,4			

**Fisher's Exact test*

Table 4.16: Comparison of the prevalence of the vertebral pathological conditions in females between the Arnhem population (Ar) and the Chelsea Old Church population (COC).

4.6.2 Arnhem (low status) vs St. Benet Sherehog (middle status)

In the overall comparison of the prevalence of the vertebral pathological conditions between the Arnhem and St. Benet Sherehog population it was concluded that fusion, vertebral osteoarthritis, osteophytes and Schmorl's nodes are statistically significantly more prevalent in the Arnhem population than in the St. Benet Sherehog population.

The difference in the prevalence of vertebral osteoarthritis (χ^2(1)=0.530, p=0.467), osteophytes (χ^2(1)=1.349, p=0.246), Schmorl's nodes (χ^2(1)=0.648, p=0.421) and fusion (p=0.463) does not remain statistically significant when it is compared between the females of the Arnhem and St. Benet Sherehog population. As stated before, these pathological conditions are, in the overall comparison of the prevalence in section 4.2, more prevalent in the Arnhem population. Vertebral osteoarthritis, osteophytes and Schmorl's nodes do remain to be more prevalent in the Arnhem population when only the females in the populations are compared. However, fusion is more prevalent in females of the St. Bride's Lower Churchyard population.

Like in the overall comparison of the prevalence in section 4.2, there is no statistically significant difference in the prevalence of intervertebral disc disease (χ^2(1)=0.829, p=0.362). This pathology also remains to be more prevalent in the Arnhem population when only the females are compared.

Group	Pathology	Number of individuals	Individuals with pathology		Statistical analysis		
			n	*%*	χ^2*-value*	*df*	*p*
Female Ar	Vertebral osteoarthritis	31	9	29	0.530	1	0.467
Female SBS		46	10	21,7			
Female Ar	Osteophytes	31	19	61,3	1.349	1	0.246
Female SBS		46	22	47,8			
Female Ar	Intervertebral disc disease	31	9	29	0.829	1	0.362
Female SBS		46	18	39,1			
Female Ar	Schmorl's nodes	31	15	48,4	0.648	1	0.421
Female SBS		46	18	39,1			
Female Ar	Fusion	31	2	6,5	-	-	0.463*
Female SBS		46	6	13			

**Fisher's Exact test*

Table 4.17: Comparison of the prevalence of the vertebral pathological conditions in females between the Arnhem population (Ar) and the St. Benet Sherehog population (SBS).

4.6.3 Arnhem (low status) vs St. Bride's Lower Churchyard (low status)

In the overall comparison of the prevalence of the vertebral pathological conditions between the Arnhem and St. Bride's Lower Churchyard population it was concluded that there was only one statistically significant difference in the prevalence of the vertebral pathological conditions, namely in Schmorl's nodes. Schmorl's nodes were statistically significantly more prevalent in the Arnhem population.

The difference in the prevalence Schmorl's nodes (χ^2(1)=4.869, p=0.027) remains statistically significant when it is compared between the females of the Arnhem and St. Bride's Lower Churchyard population. 48,4% of the females of the Arnhem population and 27,8% of the females of the St. Bride's Lower Churchyard population have Schmorl's nodes. Schmorl's nodes are thus statistically significantly more prevalent in the females of the Arnhem population.

Like in the comparison in 4.2, there is no statistically significant difference in the prevalence of vertebral osteoarthritis (χ^2(1)=0.085, p=0.770), osteophytes (χ^2(1)=0.230, p=0.632), intervertebral disc disease (χ^2(1)=0.611, p=0.434) and fusion (p=0.737) when it is compared between the females of the Arnhem and St. Bride's population.

In the comparison of the overall prevalence of the vertebral pathological conditions in section 4.2, the prevalence of osteophytes and fusion was higher in the Arnhem population and the prevalence of vertebral osteoarthritis and intervertebral disc disease was approximately equal in both populations. Although approximately equally prevalent, the percentage of individuals with vertebral osteoarthritis was still slightly higher in the Arnhem population and the percentage of individuals with intervertebral disc disease was slightly higher in the St. Bride's Lower Churchyard population.

This is not the case when only the females are compared between the two populations. Vertebral osteoarthritis and fusion are then namely approximately equally prevalent in the females of the Arnhem and St. Benet Sherehog population. However, these two pathological conditions are, even though approximately equally prevalent, slightly more prevalent in the St. Bride's Lower Churchyard population. Osteophytes and intervertebral disc disease are more prevalent in the females of the St. Bride's Lower Churchyard population as well.

Group	**Pathology**	**Number of individuals**	**Individuals with pathology**		**Statistical analysis**		
			n	*%*	χ^2*-value*	*df*	*p*
Female Ar	Vertebral osteoarthritis	31	9	29	0.085	1	0.770
Female SBLC		126	40	31,7			
Female Ar	Osteophytes	31	19	61,3	0.230	1	0.632
Female SBLC		126	83	65,9			
Female Ar	Intervertebral disc disease	31	9	29	0.611	1	0.434
Female SBLC		126	46	36,5			
Female Ar	Schmorl's nodes	31	15	48,4	4.869	1	**0.027**
Female SBLC		126	35	27,8			
Female Ar	Fusion	31	2	6,5	-	-	0.737*
Female SBLC		126	13	10,3			

**Fisher's Exact test*

Table 4.18: Comparison of the prevalence of the vertebral pathological conditions in females between the Arnhem population (Ar) and the St. Bride's Lower Churchyard population (SBLC).

Now all the results of the statistical analyses, the inter- and intra-population comparisons, have been presented. In the next chapter, the results of these analyses will be discussed, interpreted and put into a broader context to be able to answer the research questions that have been formulated for this thesis.

CHAPTER 5 Discussion

The goal of this thesis research is to test if the prevalence of vertebral pathological conditions reflect hard labour/tough life in the Arnhem Eusebiuskerk population and three populations from London. To test this, the prevalence of the vertebral pathological conditions in the Arnhem population was compared to that of the high-status Chelsea Old Church population, the middle-status St. Benet Sherehog population and the low-status St. Bride's Lower Churchyard population. The most important results, presented in the previous chapter, will be discussed and interpreted in this chapter. Lastly, the limitation of this research will be discussed.

5.1 Differences in prevalence between the Arnhem population and the London populations

In this section, the differences in the prevalence of the vertebral pathological conditions between the Arnhem population and the high-status population of Chelsea Old Church population, the middle-status population of St. Benet Sherehog population and the low-status population of St. Bride's Lower Churchyard will be discussed. These differences have been analysed in the previous chapter by the means of chi-squared tests.

The guiding principle of this research is that the frequency, type and development of vertebral pathological conditions can be influenced by (occupational) activity. The starting point is that individuals with lower social status may have had harder working conditions, and were thus more prone to developing degenerative changes in the vertebral column, than individuals of higher status (Hofmann et al., 2008, p. 14; Richardson, 2018, p. 21). So basically, people who are engaged in heavy manual work (often lower status people) are more likely to develop joint diseases than people who do not have such an active lifestyle (such as higher status people) (Robb et al., 2001, p. 213; Roberts & Manchester, 2010, p. 342-245). This means that significant differences or similarities in the prevalence of vertebral pathology between the Arnhem population and the London populations, that are each of a different social status, may give insight into the relationship between social status and activity in these populations (Robb et al., 2001, p.213; Roberts & Manchester, 2010, p. 118). It may also give insight into how labour was different or similar between the Arnhem population and the London populations.

Vertebral osteoarthritis

Vertebral osteoarthritis is statistically significantly more prevalent in the Arnhem population than in the middle-status St. Benet Sherehog population. The prevalence is not statistically significantly different between the Arnhem and low-status St. Bride's Lower Churchyard population and, interestingly, not between the Arnhem and high-status Chelsea Old Church population as well. Though, it has been argued that the difference in the prevalence of vertebral osteoarthritis between the Arnhem and Chelsea Old Church population is near to significance and that there are thus meaningfully higher rates of this pathological condition in the Arnhem population.

This non-significant difference between the Arnhem population and the high-status London population is still interesting, because when the difference in prevalence is statistically significant when comparing with the middle-status population, it would be expected that the difference is statistically significant when comparing with the high-status population as well. The reasoning behind this is that people of lower status populations should, in theory, have more vertebral osteoarthritis, as a result of harder labour, than people of high-status populations who did not have such hard working conditions (Robb et al., 2001, p. 213; Roberts & Manchester, 2010, p. 342-245). When looking at the percentage of individuals with vertebral pathology in both populations, it can be seen that the prevalence of most of the vertebral pathological conditions (all except Schmorl's nodes) is at least somewhat higher in the Chelsea Old Church population than in the St. Benet Sherehog population. This while the first population consists of higher status individuals than the latter population. However, just because the lower status people of the St. Benet Sherehog population had less vertebral pathology than the higher status Chelsea Old Church population, doesn't mean that the people of the former population did not work as hard. To elaborate, a possible explanation is that the people of the St. Benet Sherehog might have been involved in other kinds of labour that did not affect the spine as much, but mainly affected other joints that have not been examined for this thesis (Lewis, 2016, p. 163).

There is a possible explanation for the middle-status population having a higher overall prevalence than the high-status population. It has been stated that the Chelsea Old Church population represents and that it reflects a high-status population (Bekvalac & Kausmally, 2009). However, when the population was compared to another high-status population from London (St. Bride's Crypt) in another study, significant differences in the prevalence of multiple pathological conditions were found. Based on this, it was suggested that the Chelsea Old Church was likely of a somewhat lower social status relative to the other high-status population (Marklein & Crews, 2022, p. 16). The reason for this is likely that the Chelsea Old Church population does not exclusively exist of high-status individuals, but also, based on biographical data, of middle-status individuals that came from more rural/suburban areas outside of the city of London (Cowie et al., 2008). Since rural populations often have a higher prevalence of degenerative changes in the spine than urban populations this could have led to bias in the Chelsea Old Church population (van Cant, 2014, p. 151).

However, vertebral osteoarthritis is still more prevalent in the Arnhem population than in the high-status population, significantly more prevalent in the Arnhem population than in the middle-status population and approximately equally prevalent in the Arnhem population as in the low-status population. The prevalence of vertebral osteoarthritis in the Arnhem population is thus most similar to that of the low-status St. Bride's Lower Churchyard population and differs meaningfully to significantly from that of the middle-status and high-status London populations. This means that there does seem to be a relationship between vertebral osteoarthritis and social status with this condition being more prevalent in the low-status populations.

Vertebral osteoarthritis is considered to be a direct consequence of spinal stress and is highly correlated with heavy physical activity/occupation even though this is not the only factor that influences its development (Cox & Mays, 2000, p. 393; Roberts & Manchester, 2010, p. 341-343). Much valid archaeological research, and clinical research as well, has been done that investigates and confirms this relationship (e.g., Larsen, 2015; Lieverse et al., 2016; Samut-Tagliaferro, 1999; Sperduti, 1997). Therefore, this pathology is likely one of the more, if not the most, reliable indicator(s) of activity and social status out of the five.

Osteophytes

Osteophytes are statistically significantly more prevalent in the Arnhem population than in the middle-status St. Benet Sherehog population and in the high-status Chelsea Old Church population. The prevalence is not statistically significantly different between the Arnhem and low-status St. Bride's Lower Churchyard population, but this pathology is still more prevalent in the Arnhem population. The prevalence of osteophytes in the Arnhem population is thus most similar to that of the low-status St. Bride's Lower Churchyard population and differs significantly from that of the middle-status and high-status London populations. This means that there does seem to be a relationship between osteophytes and social status with this condition being more prevalent in the low-status populations.

Studies have shown that activity plays a considerable role in the development of osteophytes, though, of course, its development can be influenced by other factors (Myszka et al., 2014, p. 381; O'Neill et al., 1999). In bioarchaeology, osteophytes are often studied to learn more about the activity levels of skeletal populations (Myszka et al., 2014, p. 381). Multiple of these studies have found a relationship between osteophytes and activity (e.g., Lai & Lovell, 1992; Lieverse et al., 2016). Because of the points made above, osteophytes are likely one of the more reliable indicators of physical activity and thus social status out of the five pathological conditions.

Intervertebral disc disease

There are no statistically significant differences in the prevalence of intervertebral disc disease between the Arnhem population and all of the London populations. Still, this pathology is more prevalent in the Arnhem population than in the high-status Chelsea Old Church and middle-status St. Benet Sherehog population. It is slightly more prevalent in the low-status St. Bride's Lower Churchyard population than in the Arnhem population, but this difference is very slight and therefore it would be better to say that this pathology is approximately equally prevalent in both populations. Since there are no statistically significant differences in the prevalence of intervertebral disc disease between the Arnhem population and the three London population, this pathology is likely not related to activity and social status in this case.

Heavy physical activity is one of the factors that can influence the development of intervertebral disc disease (Kalichman, 2010, p. 396; Koyama et al., 2015, p. 65; Urban & Roberts, 2003). However, there are also clinical studies that have shown that the relationship between heavy physical activity and intervertebral disc disease is likely not as strong as initially thought (Videman & Battié, 1999). Factors that are fairly certain to affect the development of intervertebral disc disease as well are lack of nutrient supply to the disc cells, trauma and genetic predisposition (Urban & Roberts, 2003). So in this case, the factors discussed above are more likely to have influenced the development of fusion since it does not seem to be related to social status.

Schmorl's nodes

Schmorl's nodes are statistically significantly more prevalent in the Arnhem population than in all London populations. The prevalence of vertebral osteoarthritis in the Arnhem population thus differs significantly from that of the low-status, middle-status and high-status London populations. This means that there does seem to be a relationship between Schmorl's nodes and social status with this condition being more prevalent in the low-status Arnhem population.

The specific aetiology of Schmorl's nodes is unknown is most cases and can be very multifactorial, but is associated to, at least to some extent, activity. In archaeological context, this pathology is frequently studied in relation to activity and multiple (archaeological) studies have found a relationship between this pathology and activity (e.g., Novak & Slaus, 2011; Robb et al., 2001). Because of this latter point, Schmorl's nodes are likely one of the more reliable indicators of physical activity and thus social status out of the five pathological conditions.

Fusion

Fusion is statistically significantly more prevalent in the Arnhem population than in the middle-status St. Benet Sherehog population and in the high-status Chelsea Old Church population. The difference in prevalence is not statistically significant between the Arnhem and low-status St. Bride's Lower Churchyard population, but fusion is still slightly more prevalent in the Arnhem population. The prevalence of fusion in the Arnhem population is thus most similar to that of the low-status St. Bride's Lower Churchyard population and differs significantly from that of the middle- and high-status London populations. This means that there does seem to be a relationship between fusion and social status with this condition being more prevalent in the low-status populations.

Very little research has been found on the relationship between fusion and demographic factors like occupation and social status in the archaeological context. Even in contemporary clinical studies this relationship is unclear to a large extent (Lindström, 2016, p. 11). The results of a clinical study have shown that the prevalence of fusion is largely influenced by genetics and only very little by environmental factors (van der Linden & van der Heijde, 1998, p. 671). However, it has been argued, in another clinical study, that that environmental factors, social status and a lot of physical occupational activity, do make people more susceptible to the development of fusion in the spine. Still, the latter study also states that genetics influence the development of fusion to a large extent (Doran et al., 2003, p. 316). In short, this pathology may, because of the large influence of genetics on its development and because of the lack of archaeological sources found on this topic, not be one of most reliable indicators of physical activity and social status out of the five pathological conditions that have been studied for this thesis research. However, based on the comparison with the London population, it still seems to be at least somewhat associated with social status in this case.

Example: osteoarchaeological research of the crew of the Mary Rose

One study that can particularly be used as an argument for the reliability of vertebral osteoarthritis, osteophytes and Schmorl's nodes as indicators of activity and thus social status is an osteoarchaeological one that analysed the remains of the crew of flagship the Mary Rose. The prevalence of multiple degenerative pathological conditions, amongst which vertebral osteoarthritis, Schmorl's nodes and osteophytes, were compared between the crew of the Mary Rose and the contemporary Norwick population. It was already known beforehand that the crew of the Mary Rose likely was involved in heavy physical labour on board of the ship. Also, important to note is that the individuals of the Mary Rose were considerably younger than those of the Norwick population (Stirland & Waldron, 1996).

In short, it was concluded that the prevalence of the three vertebral pathological conditions did not differ much between the two populations even though there was a considerable age difference. In fact, the degenerative changes in the spine were almost indistinguishable between the two populations. Therefore, it has been suggested that ageing changes in the spine have been accelerated as a result of heavy physical work on board of the Mary Rose (Stirland & Waldron, 1996, p. 329-335).

Example: osteoarchaeological research of a Canadian fur trade population

Another study that can be used as an argument for the reliably of vertebral osteoarthritis, osteophytes and Schmorl's nodes as indicators of activity is one that examined skeletons associated with the Canadian fur trade. It has been suggested that, based on the distribution of multiple pathological conditions, three males were voyageurs that transported furs by canoe or boat. Important evidence for this is that osteoarthritis was present in the elbow and shoulder joints which could be related to paddling and rowing. The vertebral pathological conditions that contributed to the conclusion of them being voyageurs are osteophytes, osteoarthritis and Schmorl's nodes since these can be related to carrying and heavy lifting. This are activities that voyageurs were involved in since they were required to carry heavy packs of provision and/or merchandise on their backs (Lai & Lovell, 1992).

Example: osteoarchaeological research of a population involved in bronze-casting

A study that can be used as an argument for the reliability of vertebral osteoarthritis is one that focussed on osteoarthritis in multiple joints, including the spine, of an archaeological population from Yinxu in China. Specifically the Xiaomintun and Xin'anzhuang populations were examined. The goal was to gain insight into what occupations they were involved in. The findings of this study were that there was a significantly higher amount of individuals with osteoarthritis in the upper body, including the upper back, in the Xiaomintun population than in the other population. Furthermore, many bronze artifacts like bronze foundry tools and family emblems were found in the mortuary assemblages of the Xiaomintun individuals. Based on this, it has been suggested that individuals in this population may have engaged in bronze-casting. The high prevalence of (vertebral) osteoarthritis can then be linked to the lifting of heavy loads in the bronze foundry (Zhang et al., 2017).

Labour in Arnhem and London

As discussed above, nearly all the vertebral pathological conditions are significantly more prevalent in the low-status Arnhem population than in the high-status and middle-status London populations. This might suggest that the individuals of Arnhem were involved in more strenuous physical activity than the individuals of these two London population which could indicate that the kind of labour they did differed. In contrast, the prevalence of the vertebral pathological conditions was relatively similar between the Arnhem and the low-status St. Bride's Lower Churchyard population. This might suggest that the latter two populations had common, more strenuous physical activities that might be associated with manual labour. To investigate this further, the most common kind of labour that was present in Arnhem and in London in the post-medieval period will be discussed.

First, it is important to note that, as discussed in section 2.1, vertebral osteoarthritis is likely a result of repetitive actions like pushing, pulling and the lifting and carrying of heavy objects (Zhang et al., 2017, p. 13). Furthermore, Schmorl's nodes might be caused by heavy lifting, repetitive movement and flexion of the spine (Burke, 2012; d'Hemecourt et al., 2000, p. 669). In the discussion below, activities such as these will therefore be considered straining on the spine.

Since the archaeological population of Arnhem was likely of a lower social status, it has been stated that the individuals were most likely working in breweries or tanneries. Furthermore, they might have worked in the textile industry, brickyards, food production or other crafts (Baetsen et al., 2018, p. 34-39; Buisman, 2009, p. 135). Arnhem was especially well known for its breweries that specialised in making beer and it has been stated that a relatively large proportion of the people of Arnhem population was working in this industry (Baetsen et al., 2018, p. 34). A task that likely was strenuous on the spine is the moving of the ingredients, specifically the grain, since this had to be moved multiple times during the beer brewing process (van Vilsteren, 1994, p. 61-62; van de Venne, 2008, p. 40).

The lowest social class in London consisted of labouring families and the truly poor people that lived and worked in workhouses (Newman & Gowland, 2016, p. 218). The biggest industry in London was the textile industry in which about 20% of the labouring people were employed. This was followed by the building industry, metalworking and leather manufacture (Earle, 1989, p. 19-23). As discussed in subsection 3.1.4, the archaeological population of St. Bride's Lower Churchyard likely includes individuals from the Bridewell workhouse (Kausmally, 2008). In the Bridewell workhouse, the women usually engaged in spinning while the men did (heavy) manual work outside the workhouse like cleaning the sewers (Rich, 2005). The prisoners that were housed in the workhouse were often put to hard labour, usually the beating of hemp with a mallet (London Lives, n.d.).

Though there are some differences in the specific kind of labour low status people of the Arnhem and St. Bride's Lower Churchyard populations might have done, it seems like, based on the discussion above, both might have been involved in more strenuous physical activities. Common occupations between low status people from Arnhem and from London would include: tanning and working in the textile industry. Both of these involved activities that would likely have been strenuous on the spine and that could have resulted in the development of vertebral pathological conditions like vertebral osteoarthritis and Schmorl's nodes. Task that were performed in tanneries included scraping hair and flesh off hides and the moving and lifting of hides (Ervynck et al., 2003, 67–68; Yeomans, 2006, p. 31-32). The heavy hides had to be lifted frequently which was likely strenuous on the spine; hides had, for example, to be moved through eight to ten pits filled with tannin solutions during the tanning process (Yeomans, 2006, p. 31-32).

Tasks that were performed in the textile industry included spinning and weaving. Spinning likely did not result in strain on the spine, but it rather affected joints in, for example, the hands because of the repeated movements (Kalichman & Hernández-Molina, 2010, p. 471). Weaving on the other hand put a lot of strain on the spine and has been associated with vertebral osteoarthritis. The lifting of various mechanisms of the loom required a lot of force. The looms that were used for weaving required the weaver to work a fly shuttle mechanism by repeatedly moving a hand to the side. The other hand was used to pull a batten inwards. It has been stated that this combination of movements likely would have put a lot of strain on the back, neck and shoulders (Lowry, 2004; Pamplin, 2009, p. 100-101).

The highest class in post-medieval London consisted of the gentry and aristocracy. The people of a middle social status often worked as merchants, manufacturers and skilled craftsman (Newman & Gowland, 2016, p. 218). Based on this labour division and the significantly higher prevalence of the vertebral pathological conditions in the Arnhem population, it is possible that people in the Arnhem population might have had harder working conditions than those of the higher status Chelsea Old Church and St. Benet Sherehog populations. It seems like individuals of the lower class, were more likely to have been involved in heavy manual work like brewing, weaving or tanning while, for example, middle-status individuals in London were more likely to have been involved in less manual labour since they often worked as merchants, manufacturers or skilled craftsmen. Though it is important to consider that there were likely exceptions to this.

An example that can be used as an argument for less heavy manual labour in the higher classes of London can be found in the textile industry; many skilled craftsmen, who were as discussed above mainly considered to be middle-status individuals, did not work with a loom anymore after their apprenticeship. Instead, they tended to concentrate on less physically strenuous tasks that required skill like setting up the loom and warping machine by wounding silk strands onto reels while the labourers did the heavy manual work by operating them (Pamplin, 2009, p. 98-99). However, it is important to consider that skilled craftsmen in other industries might have had harder working conditions that could also have affected the spine.

5.2 Sex and vertebral pathology

The comparisons related to sex have focussed on differences in the prevalence of the vertebral pathological conditions between males and females within an between populations. First, the differences in the prevalence of the vertebral pathological conditions between males and females within each population will be discussed. After that, differences in the prevalence of the vertebral pathological conditions in males and females between the Arnhem population and the London populations will be discussed.

5.2.1 Differences in prevalence between males and females within each population

In the previous chapter, chi-squared tests have been used to compare the prevalence of the vertebral pathological conditions between males and females within each population to determine if one sex is more affected than the other. Based on these comparisons, now will be determined if there are trends that indicate a correlation between the prevalence of the vertebral pathological conditions and sex. First, the trends in the statistically significant results will be discussed. After that, it will be discussed if the same trends are visible in the results that were not statistically significant.

Statistically significant differences between the sexes have been found in two pathological conditions, namely fusion and Schmorl's nodes. Fusion is statistically significantly different in prevalence between the sexes in the middle-status St. Benet Sherehog population. In this case, the pathology is more prevalent in females.

This difference in prevalence can have multiple causes. It could be the result of differences in occupational activity/social roles between the sexes in this population meaning that females had other occupations or social roles than males in this population which made them more susceptible to the development of this pathology. This is in line with the slightly higher prevalence of vertebral osteoarthritis and intervertebral disc disease in females in this population as well. However, it could also have been influenced by other factors like genetics, which has been proven to influence the development of fusion to a large extent (Doran et al., 2003, p. 316). Besides that, differences between the sexes can also be influenced by injury or by basic sex differences like hormones and reproduction (McAfee, 2021, p.41-42) Since the St. Benet population is the only population that shows a statistically significant difference in the prevalence of fusion, it does not indicate a trend and therefore it cannot be linked to a particular social status.

What does indicate a trend is the statistically significant difference in the prevalence of Schmorl's nodes between the sexes in all populations. In all populations, Schmorl's nodes are significantly more prevalent in the males than in the females. There are multiple possible explanations for this trend of which two will be discussed below.

The first possible explanation can be found when looking at a study carried out by Slaus. This study has shown that Schmorl's nodes, together with other pathological conditions, are statistically significantly more prevalent in males than in females in a Croatian population. Since age did not seem to factor into this difference, different occupational roles have been suggested for males and females in this population with males having harder working conditions (Slaus, 2000, p. 207). Another study, carried out by Jiménez et al., compared the prevalence of multiple pathological conditions, amongst which Schmorl's nodes, between males and females in two populations from Spain. The general occupational activities of both sexes were known from historical records for both populations. It was known that the males in Villanueva were peasant-soldiers and that the females collaborated with the males in agricultural activities. In La Torrecilla the males were peasant while the women worked at home. In both cases, the expectation would then be that males displayed significantly more degenerative changes, due to harder working conditions, than the females. The results of the study show that this was indeed the case. In other words, this study has proven that differences in the prevalence of (vertebral) pathological conditions, amongst which Schmorl's nodes, can indicate different occupational roles for males and females (Jiménez et al. 2012, p. 521-525). The results of these studies suggest that, in this thesis research, the higher prevalence of Schmorl's nodes in males may reflect that they had more physically demanding jobs than females. However, it is important to note that the difference in prevalence can also have other causes.

This brings us to the second possible explanation, namely that of there being natural variation in osseous changes between males and females (Richardson, 2018, p. 16). This natural variation can be caused by males naturally having shorter vertebral bodies and higher discs than females. In females, the opposite is true, with them having higher vertebral bodies and shorter discs. Males and females thus have a different ratio between vertebral body height and disc height. As a result of these morphological differences, males have a larger nucleus pulpous (intervertebral disc) than females which puts a lot of stress on the centre of the vertebral bodies. This considerable stress, caused by the relatively large intervertebral discs, on the vertebral bodies makes males more susceptible to the development of Schmorl's nodes (Dar et al., 2009, p. 314).

In this case, the difference in the prevalence of Schmorl's nodes between the sexes is more likely, at least to some extent, a result of biological variation than it is a result of different occupational activities/social roles for males and females. The reasoning behind this is that all the populations, of different social statuses, show a statistically significant difference in the prevalence of Schmorl's nodes between males and females with it being more prevalent in males. The difference in prevalence can therefore not be linked to a particular social status.

As discussed, there is a trend in Schmorl's nodes with these being statistically significantly more prevalent in the males than in the females in all population. Now, it will be determined if the trend, of a higher prevalence in males than in females, is also visible in the other pathological conditions when the non-statistically significant results are included.

Statistical analysis has shown that there are no statistically significant differences between males and females in the prevalence of vertebral osteoarthritis, intervertebral disc disease and osteophytes in all the populations. Though it has been argued that the difference in the prevalence of osteophytes between males and females is near to significance in the Arnhem population meaning that the males have meaningfully higher rates of osteophytes than the females. There are no statistically significant differences between the sexes in the prevalence of fusion in the Arnhem population, Chelsea Old Church population and St. Bride's Lower Churchyard population. Generally speaking, although with four exceptions, the vertebral pathological conditions are more prevalent in males.

All pathological conditions are more prevalent in males than in females in the Arnhem and Chelsea Old Church population. As stated before, there are four exceptions in the trend. Three of these are present in the St. Benet Sherehog population. In this population fusion, vertebral osteoarthritis and intervertebral disc disease are slightly to significantly higher in females.

The last exception can be found in the St. Bride's Lower Churchyard population in which fusion is slightly more prevalent in females. However, this difference is so slight that it would be better to say that this pathology is equally prevalent in both sexes. Besides that, it has been suggested before that fusion is likely not the most reliable indicator of social status/occupation. Therefore, and since the other pathological conditions in this population do show a higher prevalence in males, it can be argued that this population does follow the trend of a higher prevalence in males.

To summarise, at least three out of four populations follow the trend of a higher prevalence of vertebral pathology in males than in females. This trend may indicate that, at least in three out of four population (Arnhem, St. Bride's Lower Churchyard and Chelsea Old Church), males had harder working conditions than females. However, it is important to keep in mind that the differences in prevalence between the sexes were not significant for most vertebral pathological conditions and that this difference can thus have been influenced by other factors.

Gendered roles and social status

To possibly gain insight into the social status of the Arnhem population by the means of differences in the prevalence of vertebral pathology between the sexes, it might also be useful to look at a study that has tested if there are prescribed gender roles in males and females since these are often suggested. The hypothesis of this study was that, as a result of these roles, the males should have more occupational pathology, since they were considered to be the economic providers and to engage in harder labour, than the females. The hypothesis also stated that lower status populations have less resource accessibility than high-status populations and that therefore the lower social status populations should, in theory, reflect these gender roles less clearly. Even though, this hypothesis was determined to not be reflected in the populations of this study, it might be useful to test if this trend can be found in the populations of this thesis to possibly gain insight into whether or not the Arnhem population reflects a low-social status (Barca, 2020, p. 2).

As stated before, three out of four of the population show a higher prevalence of vertebral pathology in the males than in females. However, it is important to keep in mind that only Schmorl's nodes are statistically significantly more prevalent in males than in females and this is likely due to factors like biological variation and not social status. Besides that non-statistically significant differences are present in both the high-status and low-status population. This means that the gender roles are not reflected clearly/significantly in all populations and not only in the low-status one. In conclusion, this means that there is not enough statistically significant evidence to accept this hypothesis.

5.2.2 Differences in prevalence in males and females between the Arnhem population and the London populations

The prevalence of the vertebral pathological conditions between the Arnhem population and the three London populations have also separately been compared for the male and female sample of the populations by the means of chi-squared tests. The goal of this analysis is to determine if there are differences in the prevalence of vertebral pathological conditions in males between the populations and in females between the populations, so it can be determined if, for example, the males in the Arnhem population were more affected than males in the other populations. Another goal is to determine if these differences will remain the same as in section 5.1, in which the prevalence of the vertebral pathological conditions was compared between the Arnhem population and the London populations. First, the prevalence of the vertebral pathological conditions in males between the populations will be discussed. After that, this will be discussed for the females.

Males

Almost all differences in the prevalence of the vertebral pathological conditions remain statistically significant when only the males are compared between the Arnhem population and the London populations. There are however a few exceptions to this. The first exception is that this does not remain statistically significant for osteophytes when the males of the Arnhem and high-status Chelsea Old Church population are compared. Furthermore, a statistically significant difference can be found in fusion when the males of the Arnhem and low-status St. Bride's Lower Churchyard are compared. This difference was not statistically significant when the entire Arnhem and Chelsea Old Church populations were compared.

When only looking at the statistically significant results, the pathological conditions are all more prevalent in the males of the Arnhem population than in those of the London populations. The pathological conditions that are significantly more prevalent in the males of the Arnhem population are fusion and Schmorl's nodes when compared with the Chelsea Old Church population; fusion, vertebral osteoarthritis, osteophytes and Schmorl's nodes when compared with the St. Benet Sherehog population; and fusion when compared with the St. Bride's Lower Churchyard population.

Generally speaking, also when all the non-statistically significant results are included, the vertebral pathological conditions are more prevalent in the males of the Arnhem population than in those of the London populations. The only exception to this is intervertebral disc disease in the St. Bride's Lower Churchyard population, which is slightly more, but approximately equally, prevalent in the males of this population than in the Arnhem population. Vertebral osteoarthritis is also approximately equally prevalent in both populations, but slightly more prevalent in the males of the Arnhem population.

To summarise, nearly all of the vertebral pathological conditions are statistically significantly more prevalent in the males of the Arnhem population than in those of the London populations. Furthermore, a clear trend can be seen, when the non-statistically significant results are included as well, in which the males of the Arnhem population have more vertebral pathology than those of the other populations.

The least statistically significant differences can be found between the Arnhem population and the high-status Chelsea Old Church and (two differences) low-status St. Bride's Lower Churchyard population (one difference). As stated before, it is likely that the Chelsea Old Church population does not entirely reflect a high-status population and that it also includes middle-status individuals from more rural areas outside of the city of London. Since rural populations often have more degenerative pathology in the spine than urban populations, there might be a bias in the population and thus in the results of the prevalence of vertebral pathology, including this one.

It is then important to note that the most statistically significant differences, namely four, were found in the middle-status St. Benet Sherehog population. The only vertebral pathology that was not statistically significant in prevalence was intervertebral disc disease, of which previously has been suggested that it is likely not related to social status in the populations of this thesis. The males in this population do have statistically significantly less vertebral pathology than those of the Arnhem population which might suggest that the males of Arnhem had harder working conditions. Furthermore, the percentages of individuals with pathology are most equal between the Arnhem and low-status St. Bride's Lower Churchyard population. Another argument is that, generally speaking, the vertebral pathological conditions (including the non-statistically significantly different ones) are more prevalent in the males of the Arnhem population than in those of the other populations. Based on the arguments made above, it can be argued that the males in the Arnhem may have had harder working conditions and were thus possibly part of a lower status population than those of the other populations.

Females

When comparing the females between the populations, there is not such a clear trend as in the comparison of the males. Many differences in the prevalence of the vertebral pathological conditions do not remain statistically significant when only the females are compared between the Arnhem population and the London populations. In the high-status Chelsea Old Church population the prevalence of only one out of three vertebral pathological conditions remains statistically significantly different when the females are compared with those of the Arnhem population, namely that of Schmorl's nodes. Besides that, none of the four differences remain statistically significant when only the females are compared between the Arnhem and middle-status St. Benet Sherehog population. The only statistically significant difference that remains the same can be found in Schmorl's nodes when the females of the Arnhem population and those of the low-status St. Bride's Lower Churchyard population are compared.

There are thus only two statistically significant differences in the prevalence of the vertebral pathological conditions between the females of the Arnhem population and the London populations. These can be found in Schmorl's nodes when the females of the Arnhem population are compared with those of the high-status population and with those of the low-status population. In both cases, Schmorl's nodes are more prevalent in the females of the Arnhem population.

When also including the non-statistically significant results, a clear trend, like in the comparison of the males, cannot be found. In most cases, the vertebral pathological conditions are (at least slightly) more prevalent in the females of the Arnhem population than in those of the London populations. However, there are also quite a few exceptions in which the prevalence is (slightly) higher in the London populations than in the Arnhem population. These exceptions can be found in the prevalence of fusion, which is higher in the Chelsea Old Church population and in the St. Bride's Lower Churchyard population, and in that of intervertebral disc disease, which is higher in all London populations.

However, as stated before, these two pathological conditions are the two least reliable indicators of activity and thus social status out of the five. Vertebral osteoarthritis, osteophytes and Schmorl's nodes are, as discussed before, likely more reliable indicators of activity. Of these latter three pathological conditions, only Schmorl's nodes are more prevalent in the females of the Arnhem population than is those of the low-status St. Bride's Lower Churchyard population while vertebral osteoarthritis and osteophytes, but also fusion and intervertebral disc disease, are (slightly) more prevalent in the females of the St. Bride's Lower Churchyard. Though it might be better to say that fusion and vertebral osteoarthritis are approximately equally prevalent in the females of both populations. Based on this, it may be suggested that the working conditions of the females in the Arnhem population might not have been as hard as in the low-status St. Bride's Lower Churchyard population. However, they were likely still harder than in the middle-status and high-status population from London since the three most reliable pathological conditions are more prevalent in the Arnhem population than in the high-status Chelsea Old Church population and in the middle-status St. Benet Sherehog population. This higher prevalence in the Arnhem population can then indicate that the females in this population might have had harder working conditions and were thus part of a lower status population than those of the middle-status and high-status population. However, since this is based on slight differences and very few statistically significant results, this inference might not be very reliable.

5.3 Age and vertebral pathology

The goal of comparing the prevalence of the vertebral pathological conditions between the age categories is to determine if there is a correlation between age and the prevalence of vertebral pathology and if there are thus any possible age biases in the populations. Kruskall-wallis tests have been use for this.

Vertebral osteoarthritis, intervertebral disc disease and osteophytes are statistically significantly different in prevalence across the age categories in all four populations meaning that there is a correlation between age and the prevalence of these vertebral pathological conditions. In all cases, there is a trend visible, namely the percentual increase in the prevalence of pathology with age. In this trend, the percentage of individuals with pathology is the lowest in the young adults, higher in the middle adults and the highest in the old adults. This trend suggest that the prevalence of these three vertebral pathological conditions is, at least to some extent, influenced by age and not only by social status in all populations and that there is thus a possible age bias.

There is also a correlation between age and the prevalence of fusion; fusion is statistically significantly different in prevalence across the age categories in the Arnhem and St. Bride's Lower Churchyard population. The same trend as discussed above is present in these two population meaning that the prevalence of fusion is, at least to some extent, influenced by age as well. There is no correlation between the prevalence of fusion and age in the Chelsea Old Church population and in the St. Benet Sherehog population. Instead, the percentages of individuals with these pathological conditions are fairly equal in all the age categories.

Lastly, there is no correlation between Schmorl's nodes and age in all four populations since the percentages of individuals with Schmorl's nodes are fairly equal in all the age categories. This means that prevalence of this pathology is not influenced by age and that there is likely no age bias.

5.4 Limitations

5.3.1 Representativeness of the sample

Most of the time we are dealing with samples of population in archaeology. In fact, we are (almost) always dealing with samples that are taken of samples, as can be seen in figure 5.1. This can lead to archaeological data being biased and thus biased results when trying to make statements about the past.

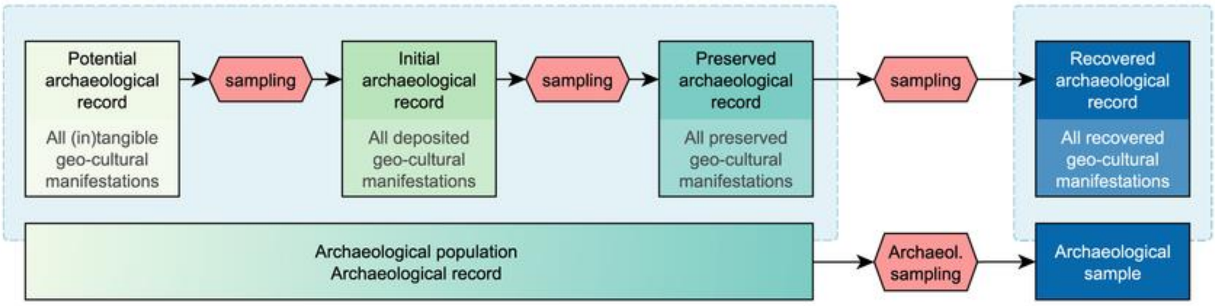

Figure 5.1: This figure shows that archaeological data (the archaeological sample) is often biased since they are only a small subset of the entire living population (Verhoeven, 2017, p. 6).

As stated by Wright and Yoder (2003, p. 44), "Our ability to make statements about the past is dependent on the representativeness of archaeological sampling of ancient human remains''. It would be ideal if the skeletal sample under study represents all the deaths in a population (Alesan et al., 1999, p. 286). However, this rarely the case (Pinhasi & Bourbou, 2007, p. 32).

It is often unknown how well the excavated skeletal population reflects the actual living population (Alesan et al., 1999, p. 286). In the Netherlands, archaeological excavation will only take place if the expected archaeological site is to be disturbed due to contemporary ground works like, in case of the excavation at the Eusebiuskerk in Arnhem, the construction of a new watercourse and sewer lines. This means that only the part of the site that is to be disturbed will be excavated, but this does not mean that the archaeological site does not exceed this excavated part. In the context of osteoarcheological excavations, this means that there are often parts of the cemetery that will not be excavated in which more skeletons, that are part of the same population, are buried. This is the case in the Arnhem population, of which only the skeletons on the northern side of the church have been excavated (Zielman & Baetsen, 2020, p. 361). We can thus only study what has been discovered and what was possible to excavate (Jackes, 2011, p. 107).

Even if the entire cemetery has been excavated, it cannot be said with certainty that it contains the entire population; it is namely possible that individuals of the same population are buried in other cemeteries/locations (Drennan, 2009, p. 80-81). Besides that, the skeletons that are excavated often died at different times which also may make the sample less representable of a population (Larsen, 2015, p. 334). Other factors that influence the representativeness of the archaeological sample are whether or not all remains are preserved and factors related to burial customs (Alesan et al., 1999, p. 286). An example of burial customs influencing the representativeness is that sometimes the location of burial on the cemetery was influenced by occupation or social status (Jackes, 2011, p. 109). It cannot be excluded that this is also the case for the Arnhem population and therefore it might be possible that the other unexcavated parts of the cemetery contain more individuals of higher social status.

Another problem in archaeology is that quite often not the entire available population can be studied, because of, for example, it being too expensive or too time-consuming (Drennan, 2009, p. 80-81). This basically forces archaeologists to study a sample of, in case of osteoarchaeology, the excavated skeletons. This was also the case for the analysis of the Arnhem individuals in this thesis research. Not all the available skeletons have been analysed for vertebral pathology due to time constraints meaning that this is also a small subset of the (excavated) skeletal population.

5.3.1 Limitations of research on vertebral pathology and social status

It is important to keep in mind that not all studies have shown skeletal differences between the social classes. Besides that, factors that are considered to be typical of social status do not necessarily bear a relationship to social status in all archaeological population. Examples of factors that are considered to be typical of social status are stature, trauma, Schmorl’s nodes, enamel hypoplasia and DISH (diffuse idiopathic skeletal hyperostosis). Enamel hypoplasia is a defect in tooth enamel that is caused by factors like prolonged food shortage or disease. As a result of this, the production of enamel is temporarily interrupted which causes lines, pits or grooves to form on the enamel of one or multiple teeth (Roberts & Manchester, 2010, p. 194). DISH causes (spinal) ligaments to ossify and is most likely caused by a metabolic disorder that is linked to the intake of high-caloric nutrition (Jankauskas, 2003, p. 289-290; Roberts & Manchester, 2010, p. 118).

There are cases in which some, or even all, of the factors mentioned above do not bear a relationship to social status and in which there are thus no differences in the prevalence of these diseases between lower and higher status individuals (Robb et al., 2001, p.213; Roberts & Manchester, 2010, p. 118). Therefore, it is important to look at as many factors as possible when making conclusions regarding the social status of an archaeological population and not just one.

5.3.2 Limitations of the vertebral pathological conditions

The prevalence of all the vertebral pathological conditions, that have been analysed in this thesis, can, at least to some extent, be influenced by activity. However, as stated before, it is important to keep in mind that this is not the only factor that influences the development of these vertebral pathological conditions. The multiple possible aetiologies of the vertebral pathological conditions complicate research that focusses on the relationship between vertebral pathology and activity/social status since it is hard/impossible to find the exact cause of the pathology and often it is caused by a combination of multiple factors. In this thesis, possible age and sex biases have been considered (which are present to some extent), but there are far more factors that influence the development of the pathological conditions like genetics, obesity and injury and/or trauma.

5.3.3 Limitations of the methods

The same methods have been used to record the vertebral pathological conditions in the Arnhem population as in the London populations meaning that there is no bias as a result of different used methods between the populations.

It is important to note that osteophytes are more prone to observers bias. At least more than is the case for fusion, intervertebral disc disease and Schmorl's nodes. To elaborate, the grades of intervertebral disc disease, Schmorl's nodes and fusion are based on the location or measurement of the degenerative changes. These are fairly objective criteria and therefore they suffer less from observers bias. Furthermore, vertebral osteoarthritis was only considered to be present if there was eburnation. This is a fairly obvious degenerative change and opinions about the presence or absence of this cannot really differ. However, when looking at osteophytes there may be different views on when these should be scored as present or absent since they can range from being very subtle to being very distinct.

CHAPTER 6 Conclusion

6.1 Answer to the research questions

The goal of this thesis research is to test if the prevalence of vertebral pathological conditions reflect hard labour/tough life in the Arnhem Eusebiuskerk population and three populations from London. First, the main research question will be answered. After that, an answer to the two sub-questions will be formulated.

To what extent is there a relationship between social status and vertebral pathology in the low status Arnhem population and the low-high status London populations?

Just about all of the vertebral pathologies were slightly to significantly more prevalent in the Arnhem population than in the London populations. The only exception to this is that intervertebral disc disease was slightly more prevalent in the low-status St. Bride's Lower Churchyard population than in the Arnhem population. Though it would be better to say that this pathology was approximately equally prevalent in both populations.

The prevalence of the vertebral pathological conditions was, in all cases, most similar to that of the low-status St. Bride's Lower Churchyard population. This might suggest that these two populations had common, more strenuous physical activities that might be associated with manual labour. Common occupations between low status people from Arnhem and London would include: tanning and working in the textile industry. Both of these were strenuous on the spine and could have resulted into the development of vertebral pathology like vertebral osteoarthritis and Schmorl's nodes.

The prevalence of most of the vertebral pathological conditions differed significantly between the Arnhem population and the middle-status St. Benet Sherehog and high-status Chelsea Old Church populations. This might suggest that the individuals of Arnhem were involved in more strenuous physical activity than the individuals of these two London population which could indicate that the kind of labour they did differed. This is possible since it has been stated that individuals of the lower class in Arnhem, were more likely to have been involved in heavy manual work like brewing, weaving or tanning while, for example, middle-status individuals in London were more likely to have been involved in less manual labour since it has been stated that they mostly worked as merchants, manufacturers or skilled craftsmen (Newman & Gowland, 2016, p. 218).

In short, there does seem to be a relationship between vertebral pathology and social status in the Arnhem and London populations. Most vertebral pathological conditions are namely more prevalent in the low-status Arnhem population than in the higher status London populations. The prevalence of the vertebral pathological conditions in the low-status St. Arnhem population is similar to that of the low-status St. Bride's Lower Churchyard population. Based on this, it can be inferred that the vertebral pathological conditions are more common in the lower status populations than in the higher status populations of this thesis. This could have been the result of the kind of labour these status groups were involved in.

To what extent is there a correlation between sex and the prevalence of vertebral pathology?

The prevalence of the vertebral pathological conditions have also been compared between males and females within each population to determine if one sex is more affected than the other, which could indicate different occupational roles for males and females or biological variation. The first trend that has been found in this comparison is that Schmorl's nodes are significantly more prevalent in males than in females in all populations. There are multiple possible explanations for this trend. A possible explanation is that there are different occupational roles for males and females in these population. Another explanation is that it is a result of biological variation. Since this trend is visible in all populations, each of a different social status, this difference in prevalence between the sexes is more likely, at least to some extent, a result of biological variation than of different occupational roles for males and females and it can thus not be linked to a particular social status.

Furthermore, three out of four populations show a trend of a slightly to significantly higher prevalence of just about all vertebral pathological conditions in males than in females which may indicate that males had harder working conditions than females in these populations. The only population that did not show this trend is that of St. Benet Sherehog. A possible explanation for this is that females might have had different occupational roles than males since three out of five pathological conditions are slightly to significantly more prevalent in females.

The prevalence of the vertebral pathological conditions between the Arnhem population and the three London populations have also separately been compared for the male and female sample of the populations. The goal of this analysis is to determine if the statistically significant differences in the prevalence of the vertebral pathological conditions remain the same when the males and females are compared separately between the Arnhem population and the London populations. Another goal is to determine if males and females had harder working conditions in the Arnhem population than in the others.

This comparison has shown that almost all differences in the prevalence of the vertebral pathological conditions remain statistically significant when only the males are compared between the Arnhem population and the London populations. When the females are compared, most of the statistically significant differences, do not remain the same which indicates that the statistically significant differences are likely more influenced by the males in the samples.

Furthermore, it has shown that, generally speaking, just about all of the vertebral pathological conditions are slightly to significantly more prevalent in the males of the Arnhem population than in those of the London populations. Based on these differences, it has been suggested that the males in the Arnhem population may have had harder working conditions than those of the other populations, which might indicate a lower social status.

The same trend is not (clearly) visible when only the females are compared. However, the three most reliable indicators of activity (vertebral osteoarthritis, osteophytes an Schmorl's nodes) are more prevalent in the females of the Arnhem population than in those of the middle-status and high-status London populations. Therefore, it has been suggested that the working conditions of the females in the Arnhem population might not have been as hard as in the low-status St. Bride's Lower Churchyard population. However, they were possibly still harder than in the middle-status and high-status population from London. This might then indicate that the females of the Arnhem population were part of a lower status population. However, it is important to note that, as discussed above, there are very few statistically significant results and that therefore this inference might not be very reliable.

To what extent is there a correlation between age and the prevalence of vertebral pathology?

The goal of comparing the prevalence of the vertebral pathological conditions between the age categories is to determine if there is a correlation between age and the prevalence of vertebral pathology and if there are thus any possible age biases in the populations.

There is a trend visible in the prevalence of vertebral osteoarthritis, intervertebral disc disease and osteophytes, namely that of a percentual increase in the prevalence of pathology with age. In this trend, the percentage of individuals with pathology is the lowest in the young adults, higher in the middle adults and the highest in the old adults. This trend suggest that the development of these three vertebral pathological conditions is, at least to some extent, influenced by age and not only by social status in all populations and that there is thus a possible age bias. A correlation with age, and thus a possible age bias, is also present in the prevalence of fusion in the Arnhem population and in the St. Bride's Lower Churchyard population. Vertebral pathological conditions of which the prevalence is not correlated with age, and that are thus not biased, are fusion in the Chelsea Old Church population and in the St. Benet Sherehog population and Schmorl's nodes in all the populations.

6.2 Suggestions for further research

A few suggestions for further research can be made. The first suggestion is to also look at the distribution and the severity of the vertebral pathological conditions in the spine to get a better understanding of the role activity plays in the prevalence of the vertebral pathological conditions in the Arnhem population. This gives more detailed information about differences in activity, and thus social status, between sites than when only the prevalence is compared. Furthermore, when the distribution and severity are compared between the sexes, insight can be gained about differences in the prevalence being a result of activity or of other factors like biological variation (Derevenski, 2000; Üstündag, 2009). The severity and distribution of all the five vertebral pathological conditions have been recorded during this thesis research since London recorded the pathological conditions like this as well. This database can thus be used for further research into the severity and distribution of vertebral pathology in the spine.

Besides that, a suggestion is to also combine the sex and age data (e.g. young adult males, middle adult females, old adult females etc.) when comparing the prevalence of the vertebral pathological conditions. The goal of this is to determine if there is a possible age bias when comparing the prevalence of the vertebral pathological conditions between the sexes.

Lastly, it could also be useful to compare the prevalence of the vertebral pathological conditions by age category between the Arnhem population and the London populations. A study namely has argued that this can be done to counteract the effects of age. To elaborate, vertebral pathological conditions are often way more common in old adults than in younger adults. When the prevalence of vertebral pathology is high in the younger age categories, the development of degenerative changes might have been influenced by other factors than aging (Stirland & Waldron, 1997, p. 332). I.e. if vertebral pathology is seen in a significantly higher amount of younger individuals in one population than in other populations it may be suggested that vertebral pathology is a result of other factors than aging like occupationally related activity (Roberts & Manchester, 2010, p. 351).

Abstract

The goal of this thesis research is to test if the prevalence of vertebral pathological conditions reflect hard labour/tough life in the Arnhem Eusebiuskerk population and a low-status, middle-status and high-status population from London. The vertebral pathological conditions that have been compared are vertebral osteoarthritis, osteophytes, intervertebral disc disease, Schmorl's nodes and fusion.

First, the prevalence of the vertebral pathological conditions have been compared between the Arnhem population and the three London populations. After that, the prevalence has been compared between the males and females within each population followed by a comparison of the prevalence across the age categories. The latter has been done for each population as well. Lastly, the male and female sample of the populations have been compared separately between the Arnhem population and the three London populations.

To summarise, there does seem to be a relationship between vertebral pathology and social status in the Arnhem and London populations. Most vertebral pathological conditions are namely more prevalent in the low-status Arnhem population than in the higher status London populations. The prevalence of the vertebral pathological conditions in the low-status St. Arnhem population is similar to that of the low-status St. Bride's Lower Churchyard population. Based on this, it can be inferred that the vertebral pathological conditions are more common in the lower status populations than in the higher status populations of this thesis. This could have been the result of the kind of labour these status groups were involved in.

Furthermore, there does seem to be a difference in the prevalence of the vertebral pathological conditions between males and females; in three out of four populations (all except the St. Benet Sherehog population) males may have had harder working conditions than the females. When the prevalence in the male and female sample of the population were compared between Arnhem and the three London populations separately, a trend can be seen that may indicate that at least the males of the Arnhem population had harder working conditions than those in the other populations.

The results have also shown that there are some biases. The first bias is that the statistically significant differences in the vertebral pathological conditions are more influenced by the male sample than by the female sample in all populations with Schmorl's nodes likely being influenced by biological variation to some extent. Furthermore, the development of many of the vertebral pathological conditions are, at least to some extent, influenced by age in all populations.

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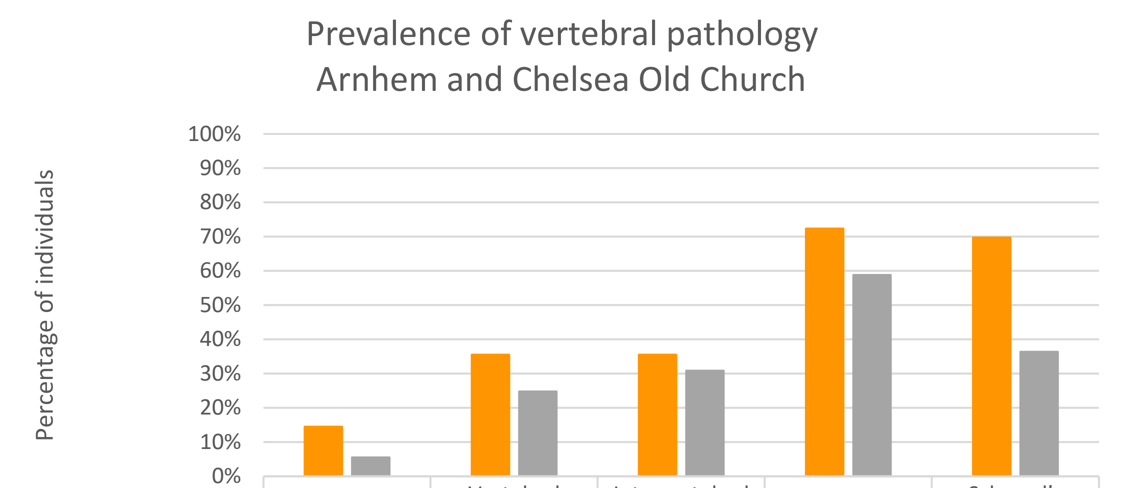
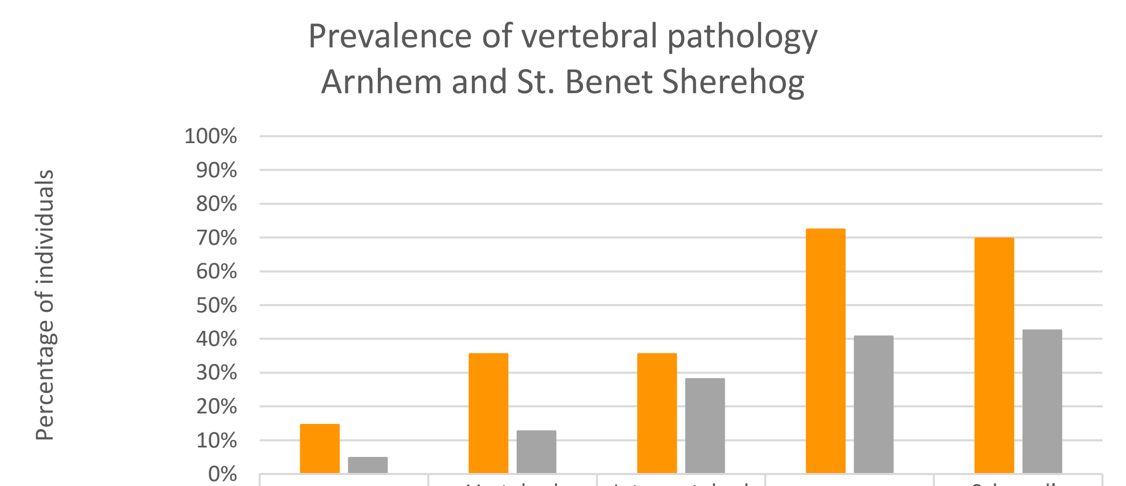
Appendices

Appendix A: Charts inter-population comparison of the prevalence of the vertebral pathological conditions



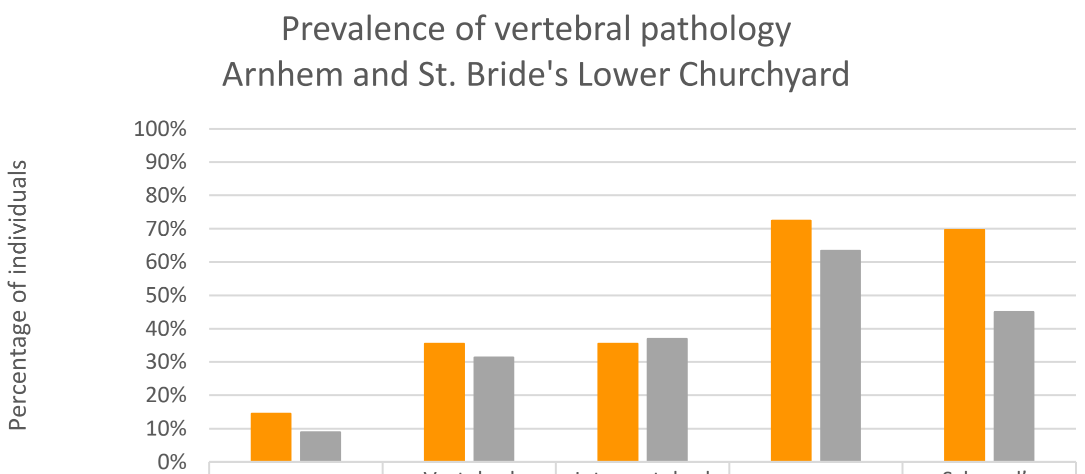
	Fusion	Vertebral osteoarthritis	Intervertebral disc disease	Osteophytes	Schmorl's nodes
Arnhem	14,5%	35,5%	35,5%	72,4%	69,7%
Chelsea Old Church	5,5%	24,8%	30,9%	58,8%	36,4%

The prevalence of the vertebral pathological conditions in the Arnhem and the Chelsea Old Church population. The numbers are expressed in percentages.



	Fusion	Vertebral osteoarthritis	Intervertebral disc disease	Osteophytes	Schmorl's nodes
Arnhem	14,5%	35,5%	35,5%	72,4%	69,7%
St. Benet Sherehog	4,8%	12,6%	28,1%	40,7%	42,5%

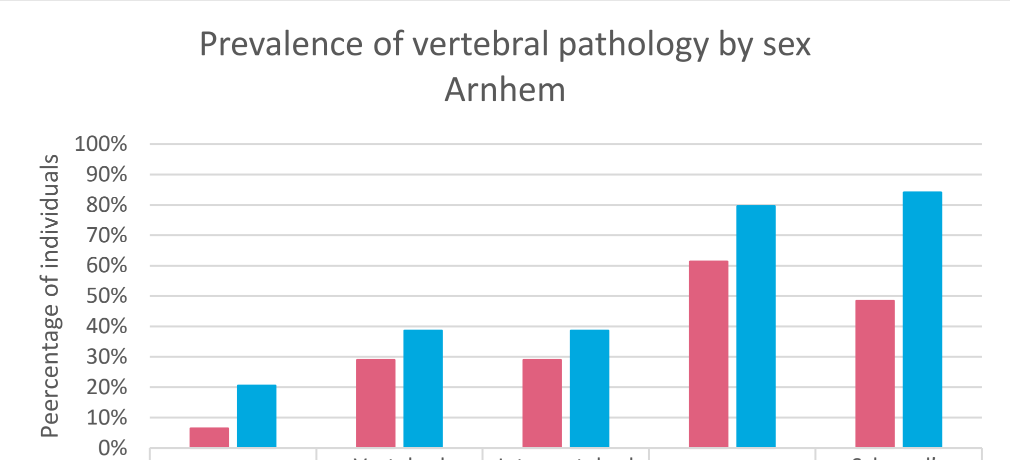
The prevalence of the vertebral pathological conditions in the Arnhem and the St. Benet Sherehog population. The numbers are expressed in percentages.



	Fusion	Vertebral osteoarthritis	Intervertebral disc disease	Osteophytes	Schmorl's nodes
Arnhem	14,5%	35,5%	35,5%	72,4%	69,7%
St. Bride's Lower	8,9%	31,4%	36,9%	63,4%	45,0%

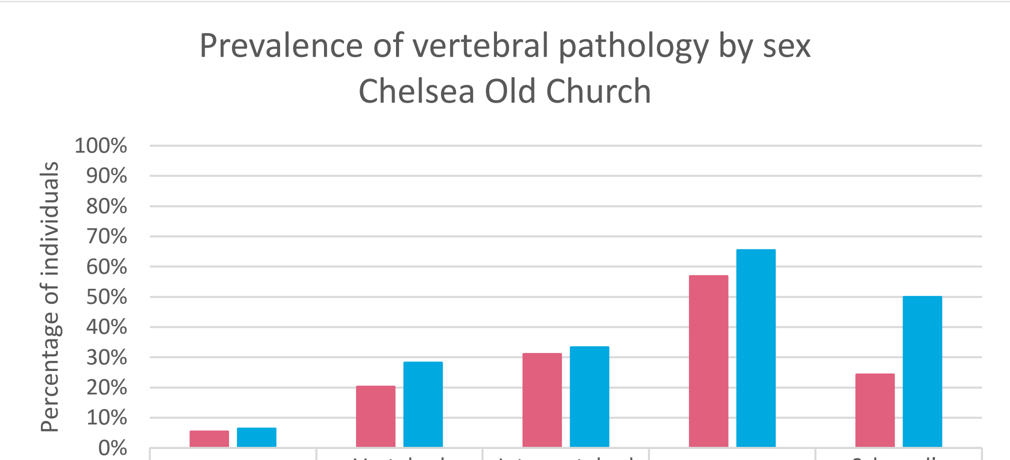
The prevalence of the vertebral pathological conditions in the Arnhem and the St. Bride's Lower Churchyard population.
The numbers are expressed in percentages.

Appendix B: Charts intra-population comparison of the prevalence of the vertebral pathological conditions between males and females



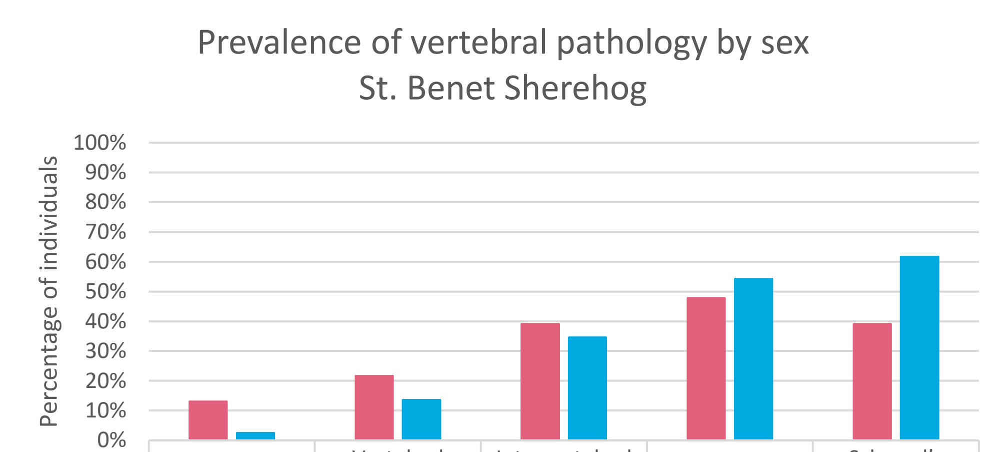
	Fusion	Vertebral osteoarthritis	Intervertebral disc disease	Osteophytes	Schmorl’s nodes
Female	6,5%	29%	29%	61,3%	48,4%
Male	20,5%	38,6%	38,6%	79,5%	84,1%

The prevalence of the vertebral pathological conditions by sex in the Arnhem population. The numbers are expressed in percentages.



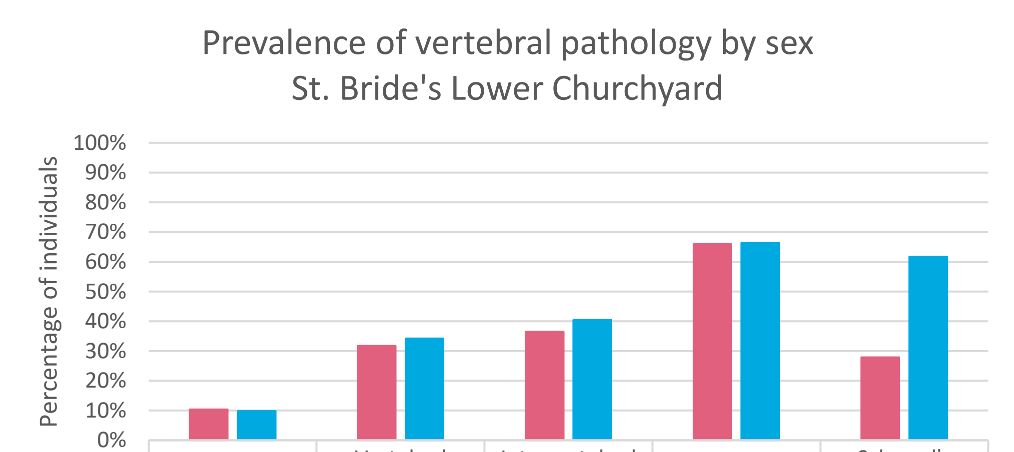
	Fusion	Vertebral osteoarthritis	Intervertebral disc disease	Osteophytes	Schmorl’s nodes
Female	5,4%	20,3%	31,1%	56,8%	24,3%
Male	6,4%	28,2%	33,3%	65,4%	50%

The prevalence of the vertebral pathological conditions by sex in the Chelsea Old Church population. The numbers are expressed in percentages.



	Fusion	Vertebral osteoarthritis	Intervertebral disc disease	Osteophytes	Schmorl's nodes
Female	13,0%	21,7%	39,1%	47,8%	39,1%
Male	2,5%	13,6%	34,6%	54,3%	61,7%

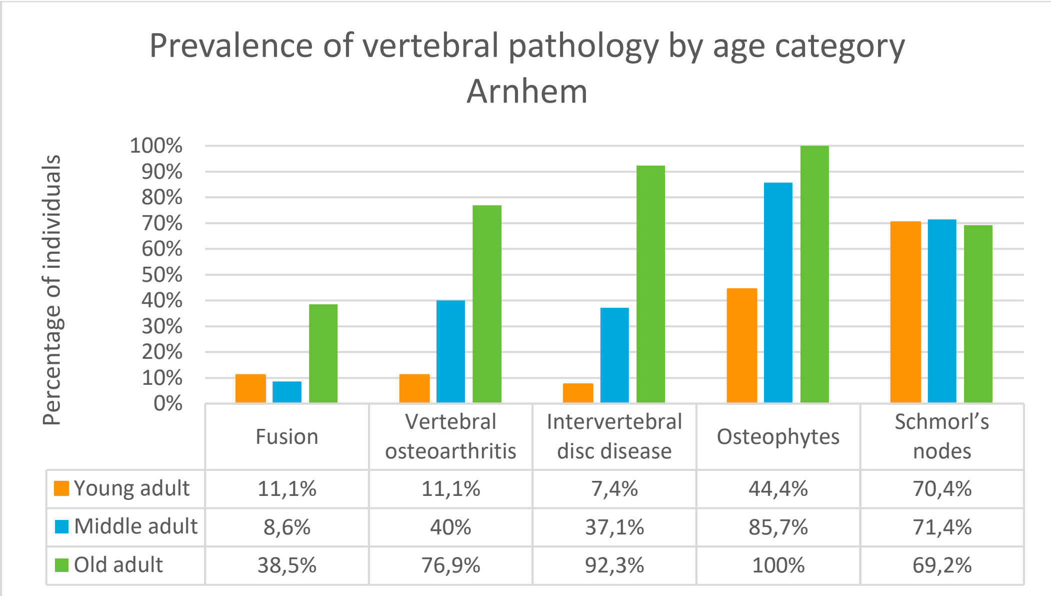
The prevalence of the vertebral pathological conditions by sex in the St. Benet Sherehog population. The numbers are expressed in percentages.



	Fusion	Vertebral osteoarthritis	Intervertebral disc disease	Osteophytes	Schmorl's nodes
Female	10,3%	31,7%	36,5%	65,9%	27,8%
Male	9,8%	34,2%	40,4%	66,3%	61,7%

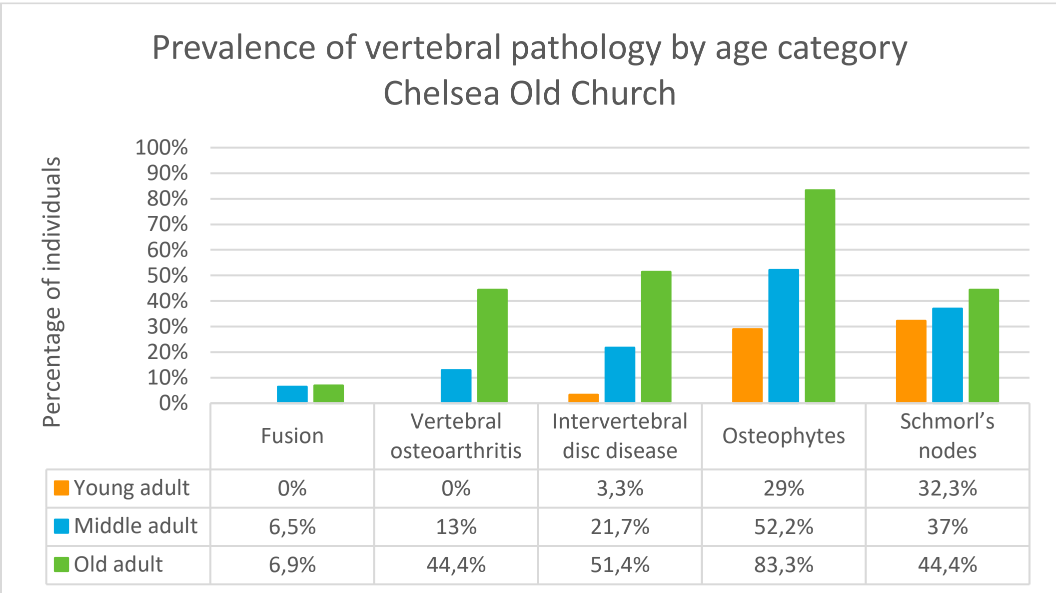
The prevalence of the vertebral pathological conditions by sex in the St. Bride's Lower Churchyard population. The numbers are expressed in percentages.

Appendix C: Charts intra-population comparison of the prevalence of the vertebral pathological conditions between the age categories



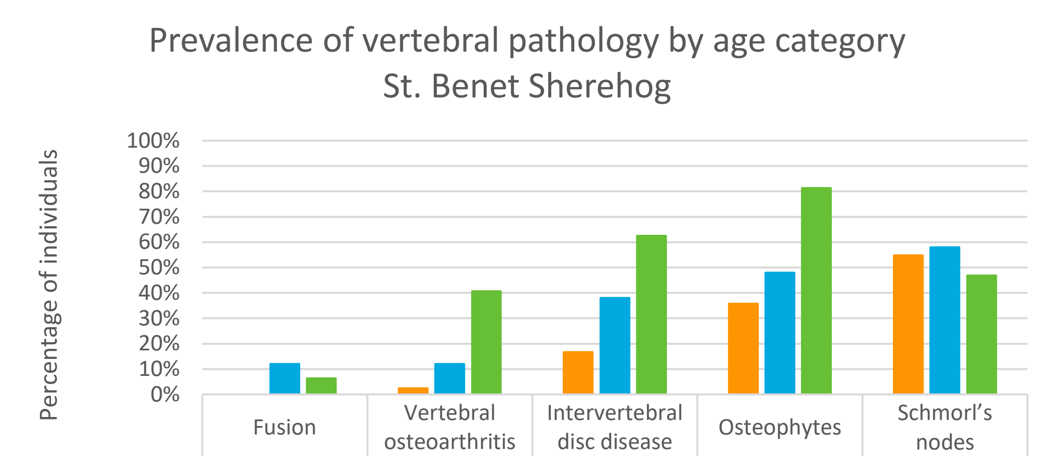
	Fusion	Vertebral osteoarthritis	Intervertebral disc disease	Osteophytes	Schmorl's nodes
Young adult	11,1%	11,1%	7,4%	44,4%	70,4%
Middle adult	8,6%	40%	37,1%	85,7%	71,4%
Old adult	38,5%	76,9%	92,3%	100%	69,2%

The prevalence of the vertebral pathological conditions by age category in the Arnhem population. The numbers are expressed in percentages.



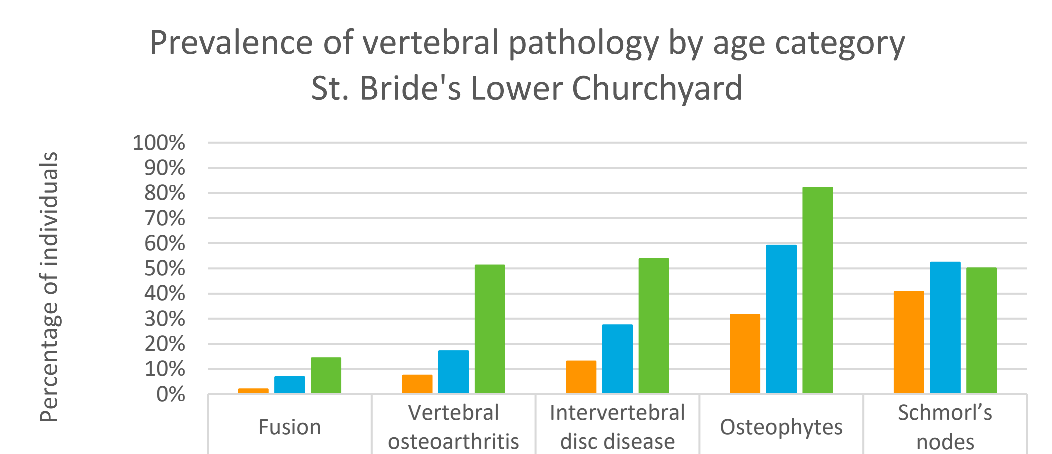
	Fusion	Vertebral osteoarthritis	Intervertebral disc disease	Osteophytes	Schmorl's nodes
Young adult	0%	0%	3,3%	29%	32,3%
Middle adult	6,5%	13%	21,7%	52,2%	37%
Old adult	6,9%	44,4%	51,4%	83,3%	44,4%

The prevalence of the vertebral pathological conditions by age category in the Chelsea Old Church population. The numbers are expressed in percentages.



	Fusion	Vertebral osteoarthritis	Intervertebral disc disease	Osteophytes	Schmorl's nodes
Young adult	0%	2,4%	16,7%	35,7%	54,8%
Middle adult	12%	12%	38%	48%	58%
Old adult	6,3%	40,6%	62,5%	81,3%	46,9%

The prevalence of the vertebral pathological conditions by age category in the St. Benet Sherehog population.. The numbers are expressed in percentages.



	Fusion	Vertebral osteoarthritis	Intervertebral disc disease	Osteophytes	Schmorl's nodes
Young adult	1,9%	7,4%	13%	31,5%	40,7%
Middle adult	6,8%	17%	27,3%	59,1%	52,3%
Old adult	14,2%	51,2%	53,7%	82,1%	50%

The prevalence of the vertebral pathological conditions by age category in the St. Bride's Lower Churchyard population.. The numbers are expressed in percentages.

Appendix D: Post-hoc Dunn-Bonferroni test results of the Kruskall-Wallis test that compared the prevalence of the vertebral pathological conditions between the age categories

Group	Pathology	P-value post-hoc test
Young adult vs middle adult	Fusion	1.000
Young adult vs old adult		0.069
Middle adult vs old adult		**0.029**
Young adult vs middle adult	Vertebral osteoarthritis	0.059
Young adult vs old adult		**0.000**
Middle adult vs old adult		0.56
Young adult vs middle adult	Intervertebral disc disease	**0.049**
Young adult vs old adult		**0.000**
Middle adult vs old adult		**0.001**
Young adult vs middle adult	Osteophytes	**0.001**
Young adult vs old adult		**0.001**
Middle adult vs old adult		0.970
Young adult vs middle adult	Schmorl's nodes	1.000
Young adult vs old adult		1.000
Middle adult vs old adult		1.000

Post-hoc Dunn-Bonferroni test results of the Kruskall-Wallis test that compared the prevalence of the vertebral pathological conditions between young adults, middle adults and old adults in the Arnhem population.

Group	Pathology	P-value post-hoc test
Young adult vs middle adult	Fusion	0.644
Young adult vs old adult		0.459
Middle adult vs old adult		1.000
Young adult vs middle adult	Vertebral osteoarthritis	0.598
Young adult vs old adult		**0.000**
Middle adult vs old adult		**0.000**
Young adult vs middle adult	Intervertebral disc disease	0.268
Young adult vs old adult		**0.000**
Middle adult vs old adult		**0.002**
Young adult vs middle adult	Osteophytes	0.121
Young adult vs old adult		**0.000**
Middle adult vs old adult		**0.002**
Young adult vs middle adult	Schmorl's nodes	1.000
Young adult vs old adult		0.743
Middle adult vs old adult		1.000

Post-hoc Dunn-Bonferroni test results of the Kruskall-Wallis test that compared the prevalence of the vertebral pathological conditions between young adults, middle adults and old adults in the Chelsea Old Church population.

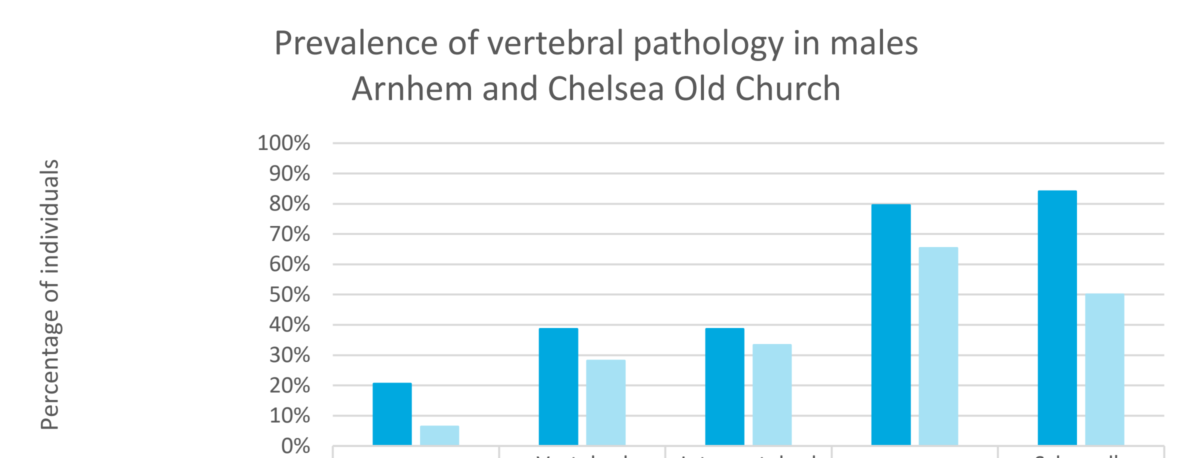
Group	Pathology	P-value post-hoc test
Young adult vs middle adult	Fusion	0.841
Young adult vs old adult		0.060
Middle adult vs old adult		0.909
Young adult vs middle adult	Vertebral osteoarthritis	0.640
Young adult vs old adult		**0.000**
Middle adult vs old adult		**0.002**
Young adult vs middle adult	Intervertebral disc disease	0.107
Young adult vs old adult		**0.000**
Middle adult vs old adult		0.077
Young adult vs middle adult	Osteophytes	0.725
Young adult vs old adult		**0.000**
Middle adult vs old adult		**0.010**
Young adult vs middle adult	Schmorl's nodes	1.000
Young adult vs old adult		1.000
Middle adult vs old adult		0.978

Post-hoc Dunn-Bonferroni test results of the Kruskall-Wallis test that compared the prevalence of the vertebral pathological conditions between young adults, middle adults and old adults in the St. Benet Sherehog population.

Group	Pathology	P-value post-hoc test
Young adult vs middle adult	Fusion	1.000
Young adult vs old adult		**0.026**
Middle adult vs old adult		0.186
Young adult vs middle adult	Vertebral osteoarthritis	0.715
Young adult vs old adult		**0.000**
Middle adult vs old adult		**0.000**
Young adult vs middle adult	Intervertebral disc disease	0.270
Young adult vs old adult		**0.000**
Middle adult vs old adult		**0.000**
Young adult vs middle adult	Osteophytes	**0.002**
Young adult vs old adult		**0.000**
Middle adult vs old adult		**0.001**
Young adult vs middle adult	Schmorl's nodes	0.718
Young adult vs old adult		0.548
Middle adult vs old adult		1.000

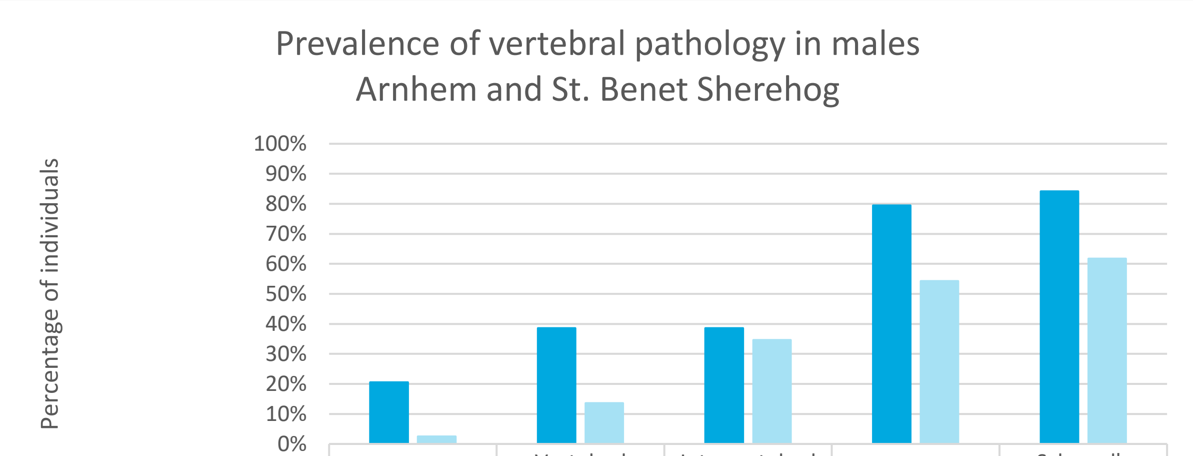
Post-hoc Dunn-Bonferroni test results of the Kruskall-Wallis test that compared the prevalence of the vertebral pathological conditions between young adults, middle adults and old adults in the St. Bride's Lower Churchyard population.

Appendix E: Charts inter-population comparison of the prevalence of the vertebral pathological conditions in males



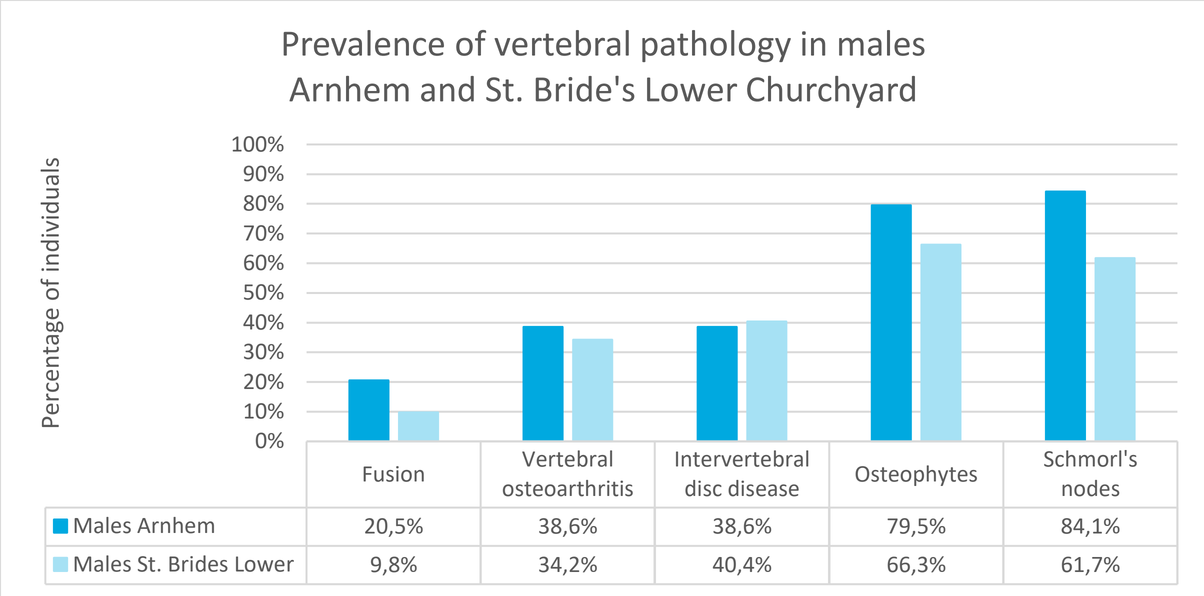
	Fusion	Vertebral osteoarthritis	Intervertebral disc disease	Osteophytes	Schmorl's nodes
Males Arnhem	20,5%	38,6%	38,6%	79,5%	84,1%
Males Chelsea Old Church	6,4%	28,2%	33,3%	65,4%	50%

The prevalence of the vertebral pathological conditions in males in the Arnhem and Chelsea Old Church population. The numbers are expressed in percentages.



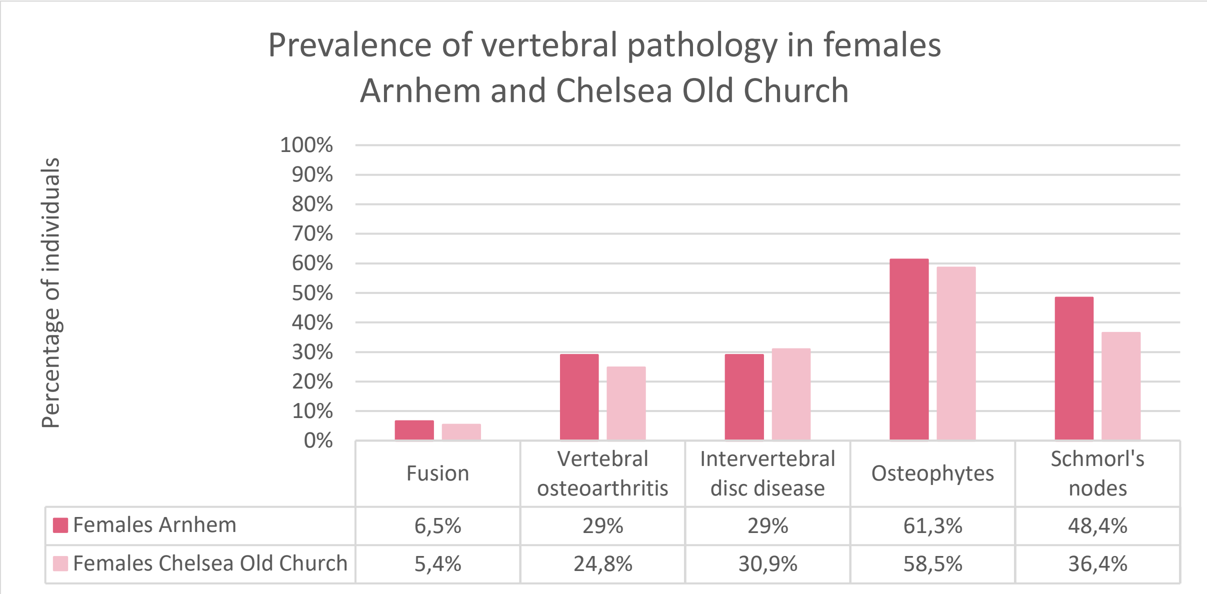
	Fusion	Vertebral osteoarthritis	Intervertebral disc disease	Osteophytes	Schmorl's nodes
Males Arnhem	20,5%	38,6%	38,6%	79,5%	84,1%
Males St. Benet Sherehog	2,5%	13,6%	34,6%	54,3%	61,7%

The prevalence of the vertebral pathological conditions in males in the Arnhem and St. Benet Sherehog population. The numbers are expressed in percentages.



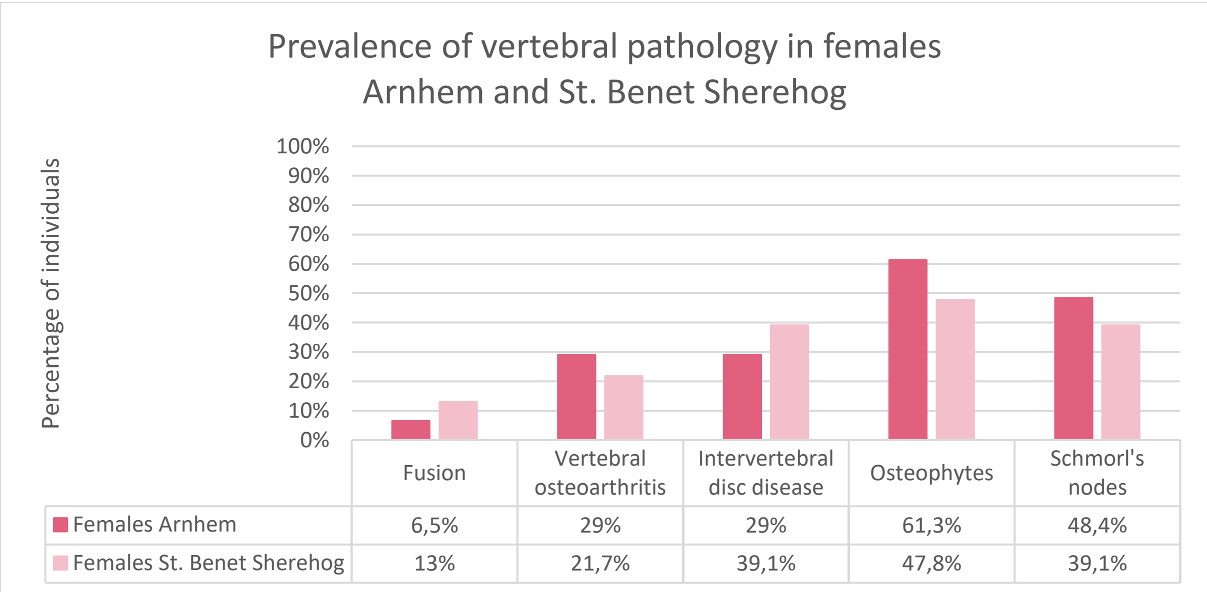
The prevalence of the vertebral pathological conditions in males in the Arnhem and St. Bride's Lower Churchyard population. The numbers are expressed in percentages.

Appendix E: Charts inter-population comparison of the prevalence of the vertebral pathological conditions in females



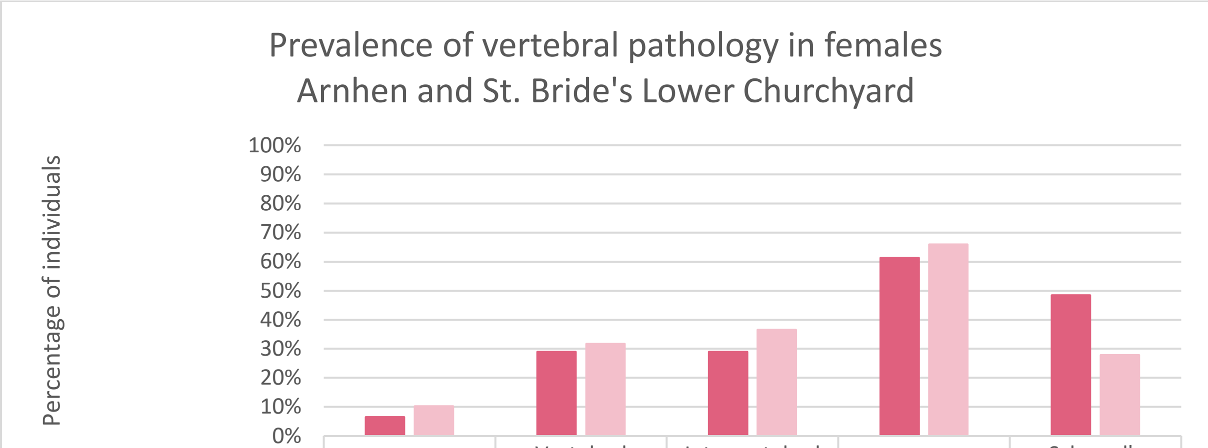
	Fusion	Vertebral osteoarthritis	Intervertebral disc disease	Osteophytes	Schmorl's nodes
Females Arnhem	6,5%	29%	29%	61,3%	48,4%
Females Chelsea Old Church	5,4%	24,8%	30,9%	58,5%	36,4%

The prevalence of the vertebral pathological conditions in females in the Arnhem and Chelsea Old Church population. The numbers are expressed in percentages.



	Fusion	Vertebral osteoarthritis	Intervertebral disc disease	Osteophytes	Schmorl's nodes
Females Arnhem	6,5%	29%	29%	61,3%	48,4%
Females St. Benet Sherehog	13%	21,7%	39,1%	47,8%	39,1%

The prevalence of the vertebral pathological conditions in females in the Arnhem population and the St. Benet Sherehog population. The numbers are expressed in percentages.



	Fusion	Vertebral osteoarthritis	Intervertebral disc disease	Osteophytes	Schmorl's nodes
Females Arnhem	6,5%	29,0%	29,0%	61,3%	48,4%
Females St. Brides Lower	10,3%	31,7%	36,5%	65,9%	27,8%

The prevalence of the vertebral pathological conditions in females in the Arnhem population and the St. Bride's Lower Churchyard population. The numbers are expressed in percentages.

Appendix F: Raw data of the Arnhem Eusebiuskerk population

SITECODE	CONTEXT	SEX	AGE	F Occipital condyles-C1	F C1-2	F C2-3	F C3-4	F C4-5	F C5-6	F C6-7	F C7-T1
ARJB	218	Female	Middle adult								
ARJB	246	Male	Middle adult								
ARJB	476	Male	Old adult								
ARJB	481	Male	Middle adult								
ARJB	490	Male	Old adult								
ARJB	492	Probable male	Middle adult								
ARJB	687	Probable female	Late young adult								
ARJB	814	Female	Old adult			4					
ARJB	855	Probable female	Late young adult								
ARJB	868	Male	Middle adult								
ARJB	973	Probable male	Middle adult								
ARJB	1043	Male	Old adult								
ARJB	1087	Probable female	Middle adult								
ARJB	1247	Male	Late young adult								
ARJB	1253	Male	Late young adult								
ARJB	1259	Probable male	Middle adult								
ARJB	1298	Male	Old adult								
ARJB	1299	Male	Middle adult								
ARJB	1339	Male	Old adult								
ARJB	1346	Probable male	Early young adult								
ARJB	1350	Female	Old adult								
ARJB	1375	Male	Middle adult								
ARJB	1399	Male	Middle adult								
ARJB	1428	Male	Middle adult								
ARJB	1432	Male	Early young adult								
ARJB	1434	Female	Early young adult								
ARJB	1436	Probable female	Middle adult								
ARJB	1440	Intermediate	Middle adult								
ARJB	1454	Probable female	Early young adult								
ARJB	1495	Probable male	Late young adult								
ARJB	1500	Probable male	Late young adult								
ARJB	1506	Female	Middle adult								
ARJB	1530	Probable female	Early young adult								
ARJB	1547	Probable male	Old adult								
ARJB	1561	Probable male	Middle adult								
ARJB	1585	Probable female	Late young adult								
ARJB	1588	Female	Middle adult								
ARJB	1596	Male	Late young adult								
ARJB	1621	Male	Late young adult								
ARJB	1623	Probable male	Early young adult								
ARJB	1633	Probable female	Middle adult								
ARJB	1655	Probable female	Middle adult								
ARJB	1659	Male	Middle adult								
ARJB	1727	Probable female	Early young adult								
ARJB	1743	Female	Adult								
ARJB	1752	Female	Middle adult								
ARJB	1754	Probable female	Middle adult								
ARJB	1780	Probable male	Late young adult								
ARJB	1802	Male	Middle adult								
ARJB	1822	Probable male	Middle adult								
ARJB	1837	Male	Old adult								
ARJB	1840	Probable female	Middle adult								
ARJB	1862	Probable male	Old adult								
ARJB	1864	Probable male	Middle adult								
ARJB	1873	Probable male	Middle adult								
ARJB	1881	Probable male	Late young adult								
ARJB	1883	Female	Late young adult								
ARJB	1889	Probable male	Middle adult								
ARJB	1901	Male	Late young adult								
ARJB	1967	Probable male	Old adult								
ARJB	1981	Female	Middle adult								
ARJB	2044	Female	Middle adult								
ARJB	2053	Female	Middle adult								
ARJB	2062	Male	Late young adult								
ARJB	2064	Male	Late young adult					5	4		
ARJB	2090	Female	Old adult								
ARJB	2101	Probable female	Late young adult								
ARJB	2107	Probable male	Middle adult								
ARJB	2114	Probable female	Early young adult								
ARJB	2120	Probable male	Middle adult								
ARJB	2213	Male	Late young adult								
ARJB	2433	Female	Middle adult								
ARJB	2451	Male	Old adult								
ARJB	2481	Female	Middle adult								
ARJB	2484	Female	Late young adult								
ARJB	2489	Probable female	Late young adult								

F T1-2	F T2-3	F T3-4	F T4-5	F T5-6	F T6-7	F T7-8	F T8-9	F T9-10	F T10-11	F T11-12	F T12-L1	F L1-2	F L2-3	F L3-4	F L4-5	F L5-S1	F
																	Absent
							4	4	4	4	4	5	5	5	5		Present
																	Absent
																	Absent
																	Absent
																	Absent
																	Absent
			5														Present
																	Absent
																	Absent
		5			4	4	4	4	4								Present
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																	Absent
																	Absent
					5												Present
																	Absent
		4															Present
	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	Present
						3											Present
																	Absent
																	Absent
																	Absent
																	Absent
																	Absent
																	Absent
																	Absent
																	Absent
																	Absent
			4	4	4												Present
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																	Absent
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																	Absent
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																	Absent
																	Absent
																	Absent
					2	2	2	6									Present
																	Absent
																	Absent
																	Absent
																	Absent
																	Absent
																	Absent
																	Absent
																	Absent
																	Absent
																	Absent
																	Absent
																	Present
																	Absent
																	Absent
																	Absent
																	Absent
			5		1	1	1	1	1	1	1						Present
																	Absent
																	Absent
																	Absent
																	Absent
																	Absent
																	Absent

SITECODE	CONTEXT	SEX	AGE	VOA Occipital condyles-C1	VOA C1-2	VOA C2-3	VOA C3-4	VOA C4-5	VOA C5-6	VOA C6-7	VOA C7-T1
ARJB	218	Female	Middle adult								
ARJB	246	Male	Middle adult								
ARJB	476	Male	Old adult			3	3	1	1	1	
ARJB	481	Male	Middle adult			1	1	1	1		1
ARJB	490	Male	Old adult		1	3	1	3	3	3	3
ARJB	492	Probable male	Middle adult					1			
ARJB	687	Probable female	Late young adult								
ARJB	814	Female	Old adult		3	3	3		1		3
ARJB	855	Probable female	Late young adult								
ARJB	868	Male	Middle adult								
ARJB	973	Probable male	Middle adult				1		1		1
ARJB	1043	Male	Old adult		1	3	3	3	3	3	3
ARJB	1087	Probable female	Middle adult						1		
ARJB	1247	Male	Late young adult								
ARJB	1253	Male	Late young adult								
ARJB	1259	Probable male	Middle adult						1		
ARJB	1298	Male	Old adult		1						
ARJB	1299	Male	Middle adult		1	3					
ARJB	1339	Male	Old adult		1	2	3	1	1	1	2
ARJB	1346	Probable male	Early young adult					1	2	1	
ARJB	1350	Female	Old adult		1	3	2	2	1	3	3
ARJB	1375	Male	Middle adult		1			1	1		
ARJB	1399	Male	Middle adult					1			
ARJB	1428	Male	Middle adult					3		1	
ARJB	1432	Male	Early young adult								
ARJB	1434	Female	Early young adult								
ARJB	1436	Probable female	Middle adult		1				1		3
ARJB	1440	Intermediate	Middle adult			1					
ARJB	1454	Probable female	Early young adult								
ARJB	1495	Probable male	Late young adult								
ARJB	1500	Probable male	Late young adult					1	1	1	
ARJB	1506	Female	Middle adult			1	1	1	1	1	
ARJB	1530	Probable female	Early young adult								
ARJB	1547	Probable male	Old adult				3	3	1		1
ARJB	1561	Probable male	Middle adult		2		1	1	1		1
ARJB	1585	Probable female	Late young adult						1		1
ARJB	1588	Female	Middle adult				1	1	1		3
ARJB	1596	Male	Late young adult					1	1	1	
ARJB	1621	Male	Late young adult								
ARJB	1623	Probable male	Early young adult								
ARJB	1633	Probable female	Middle adult						1	1	
ARJB	1655	Probable female	Middle adult		1						
ARJB	1659	Male	Middle adult					1	1	1	
ARJB	1727	Probable female	Early young adult		3			1			
ARJB	1743	Female	Adult								
ARJB	1752	Female	Middle adult		3	3		1	1	1	3
ARJB	1754	Probable female	Middle adult		2	2	3	3	3	1	1
ARJB	1780	Probable male	Late young adult								
ARJB	1802	Male	Middle adult								
ARJB	1822	Probable male	Middle adult		3			3	1	1	1
ARJB	1837	Male	Old adult			3	3		1	1	
ARJB	1840	Probable female	Middle adult								
ARJB	1862	Probable male	Old adult	1			3	3	1		3
ARJB	1864	Probable male	Middle adult								
ARJB	1873	Probable male	Middle adult		1	3	3	2			1
ARJB	1881	Probable male	Late young adult								
ARJB	1883	Female	Late young adult								
ARJB	1889	Probable male	Middle adult				1	1		1	
ARJB	1901	Male	Late young adult								
ARJB	1967	Probable male	Old adult						3	1	
ARJB	1981	Female	Middle adult				1	1	1		
ARJB	2044	Female	Middle adult	1			1	1	1		
ARJB	2053	Female	Middle adult					1		1	
ARJB	2062	Male	Late young adult								
ARJB	2064	Male	Late young adult								
ARJB	2090	Female	Old adult			2			1	1	
ARJB	2101	Probable female	Late young adult				1				
ARJB	2107	Probable male	Middle adult					1	1	1	
ARJB	2114	Probable female	Early young adult								
ARJB	2120	Probable male	Middle adult					3	1	1	
ARJB	2213	Male	Late young adult								
ARJB	2433	Female	Middle adult				3	2			
ARJB	2451	Male	Old adult								
ARJB	2481	Female	Middle adult								
ARJB	2484	Female	Late young adult								
ARJB	2489	Probable female	Late young adult								

VOA T1-2	VOA T2-3	VOA T3-4	VOA T4-5	VOA T5-6	VOA T6-7	VOA T7-8	VOA T8-9	VOA T9-10	VOA T10-11	VOA T11-12	VOA T12-L1	VOA L1-2	VOA L2-3	VOA L3-4	VOA L4-5	VOA L5-S1	VOA
																	Absent
		2	1													1	Absent
		1										1	1	1			Present
		1	3	3			1	1	1	1			1	1	1	1	Present
2	2	1	2	2	1	1		1	1	1	2	2	2	2	3	1	Present
			1	2		1			1	1	1						Absent
1						1		1									Absent
	2	3	3	2			1				1	1	1	1	1	1	Present
																	Absent
			1						1								Absent
1	1		1							1	1	1	1	1	1		Absent
3	1		3	1		1	3	2	1		1	1	2	1	1		Present
1			1			1				1	1	1	1	1			Absent
																	Absent
																	Absent
				1													Absent
		1	1														Absent
														3	1		Present
	1		2	1	1												Present
1																	Absent
											1		1	1		1	Present
1	1	3	2			1	1	1				1	1	1	1	1	Present
1	1		1	1				1									Absent
															1		Present
																	Absent
																	Absent
																	Present
				3										1	2		Present
																	Absent
																	Absent
	3	3				3	1		2	1							Present
			1	1	1	1				1	1	1	1		1		Absent
1	1	1	1	1										1	1		Absent
1									2				1		1	1	Present
1	1		1	1									1	1	2		Absent
				1											1		Absent
		3	3	3	2				1	1							Present
		1	1									1		1	1		Absent
																	Absent
																	Absent
																	Absent
1			1						1								Absent
		1		1							1	1	1	1			Absent
1											1						Present
																	Absent
		2	2										1	1			Present
											1		1	1	1	3	Present
																	Absent
			1										1	1	1		Absent
													1	1	1		Present
		1					1	1	3	3	1		3	1	3	2	Present
																	Absent
		2	1	3					1		3	1	1	1	1		Present
																	Absent
				3									3	1	1	1	Present
																	Absent
1		1							1		1	1	1	1	1		Absent
																	Absent
																	Absent
		3	3	1					1				1	1	1		Present
																	Absent
	3	3		1										1	1		Present
1			1									1	1		1	1	Absent
																	Absent
	3	2			1	1	3										Present
			2	1						1			1	1	1	1	Absent
		1											1	1	1	1	Absent
									1						1		Absent
																	Absent
	1			3						1	1	1	1	1	1	1	Present
										1				1			Absent
																	Present
			1	1							1	1	1	1	1	1	Absent
																	Absent
																	Absent
																	Absent

SITECODE	CONTEXT	SEX	AGE	IVD Occipital condyles-C1	IVD C1-2	IVD C2-3	IVD C3-4	IVD C4-5	IVD C5-6	IVD C6-7	IVD C7-T1
ARJB	218	Female	Middle adult								
ARJB	246	Male	Middle adult								
ARJB	476	Male	Old adult				3	3	3	3	
ARJB	481	Male	Middle adult						1		
ARJB	490	Male	Old adult				3			2	
ARJB	492	Probable male	Middle adult								
ARJB	687	Probable female	Late young adult								
ARJB	814	Female	Old adult						2	3	
ARJB	855	Probable female	Late young adult								
ARJB	868	Male	Middle adult								
ARJB	973	Probable male	Middle adult								
ARJB	1043	Male	Old adult								
ARJB	1087	Probable female	Middle adult								
ARJB	1247	Male	Late young adult								
ARJB	1253	Male	Late young adult								
ARJB	1259	Probable male	Middle adult								
ARJB	1298	Male	Old adult								
ARJB	1299	Male	Middle adult				1	1	3	3	
ARJB	1339	Male	Old adult					3	3	3	3
ARJB	1346	Probable male	Early young adult								
ARJB	1350	Female	Old adult				1	1	3	3	
ARJB	1375	Male	Middle adult				3	3	3		
ARJB	1399	Male	Middle adult					1		3	
ARJB	1428	Male	Middle adult								
ARJB	1432	Male	Early young adult								
ARJB	1434	Female	Early young adult								
ARJB	1436	Probable female	Middle adult								
ARJB	1440	Intermediate	Middle adult								
ARJB	1454	Probable female	Early young adult								
ARJB	1495	Probable male	Late young adult								
ARJB	1500	Probable male	Late young adult					3	3		
ARJB	1506	Female	Middle adult								
ARJB	1530	Probable female	Early young adult								
ARJB	1547	Probable male	Old adult							3	
ARJB	1561	Probable male	Middle adult								
ARJB	1585	Probable female	Late young adult								
ARJB	1588	Female	Middle adult								
ARJB	1596	Male	Late young adult								
ARJB	1621	Male	Late young adult								
ARJB	1623	Probable male	Early young adult								
ARJB	1633	Probable female	Middle adult							2	
ARJB	1655	Probable female	Middle adult								
ARJB	1659	Male	Middle adult								
ARJB	1727	Probable female	Early young adult								
ARJB	1743	Female	Adult								
ARJB	1752	Female	Middle adult								
ARJB	1754	Probable female	Middle adult								
ARJB	1780	Probable male	Late young adult								
ARJB	1802	Male	Middle adult								
ARJB	1822	Probable male	Middle adult				1	1	3	3	
ARJB	1837	Male	Old adult				3	3	1	1	
ARJB	1840	Probable female	Middle adult						3		
ARJB	1862	Probable male	Old adult				1	1	1	2	1
ARJB	1864	Probable male	Middle adult								
ARJB	1873	Probable male	Middle adult							3	
ARJB	1881	Probable male	Late young adult								
ARJB	1883	Female	Late young adult								
ARJB	1889	Probable male	Middle adult								
ARJB	1901	Male	Late young adult								
ARJB	1967	Probable male	Old adult				1	1			
ARJB	1981	Female	Middle adult					3			
ARJB	2044	Female	Middle adult				3	1		1	
ARJB	2053	Female	Middle adult								
ARJB	2062	Male	Late young adult								
ARJB	2064	Male	Late young adult								
ARJB	2090	Female	Old adult			1		3	1	3	
ARJB	2101	Probable female	Late young adult								
ARJB	2107	Probable male	Middle adult								
ARJB	2114	Probable female	Early young adult								
ARJB	2120	Probable male	Middle adult								
ARJB	2213	Male	Late young adult								
ARJB	2433	Female	Middle adult								
ARJB	2451	Male	Old adult					1	3	3	
ARJB	2481	Female	Middle adult								
ARJB	2484	Female	Late young adult								
ARJB	2489	Probable female	Late young adult								

IVD T1-2	IVD T2-3	IVD T3-4	IVD T4-5	IVD T5-6	IVD T6-7	IVD T7-8	IVD T8-9	IVD T9-10	IVD T10-11	IVD T11-12	IVD T12-L1	IVD L1-2	IVD L2-3	IVD L3-4	IVD L4-5	IVD L5-S1	IVD
																	Absent
	1		3	3													Present
														3			Present
								2			1		1	2	1	1	Present
										1					1		Present
																	Absent
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																	Absent
																	Absent
																3	Present
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																	Absent
																	Absent
1																	Present
												2					Present
																	Absent
2	2	3	2	2	2		2			2							Present
																	Present
								3									Present
																	Absent
																	Absent
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								1			1				3		Present
																	Absent
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								2									Present
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										1			1	1			Present
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				3	1	2	2	2	3					3		2	Present
																	Present
						2										3	Present
																	Present
																	Absent
					2				2	2							Present
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		1				2	3	2									Present
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																	Absent
																	Present
																	Absent
																	Absent
				1	2	1	2	2	1		1		2	1			Present

SITECODE	CONTEXT	SEX	AGE	OP Occipital condyles-C1	OP C1-2	OP C2-3	OP C3-4	OP C4-5	OP C5-6	OP C6-7	OP C7-T1
ARJB	218	Female	Middle adult								
ARJB	246	Male	Middle adult								
ARJB	476	Male	Old adult			1	2	2	2	1	
ARJB	481	Male	Middle adult						1		
ARJB	490	Male	Old adult				2	1	1	1	1
ARJB	492	Probable male	Middle adult								
ARJB	687	Probable female	Late young adult								
ARJB	814	Female	Old adult				1	1	1		1
ARJB	855	Probable female	Late young adult								
ARJB	868	Male	Middle adult								
ARJB	973	Probable male	Middle adult					1			1
ARJB	1043	Male	Old adult		1	1	1	1	1	1	1
ARJB	1087	Probable female	Middle adult								
ARJB	1247	Male	Late young adult			1			1		
ARJB	1253	Male	Late young adult								
ARJB	1259	Probable male	Middle adult			1		1			
ARJB	1298	Male	Old adult		1						
ARJB	1299	Male	Middle adult		1		1	1	1	2	
ARJB	1339	Male	Old adult					1	2	2	1
ARJB	1346	Probable male	Early young adult			2	2	1	1	1	1
ARJB	1350	Female	Old adult				1	1	2	2	1
ARJB	1375	Male	Middle adult				2	2	2	2	
ARJB	1399	Male	Middle adult				1	1	1	1	
ARJB	1428	Male	Middle adult		1		1	1	1	1	
ARJB	1432	Male	Early young adult								
ARJB	1434	Female	Early young adult								
ARJB	1436	Probable female	Middle adult		1						
ARJB	1440	Intermediate	Middle adult								
ARJB	1454	Probable female	Early young adult								
ARJB	1495	Probable male	Late young adult								
ARJB	1500	Probable male	Late young adult				1	1	1		
ARJB	1506	Female	Middle adult						1	1	1
ARJB	1530	Probable female	Early young adult								
ARJB	1547	Probable male	Old adult			1	1	1	3	2	
ARJB	1561	Probable male	Middle adult		1						
ARJB	1585	Probable female	Late young adult								
ARJB	1588	Female	Middle adult								
ARJB	1596	Male	Late young adult		1				2	1	
ARJB	1621	Male	Late young adult								
ARJB	1623	Probable male	Early young adult								
ARJB	1633	Probable female	Middle adult				1	1	1	2	
ARJB	1655	Probable female	Middle adult								
ARJB	1659	Male	Middle adult				1	2	2	2	1
ARJB	1727	Probable female	Early young adult								
ARJB	1743	Female	Adult								
ARJB	1752	Female	Middle adult								1
ARJB	1754	Probable female	Middle adult		1	1	1	1		1	
ARJB	1780	Probable male	Late young adult								
ARJB	1802	Male	Middle adult								
ARJB	1822	Probable male	Middle adult		1			2	2	2	
ARJB	1837	Male	Old adult		1	1	2	2	2	2	
ARJB	1840	Probable female	Middle adult				1		2	1	
ARJB	1862	Probable male	Old adult				2	2	1	1	
ARJB	1864	Probable male	Middle adult								
ARJB	1873	Probable male	Middle adult		1	1	1	1	1	2	1
ARJB	1881	Probable male	Late young adult								
ARJB	1883	Female	Late young adult								
ARJB	1889	Probable male	Middle adult								
ARJB	1901	Male	Late young adult								
ARJB	1967	Probable male	Old adult	1	1			1			
ARJB	1981	Female	Middle adult					1			
ARJB	2044	Female	Middle adult	1	1	1	2	1		1	
ARJB	2053	Female	Middle adult		1		1		1	1	
ARJB	2062	Male	Late young adult								
ARJB	2064	Male	Late young adult	1	1		1		1	1	
ARJB	2090	Female	Old adult				1	2	2	1	1
ARJB	2101	Probable female	Late young adult								
ARJB	2107	Probable male	Middle adult								
ARJB	2114	Probable female	Early young adult								
ARJB	2120	Probable male	Middle adult								1
ARJB	2213	Male	Late young adult								
ARJB	2433	Female	Middle adult								
ARJB	2451	Male	Old adult		1				1	2	
ARJB	2481	Female	Middle adult								
ARJB	2484	Female	Late young adult								
ARJB	2489	Probable female	Late young adult								

OP T1-2	OP T2-3	OP T3-4	OP T4-5	OP T5-6	OP T6-7	OP T7-8	OP T8-9	OP T9-10	OP T10-11	OP T11-12	OP T12-L1	OP L1-2	OP L2-3	OP L3-4	OP L4-5	OP L5-S1	OP
																	Absent
				1		1						1	1	1	1		Present
	1										1	1	2	3	1		Present
1						1			1	1	1	1	2		1		Present
	1	1	1		1	1			1	2	1	3	1	2	1	1	Present
																	Absent
																	Absent
	1	1	1	1	1	1	1	1	1	1						1	Present
																	Absent
				1	1	1	1	1									Present
1	1			1					1				1	1		1	Present
1	1	1	1	1	1	1	1	2	1	1		1	1	1	1	3	Present
		1	1	1		1	1										Present
						1	1						1	1			Present
																	Absent
	1	1	1			1	1	1	1	1			1	1	1	1	Present
	1			1			1	1	1				1	1			Present
1	1							1	1	1	1		1	1	1	1	Present
					1	1	1	1	1	1	1	1	2	1	1	1	Present
1																	Present
1	1	1	1	1	1		2	2	2	2	2	1	1	1	1	1	Present
	1					1	1	1	1	1	1	1	2	2	1		Present
		1		1	1	1	1	1	1				1	1	1		Present
				1	1	1	1	1		1	1						Present
																	Absent
																	Absent
							1		1	1	1	1	1	1			Present
				1	1		1	1	1	1	1			2			Present
																	Absent
					1	1	1	1									Present
		3				3	1	1	1								Present
1	1	1	1	1	1	1	1	1	1	1	1	1		1		2	Present
																	Absent
	1	1	1	1	1	1	1	2	1	2	2	2	1	1	1	3	Present
			1	1	1	1	1	1	1					2			Present
			1			1	1	1								1	Present
																	Absent
				1		1		1				1	1				Present
																	Absent
																	Absent
		1		1	1	1	1	2	1	1		1	1	1	1		Present
		1	1	1	1	1	1	1	1		1	1			1		Present
		1		1	1	1	1	1	1	2	3	1	1	1			Present
	2	1	1	1	1	1	1	1	1								Present
																	Absent
			1	1	1	1											Present
					1	1							2	2	1		Present
																	Absent
	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	Present
			1	1	1		1	1	1			1			2		Present
							1	1	1	2	1		1	1	1		Present
				1	1					1				1		1	Present
1	1	1	1	1					3	1	1	1	1	1	1	1	Present
		1	1	1	1	1	1	1					1	1	1		Present
1	1	2	1	2	2	1	1	1	1	2	2	1	1		1		Present
			1	1	1	1											Present
																	Absent
	1	1		1	1			1				1					Present
						1	1	1									Present
	1		1	1		1	1	1	1	2	1	1	1	1			Present
	1	1	1	1	1	1	1										Present
	1																Present
	1	1					1	1								1	Present
																	Absent
	1	1			1	1	1			1			1		1	1	Present
		1	1	1	1	1	1	1	1	2	1		1	1	1		Present
		1	1			1									1		Present
																	Absent
																	Absent
1	1	1		1			2	2		1	1	2	1	1	1	3	Present
																	Absent
																	Absent
	1	1	1	1	1	1	1	1	1	1	1	2		1	1	1	Present
1			1	1	1	1	1	1									Present
			1		1	1	1	1						1			Present
																	Absent

SITECODE	CONTEXT	SEX	AGE	SN Occipital condyles-C1	SN C1-2	SN C2-3	SN C3-4	SN C4-5	SN C5-6	SN C6-7	SN C7-T1
ARJB	218	Female	Middle adult								
ARJB	246	Male	Middle adult								
ARJB	476	Male	Old adult								
ARJB	481	Male	Middle adult								
ARJB	490	Male	Old adult								
ARJB	492	Probable male	Middle adult								
ARJB	687	Probable female	Late young adult								
ARJB	814	Female	Old adult								
ARJB	855	Probable female	Late young adult								
ARJB	868	Male	Middle adult								
ARJB	973	Probable male	Middle adult								
ARJB	1043	Male	Old adult								
ARJB	1087	Probable female	Middle adult								
ARJB	1247	Male	Late young adult								
ARJB	1253	Male	Late young adult								
ARJB	1259	Probable male	Middle adult								
ARJB	1298	Male	Old adult								
ARJB	1299	Male	Middle adult								
ARJB	1339	Male	Old adult								
ARJB	1346	Probable male	Early young adult								
ARJB	1350	Female	Old adult								
ARJB	1375	Male	Middle adult								
ARJB	1399	Male	Middle adult								
ARJB	1428	Male	Middle adult								
ARJB	1432	Male	Early young adult								
ARJB	1434	Female	Early young adult								
ARJB	1436	Probable female	Middle adult								
ARJB	1440	Intermediate	Middle adult								
ARJB	1454	Probable female	Early young adult								
ARJB	1495	Probable male	Late young adult								
ARJB	1500	Probable male	Late young adult								
ARJB	1506	Female	Middle adult								
ARJB	1530	Probable female	Early young adult								
ARJB	1547	Probable male	Old adult								
ARJB	1561	Probable male	Middle adult								
ARJB	1585	Probable female	Late young adult								
ARJB	1588	Female	Middle adult								
ARJB	1596	Male	Late young adult								
ARJB	1621	Male	Late young adult								
ARJB	1623	Probable male	Early young adult								
ARJB	1633	Probable female	Middle adult								
ARJB	1655	Probable female	Middle adult								
ARJB	1659	Male	Middle adult								
ARJB	1727	Probable female	Early young adult								
ARJB	1743	Female	Adult								
ARJB	1752	Female	Middle adult								
ARJB	1754	Probable female	Middle adult								
ARJB	1780	Probable male	Late young adult								
ARJB	1802	Male	Middle adult								
ARJB	1822	Probable male	Middle adult								
ARJB	1837	Male	Old adult								
ARJB	1840	Probable female	Middle adult								
ARJB	1862	Probable male	Old adult								
ARJB	1864	Probable male	Middle adult								
ARJB	1873	Probable male	Middle adult								
ARJB	1881	Probable male	Late young adult								
ARJB	1883	Female	Late young adult								
ARJB	1889	Probable male	Middle adult								
ARJB	1901	Male	Late young adult								
ARJB	1967	Probable male	Old adult								
ARJB	1981	Female	Middle adult								
ARJB	2044	Female	Middle adult							1	
ARJB	2053	Female	Middle adult								
ARJB	2062	Male	Late young adult								
ARJB	2064	Male	Late young adult								
ARJB	2090	Female	Old adult								
ARJB	2101	Probable female	Late young adult								
ARJB	2107	Probable male	Middle adult								
ARJB	2114	Probable female	Early young adult								
ARJB	2120	Probable male	Middle adult								
ARJB	2213	Male	Late young adult								
ARJB	2433	Female	Middle adult								
ARJB	2451	Male	Old adult								
ARJB	2481	Female	Middle adult								
ARJB	2484	Female	Late young adult								
ARJB	2489	Probable female	Late young adult								

SN T1-2	SN T2-3	SN T3-4	SN T4-5	SN T5-6	SN T6-7	SN T7-8	SN T8-9	SN T9-10	SN T10-11	SN T11-12	SN T12-L1	SN L1-2	SN L2-3	SN L3-4	SN L4-5	SN L5-S1	SN
						1											Present
				1													Present
										1	1						Present
						2	1	1	1	1	3	1	1		1		Present
			2		1	1			2	2	3	3					Present
					1	1	2	2	2	1	2	1	1	1	1		Present
				1	1	1	1										Present
																	Absent
																	Absent
				1	2	1	1	2	1	1	3	1	1	1			Present
																	Absent
									2	2	1						Present
																	Absent
			1	1	1	1	1	1	2	2	1	2	1	1			Present
					1	1	2	1	1	1	1	1			1		Present
						1	1	1	1	2		2	1		1		Present
																	Absent
				1	1	1	1	1	2	1	2			1			Present
																	Absent
																	Absent
																	Absent
				2	2	2	2	1	1	2	1	2	2	1			Present
				1	2	3	3	1	2	3	2			1			Present
						1											Present
					1	1	1	1	1	1	1	1	2				Present
						1	1	1	1	1	1	1	1	1			Present
				1	1		1		1	1							Present
			1	1	2	2	2	2	1	1	1	1	2	1			Present
																	Absent
					1	1		2	2		1						Present
																	Absent
						2	2										Present
							2					3	2	1			Present
					1	1		1									Present
			1	1	1	1	1		1	3	3	1	1				Present
						1	2	2	1	1			2	1			Present
							2	1									Present
							1	1	2	1	2		1				Present
					2	2	2	2	3	2	1	1					Present
						1	2	1		1							Present
				1	1	1	2	2	2	1	1		1				Present
																	Absent
						2	3	2	2	1	1	1	1				Present
					1												Present
																	Absent
																	Absent
						1											Present
						1	1	2	1				1				Present
																	Absent
				2	2	1	2	2	1	1	2	2	1	3			Present
						1		1									Present
																	Absent
									1	1	2	3	1				Present
																	Absent
						2	1	2	3	2		1	1				Present
					1	1	2	1	1	1	1	1	1				Present
																	Absent
													1				Present
				1	1	1	1										Present
1				1	1	3	2	1	2	1	1	1	1	1			Present
																	Absent
			1	1	1	2	1	1	1	2	1	2	1	1			Present
																	Absent
					2	1	1	1	1	1							Present
						1	1	1	1	1	1	2	2	1			Present
		1			1		1	1			1						Present
						2											Present
			2	2	2	2	2	2	2	2	1	1	1	1			Present
																	Absent
							2	1		1		1	1	2	1		Present
					2	2			1								Present
			2		1	1	2	1	1	2				2			Present
							1	2						1			Present
																	Absent
																	Absent
																	Absent